ORGANIZING AN INTEGRATED RESISTANCE MANAGEMENT CAMPAIGN

ADVANCED TRAINING MODULE

IRAC

Insecticide Resistance Action Committee

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This module is designed to provide guidance on how to set up a successful resistance management strategy that is sustainable. In addition to technical aspects, this requires a good coordination and collaboration between relevant stakeholders on a community basis. The target audience for this module includes farmers, cooperatives, extension services, distributors, private service providers and public service or researchers in crop protection and plant biotechnology.

Introduction

Insecticide Resistance

Resistance to insecticides is a 'heritable change in the sensitivity of a pest population against a certain insecticide mode of action (MoA) that leads to control failure of a product or active ingredient (a.i.) when used according to label recommendations.

Resistance management

Resistance management can be defined as the use of strategies, that extend the number of generations that a given pest can be controlled with the same pesticide according to label recommendations.

Technical approaches to delay the onset of resistance

Most of the tactics aim to minimize the fitness of resistant individuals in a pest population, either by allowing some susceptible individuals to survive or by assuring that no resistant individual survives.

Preserving susceptible individuals

Mating between susceptible and resistant homozygotes, results in the conversion of resistant homozygous parents into susceptible heterozygotes (if resistance is recessive). If possible, susceptible individuals in a pest population can be preserved by avoiding unnecessary pesticide applications, treating the most sensitive life stages in the target pest life cycle, or providing untreated refuges. The negative aspect of this approach is that low level pest population survival may not be tolerated in some cropping scenarios.

INSECTICIDE APPLICATIONS BASED ON THRESHOLDS

If possible, foliar insecticide applications should not be applied prophylactically. Instead, they should be applied based on well-established infestation thresholds. In addition, IPM techniques, including cultural, chemical, biological and plant biotechnology pest control measures can be used to reduce the number of spray applications. As for curative foliar applications, the alternation of different modes of action is recommended to reduce the risk of resistance development (IRAC International statement on the resistance management considerations of utilizing soil & seed applied insecticides). Prophylactic seed treatments should be considered within the alternation of modes of action scheme.

ESTABLISH REFUGES

Planting non-treated refuges can be a successful resistance management strategy, in combination with high dose exposure and if in the target insect, fitness costs for resistance are high. This approach is mainly used for resistance management in transgenic crops expressing insecticidal proteins, where the target insect population is exposed to high concentrations over a long period of time and a large area. Portions of the crop are planted with non-transgenic conventional varieties to assure survival of susceptible insects. The refuge can be a well-defined surface area within a crop field, or when applying a refuge in the bag approach,

simply a defined proportion of the seed in a bag is kept non-transgenic. The seed in the bag approach however only works for species with less mobile larval stages.

Further reading:

- How to Develop an Insect Resistance Management Plan: Practical Approaches for Local Environments

Killing resistant genotypes

The approach of combining insecticides with different Modes of Action (different IRAC classes) assumes that individuals resistant to one MoA will be killed by an insecticide with a different Mode of action. This works under the assumption, that there is no cross resistance between alternated MoAs for the pest insect treated. This approach is most common when using conventional crop protection products.

INSECTICIDE ROTATION USING THE WINDOWS APPROACH

Rotation of insecticides from different IRAC classes has long been advocated as a resistance management strategy, but a special kind of alternation is suggested, namely by generations (windows approach). In the windows approach, resistance to any given Mode of Action is only advantageous to a pest insect every other generation.

Further reading:

- Insecticide Resistance Training – Basic Module.
- IRAC Insecticide Resistance Management Guidelines for sucking pests.
- Insecticide Resistance Management Guidelines for Lepidopteran Pests).

INSECTICIDE MIXTURES (TANK MIX OR PRE-MIX)

Insecticide mixtures can provide benefits for the control of several pests simultaneously or hard to control individual pests. For mixtures to be

effective in resistance management, the need to be properly incorporated into a rotation scheme according to the "window approach" and the active ingredients used in a mixture should belong to different IRAC MoA classifications with no cross resistance in the pest species addressed. Usually, the concentrations of the respective insecticide should be equal to those recommended for solo applications. Mixtures are most effective in managing resistance when individuals resistant to both pesticides are rare. There are however situations, where low-dose mixtures have been demonstrated to be effective in resistance management, depending on population genetics, populations dynamics and interactions of the target species with their natural enemies.

Further reading:

- IRAC International Insecticide Mixture Statement

Application of conventional insecticides in transgenic crops

Conventional insecticides may be applied to transgenic crops to broaden the range of pests controlled or to increase the level of target pest control. In certain circumstances, the application of chemical insecticides to transgenic crops also may be considered for insecticide resistance management (IRM) purposes. All currently commercialized synthetic insecticidal chemistries offer a different MoA to the insecticidal proteins expressed in transgenic crops. Therefore, the combined use of synthetic insecticidal chemicals and proteins which target the same pest offers the potential for an IRM tactic for preserving the susceptibility of a target pest to both MoAs. However, the application of insecticides to the refuge can reduce the resistance management benefits of sowing the structured refuge, because it reduces the population of insects, susceptible to the insecticidal protein. Therefore, under low pest pressure conditions it is recommended not to apply or at least to minimize the use of insecticide applications to the refuge.

Further reading:

- IRAC International Statement: Considerations for the resistance management value of using insecticidal chemistry on transgenic crops expressing insecticidal proteins.
- Insecticide resistance management guidelines for insect pests of corn, soybean and cotton in Brazil

Levels of integration

Resistance management doesn't offer a silver bullet solution. Programs are most successful when pests are controlled using a diverse array of chemical and non-chemical tactics. Instead of focusing on a single pest species, the strategies discussed above need to be implemented in an integrated approach (IPM), involving a whole pest complex or a cropping system. Pest species interact with their environment, containing natural enemies, competitors, oviposition sites, and food sources in different crops. Poorly planned spray programs can provoke the establishment of secondary pests. The continuous presence of suitable crops for a given pest, in combination with a lack of resistance management will lead to resistant insect populations. The best way to address higher levels of integration, is to coordinate strategies at the farmer community level, covering the whole region, where a given pest problem occurs.

Stakeholder involvement and areawide community action

Coordination

Resistance management requires a change in grower behavior at a community level. No single farmer can be successful in managing resistance. Many current pesticide application practices represent a mosaic

situation because neighboring farmers do not use the same products or crop protection strategies. Because pests do not know border and some pests significantly move around the landscape, successive generations of a given pest population might be exposed to the same Mode of Action across successive generations, eventually leading to resistance. Therefore, a resistance management strategy can only be successful if coordinated across a region or landscape.

Collaboration

Experience tells us, that effective resistance management strategies are based on collaborative community efforts, where farmers were actively engaged in all aspects including the collective agreement on the problem, a solution program design, decision-making, program financing, program implementation, and program enforcement based on rules in mandatory systems or peer pressure for voluntary systems.

Successful programs are usually based on an extensive collaboration between all impacted stakeholders such as:

- Individual users, e.g., farmers
- Pest control technology manufacturers
- Independent pest consultants, spray operation contractors or agricultural retailers who provide pest management products and services
- Government or private extension agencies that have oversight or assistance roles with pest management technologies,
- University researchers providing scientific support
- Non-governmental organizations involved in IPM, food and natural resource management
- Consumers of food, fiber and bioenergy products

Implementation, the importance of an incremental approach

Start simple

It is possible to design a reasonable resistance management strategy, based on limited information regarding a present resistance scenario. With time, more information might become available to incrementally improve an initial “first approximation” strategy.

FIRST STEPS

- Make use of the information given by the Mode of Action label on product labels. If no Mode of Action label is available, consult the IRAC website.
- Don’t apply products with the same MoA continuously
- Rotate insecticides with different MoAs using the windows approach.
- A window represents the time interval between two insect pest generations (30 days), or approximately 15 days if the pest generation time is short, or in case of a short cycle crop. After completion of one window switch to an insecticide with a different MoA.
- Apply insecticides according to the label rate. Do not under- or over-dose.
- Apply insecticides at a volume application rate that results in good crop coverage
- Start to coordinate product rotations with the farming community in time and space

LIMIT THE NUMBER OF INSECTICIDE APPLICATIONS TO WHAT IS NEEDED TO ACHIEVE SUSTAINABLE CONTROL

- Access expert knowledge, ask for advice from private or public extension services
- Establish a pest insect monitoring scheme

- Understand and establish economic action thresholds
- Allow natural enemies to survive and avoid buildup of secondary pest populations.

Develop a full-scale integrated pest management (IPM) program

- Identify critical stakeholders to be involved in a community based IPM and resistance management program. Consider IPM specialists, crop consultants, industry representatives, local extension service, community-based interested businesses (Coops, Ag Retailers, Bank members, etc.)
- IPM is a systemic approach that aims to reduce pest insect populations using techniques other than insecticide application
- IPM can include:
    - Crop rotation. Rotate your crop with a non-host crop for a given insect pest population.
    - Planting your crop when insect pest pressure is low
    - Selection of crop varieties which are less susceptible to a given insect pest, including genetically modified crops
    - Application of fertilizers at amounts which don't support insect pest populations. Maintain soil organic matter.
    - Optimization of soil management, i.e., no-till
    - Removal of crop residues or weed, which can host life stages of a given insect pest or be an alternative host plant
    - Optimization of irrigation patterns
- Use IPM and resistance management tactics to establish local community alignment on Best Management Practices (BMPs) for all to follow.

Make your strategy sustainable

You can improve your community strategy though collaboration with the stakeholders mentioned above. Public sector support can be important. Strong scientific foundations can support the implementation of new strategies and monitoring programs. This is important for increasing grower confidence. In addition to extension experts, IPM specialists and

agronomist, the involvement of socio-economists can be very helpful in identifying local barriers that might affect community adoption of agreed upon BMPs. Finally, the successful implementation of a sustainable resistance management strategy requires long-term commitment by all stakeholders.

Area wide expansion

Initially built on more modest localized improvements, successful programs expand in terms of geography and complexity, where initial successes felt by actual growers and their local communities can encourage broader, more regional adoption elsewhere.

References

Carrière, Y., Brown, Z. S., Downes, S. J., Gujar, G., Epstein, G., Omoto, C., Storer, N. P., Mota-Sanchez, D., Søgaard Jørgensen, P., & Carroll, S. P. (2020). Governing evolution: A socioecological comparison of resistance management for insecticidal transgenic Bt crops among four countries. Ambio, 49(1), 1–16. https://doi.org/10.1007/s13280-019-01167-0

Horowitz, A. R., Ghanim, M., Roditakis, E., Nauen, R., & Ishaaya, I. (2020). Insecticide resistance and its management in Bemisia tabaci species. Journal of Pest Science, 93(3), 893–910. https://doi.org/10.1007/s10340-020-01210-0

Levine, A. S., Matlock, M. D., Tweeten, L. G., Owens, J. C., & Soper, J. F. (2020). CAST Commentary. Energy, 2020–2, 1–12.

Umina, P. A., McDonald, G., Maino, J., Edwards, O., & Hoffmann, A. A. (2019). Escalating insecticide resistance in Australian grain pests: contributing factors, industry trends and management opportunities. Pest Management Science. https://doi.org/10.1002/ps.5285