Insecticide Resistance Action Committee

# Insecticide resistance management guidelines for lepidopteran pests

IRAC Lepidopteran Working Group



## IRAC Lepidoptera Working Group

**The guidelines presented here are designed by the Lepidoptera Working Group of the Insecticide Resistance Action Committee (IRAC).** Our objective as industry technical experts and IRAC members is to provide a reference document for designing IRM strategies for lepidopteran pests. The information provided is based on published information and to the best knowledge of IRAC International at the time of writing (February 2017).

As pest problems and control practices differ considerably between countries, crops and climatic conditions, these guidelines are meant to be flexible and allow experts to develop, adapt and implement these options to take local conditions into account. However, exceptions will need to be addressed by experts on a case by case basis.

## Introduction

Resistance to insecticides is a 'heritable change in the sensitivity of a pest population' that is reflected in the repeated failure of a product to achieve the expected level of control when used according to label recommendations for that pest species. The aim of this guideline is to summarize strategies that companies, influencers and growers can use to slow the development of resistance and provide more effective and sustainable pest control.

## IRAC Mode of Action Classification

Lepidoptera insects can be controlled by insecticide compounds with different mode of action (MoA). Repeated use of any insecticide can lead to resistance to that specific insecticide. In addition, if insects become resistant because of a change in the binding site of the insecticide, insects will become resistant to all insecticides with the same mode of action.

The IRAC MoA classification is intended to identify insecticides acting at specific target sites where mutations could confer cross-resistance to all compounds acting on the same site. It provides a guide to the selection of insecticides for use in an effective and sustainable insecticide resistance management (IRM) strategy.

A summary list of insecticide MoA and corresponding chemical groups is shown in Appendix 1. More details on insecticide Modes of Action can be found on the IRAC web site irac-online.org and the IRAC MOA App can be downloaded on to your cell phone.

The IRAC Mode of Action group numbers are now included on product labels in many countries. Additionally, statements providing insecticide resistance management guidance are also often given on the labels.

## Status of Resistance to Lepidoptera insecticides

There are many published instances of Lepidopteran species where resistance to insecticides has developed and others which have the potential to develop resistance. For the latest information please refer to the IRAC web site irac-online.org.

## Guidelines:

**1. IRAC member companies are responsible for including IRM information in product labels.**
The principle is to provide clear IRM information using language and a format understandable to farmers. Moreover, IRAC member companies recommend stating on product labels the maximum number of applications and the maximum amount of insecticide applied per crop /year. Implementation in countries depends on the local regulatory label guidelines. Examples are provided in Appendix 2 giving options for label text statements and Mode of Action icons.

**2. Always use products at the recommended label rates and spray intervals with the appropriate application equipment.**
Insecticides used at rates higher or lower than recommended on the label can result in resistance and/or unwanted effects on non-target organisms and the environment. Ensure that all the spray equipment is well maintained and there are no blocked nozzles or filters since this results in incorrect rates. Target the most susceptible insect life stages whenever possible.

**3. Rotation of insecticide Mode of Action groups prevents rapid selection of resistant populations.**
Farmers can avoid prolonged selection for insecticide resistance by rotating and diversifying the insecticide modes of action used in a crop cycle. **The recommended approach is to use products of the same MoA within a discrete period of time commonly called a "window". A window is defined by the duration of an insect generation or approximately 30 days. The period of residual activity provided by a single or sequence of product applications with the same mode of action should fit within a window.**

a) Avoid exclusive use of any mode of action group insecticides throughout a crop cycle.
b) Apply insecticides of the same mode of action group within a window to avoid exposure of consecutive insect pest generations to the same mode of action.
c) Multiple applications (generally less than 3) of the same MoA insecticide are acceptable if they are used to treat a single insect generation or are used within a window. Make sure that the residual activity of the multiple applications fits within the window.
d) Following a window of any mode of action group, rotate to a window of applications of effective insecticides with a different mode of action.
e) If insecticides from several mode of action groups are available, then the use of multiple modes of action within a window is recommended provided that different modes of action are used in the following window (see Appendix 3 for an example).
f) For short cycle crops (<50 days), consider the duration of the crop cycle as a window, so it is recommended to alternate to different modes of action within the next crop cycle.
g) As a general rule, the total exposure period of all windows with the same MoA applied throughout the crop cycle (from seedling to harvest) should not exceed 50% of the crop cycle. The total number of insecticide applications of the same MoA should not exceed 50% of the total number of insecticide applications targeted against the same pest species.
h) Avoid rotating products in different sub-groups of the same MoA except if there are no effective alternatives.
i) Examples of IRM rotation strategies are shown in Appendix 4.

**4. Use Integrated Pest management (IPM) practices to protect crops from pest damage and reduce the risk of insecticide resistance.**

IPM considers all available techniques to discourage the development of pests, which are economic, safe and environmentally-sound. It does not exclusively rely on insecticides, hence in IPM systems selection pressure by specific modes of action is reduced and the risk of resistance minimized.

IPM strategies consist of basic components:

a) Understand pest threshold levels resulting in economic losses. Observe pest populations in the field to identify species, pest stages, population densities, and presence of natural enemies so rational pest control decisions can be made.

b) Integrate effective control techniques including cultural, chemical, biological and plant biotechnology pest control measures, which minimize effects on non-target organisms:
   - Use resistant or damage tolerant crop varieties.
   - Practice sanitation and removal of infested post-harvest crop residues.
   - Avoid year round cultivation of susceptible crops to limit survival of treated pest populations.
   - Integrate non treated refuge crops into the cropping system (to allow breeding of treated survivors with untreated populations to dilute resistance genes).
   - Deploy mating disruption.

c) Plan the use of selective insecticides to conserve and complement the efficacy of beneficial organisms.

d) Contributions of beneficial organisms to pest control can be significant in many cropping systems and can also play an important role in resistance management. Beneficials can effectively control target pests regardless of insecticide resistance and thus may slow down the resistance selection process. Different application techniques e.g. soil drench or seed treatment can help conserve beneficial organisms since they may escape direct exposure. Choose insecticides that are safe to beneficial insects and time insecticide applications during periods of low beneficial activity or during their protected life stages when direct contact with the insecticide is limited.

**5. Consider the systemic properties of some soil and seed-applied products.**

The systemic properties of some active ingredients allow these products to be applied either directly to the soil, as a seed treatment or as foliar spray. Systemic activity may extend the residual efficacy and the length of the MoA spray window and needs to be considered when planning a program to minimize resistance development. Generally, it is recommended to use an effective foliar product with a different mode of action after either a seed treatment or a soil root uptake application.

**6. Using insecticide mixtures.**

IRAC has issued advice about the use of insecticide mixtures. For guidance refer to the IRAC-mixture-statement and IRAC leaflet-on-use-of-mixtures. As with applying single active ingredient products, insecticide mixture products should be used with careful consideration of the characteristics of the individual active substances, use pattern and pest complex targeted. In most cases, the primary objective for the use of an insecticide mixture (tank-mix or pre-formulated mixture) is not resistance management, but a broader spectrum or improved pest management.

**7. The use of insecticides of the same Mode of Action against different pests in the same crop.**

Multiple uses of different insecticides against more than one pest species in the same crop are feasible, but should be considered within the framework of insecticide resistance management programs and developed at local level, taking into account changes in pest populations, overlapping of different species, the relative importance and the risk of resistance development. Good resistance management practices such as avoiding repeated applications of the same mode of action across multiple treatment windows due to application against multiple pest species are key to successful IRM implementation. Where two species appear simultaneously always use the higher recommended rate for the more difficult to control species.

**8. Never use insecticides from the same Mode of Action where resistance is known.**

Continuous use of the same Mode of Action on a resistant population may escalate resistance levels and should be avoided, particularly if the product is used at higher than recommended rates. This recommendation is valid for solo and mixture products that contain the ineffective MoA.

**9. The use of non-specific mode of action products helps to prevent the development of resistance.**

Plant protection products such as oils and soaps which have a non-specific Mode of Action are good resistance management tools which should be recommended for use in rotation or combination with insecticides, provided that they similarly control both susceptible and resistant target pest populations.

**10. Monitor problematic pest populations in order to detect first shifts in sensitivity.**

Baseline sensitivity data for representative field populations of pests should be established by industry experts before the products became widely used. Re-examining the insecticide sensitivity of pest populations at regular intervals can be used to detect changes in susceptibility.

Monitoring methods for many of the major agricultural pests have been established by IRAC and can be found on the IRAC website www.irac-online.org/teams/methods/. Reporting of field failures to IRAC company representatives is also a good way detect early shifts in pest sensitivity.

**11. Where local information is known about cross-resistance between different MoA groups.**

Although in most situations rotation between different Mode of Action (MoA) insecticides will be useful, there have been some cases of metabolic cross resistance between molecules belonging to different groups. Therefore, it is recommended to consult local experts to find out the known status of resistance in your area. Avoidance of cross-resistance may help to build up a more effective rotation strategy.

**Never use a product of questionable origin or composition.**

Products from unknown or non-approved sources may not have the advertised composition, in which case efficacy may be affected and IRM becomes impossible. Moreover, illegal products may pose risks for users and the environment.

**12. Make sure to follow appropriate country label instructions.**

On the internet, using search engines, it is possible to locate product labels from most countries where the product is registered. Directions for use, even for the same crop, vary from country to country. Make sure to verify that the label pertains to the country of intended use, so that important instructions such as application rates and methods do not inadvertently contribute to generate or worsen resistance problems.

**13. The use of the same insecticide to control different types of insect pests (Lepidoptera, Coleoptera, sucking insects).**

These Lepidoptera IRM guidelines also apply to non-Lepidopteran pests unless more specific recommendations are available.

## 1. Summary list of insecticide modes of action useful for controlling Lepidopteran pests.

### Lepidoptera - Mode of Action Classification by Target Site

**Nerve & Muscle Targets**

1. Acetylcholinesterase (AChE) inhibitors
   *1A: Carbamates*
   *1B: Organophosphates*
2. GABA-gated chloride channel blockers
   *2A: Cyclodiene Organochlorines*
   *2B: Phenylpyrazoles*
3. Sodium channel modulators
   *3A: Pyrethrins, Pyrethroids*
4. Nicotinic acetylcholine receptor (nAChR) competitive modulators
   *4A: Neonicotinoids*
5. Nicotinic acetylcholine receptor (nAChR) allosteric modulators
   *5 Spinosyns*
6. Glutamate-gated chloride channel (GluCl) allosteric modulators
   *6: Avermectins, Milbemycins*
14. Nicotinic acetylcholine receptor (nAChR) channel blockers
    *14: Nereistoxin analogues*
22. Voltage-dependent sodium channel blockers
    *22A: Indoxacarb*
    *22B: Metaflumizone*
28. Ryanodine receptor modulators
    *28: Diamides*

**Respiration Targets**

13. Uncouplers of oxidative phosphorylation via disruption of the proton gradient
    *13: Chlorfenapyr*
21. Mitochondrial complex I electron transport inhibitors
    *21A: Tolfenpyrad*

**Midgut Targets**

11. Microbial disruptors of insect midgut membranes
    *11A: Bacillus thuringiensis,*
    *11B: Bacillus sphaericus*

**Growth & Development Targets**

7. Juvenile hormone mimics
   *7B: Juvenile hormone analogues*
15. Inhibitors of chitin biosynthesis, type 0
    *15: Benzoylureas*
18. Ecdysone receptor agonists
    *18: Diacylhydrazines*

**Unknown or uncertain MoA**

*Azadirachtin, Pyridalyl*

## 2. Recommended label formats and language

### A. Mode of Action icons for use on product labels

Include the MOA classification (example designs shown below for solo and mixture products) on the label. Preferably place by the list of ingredients on the label or within the IRM statement, if permitted by local regulatory label guidelines.

Example 1

**Insecticide A® 20SC**

Active ingredient: [Compound name]

Formulation details

| GROUP | 28 | INSECTICIDE |
|---|---|---|

Example 2

**Insecticide B® 25SC**

Active ingredients: [Compound names]

Formulation details

| GROUP | 3 | INSECTICIDE |
|---|---|---|
| GROUP | 28 | INSECTICIDE |

**B. Examples of Insecticide Resistance Management (IRM) statements for inclusion of product labels**

Include an IRM statement on the label. Propose the most comprehensive IRM statement legally permitted by local regulations. Three examples are provided; a short, a medium length and a most inclusive version.

**Example: short IRM statement**

**Insecticide Resistance Management (IRM) - General Recommendations**

- ____ (product name) contains _____ (active ingredient name), a Group XX Insecticide representing ____ chemistry.
- Avoid treating consecutive generations of the target pest with products having the same mode of action. Apply ____ (product name) using a "window" approach (duration of an insect generation or approximately 30 days). Alternate blocks of treatments with ____ (product name) or products with the same mode of action followed by blocks of treatments with other effective products with different modes of action. For short cycle crops (< 50 days), consider the duration of the crop cycle as a "window", thus alternate to different modes of action during subsequent plantings at the same farm location.

**Example: medium length IRM statement**

**Insecticide Resistance Management (IRM) - General Recommendations**

- Avoid exclusive use of _____(Product Name; Mode of Action Group Number XX throughout a crop cycle.
- Apply____ (Product Name) and other Group XX insecticides of the same mode of action group within a window to avoid exposure of consecutive insect pest generations to the same mode of action.
- A window is defined by the duration of an insect generation or approximately 30 days. The period of residual activity provided by a single or sequence of product applications with the same mode of action should fit within a window.
- Multiple applications (generally less than 3) of the same MoA insecticide are acceptable if they are used to treat a single insect generation or are used within a window.
- If insecticides from several mode of action groups are available, then the use of multiple modes of action within a window is recommended provided that different modes of action are used in the following window.
- Following a window of any mode of action group, rotate to a window of applications of effective insecticides with a different mode of action.
- For short cycle crops (<50 days), consider the duration of the crop cycle as a window, so it is recommended to alternate to different modes of action within the next crop cycle.
- As a general rule, the total exposure period of all windows with the same MoA applied throughout the crop cycle (from seedling to harvest) should not exceed 50% of the crop cycle. The total number of insecticide applications of the same MoA should not exceed 50% of the total number of insecticide applications targeted against the same pest species.

**Example: most inclusive IRM statement**

**Insecticide Resistance Management (IRM) – General Recommendations**

- A resistance management strategy should be established for the area that includes incorporation of cultural and biological control practices, alternation to different mode of action insecticides, and timing applications with adequate spray volumes to achieve the best crop coverage and highest mortality possible of the pest population.
- Avoid exclusive use of _____(Product Name; Mode of Action Group Number XX throughout a crop cycle.
- Apply____ (Product Name) and other Group XX insecticides of the same mode of action group within a window to avoid exposure of consecutive insect pest generations to the same mode of action.
- A window is defined by the duration of an insect generation or approximately 30 days. The period of residual activity provided by a single or sequence of product applications with the same mode of action should fit within a window.
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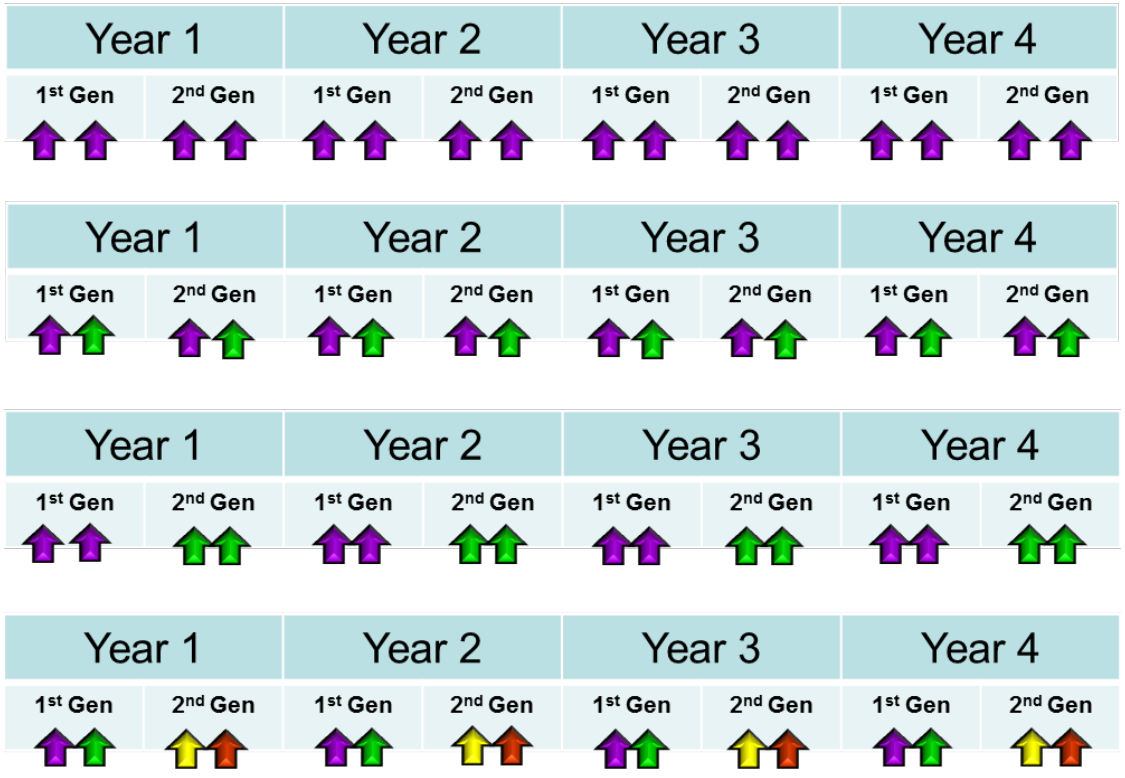
- Avoid using less than label rates of _____ (Product Name) when applied alone or in tank mixtures.
- Target the most susceptible insect life stages whenever possible.
- Monitor insect populations to most effectively time product application. If poor performance occurs and it cannot be attributed to improper application or weather conditions, a resistant strain of insect may be present.

## 3. Recommended rotation practices

Examples of good and poor IRM rotation practices: 4 year programs utilizing different effective modes of action.




***No alternation/rotation***

High selection pressure
No recovery of sensitive population.

***Rotation within generation***

Consecutive generations exposed to same MoA. Selection pressure remains over all generations. Risk of resistance development for both MoA

***Rotation between generations***

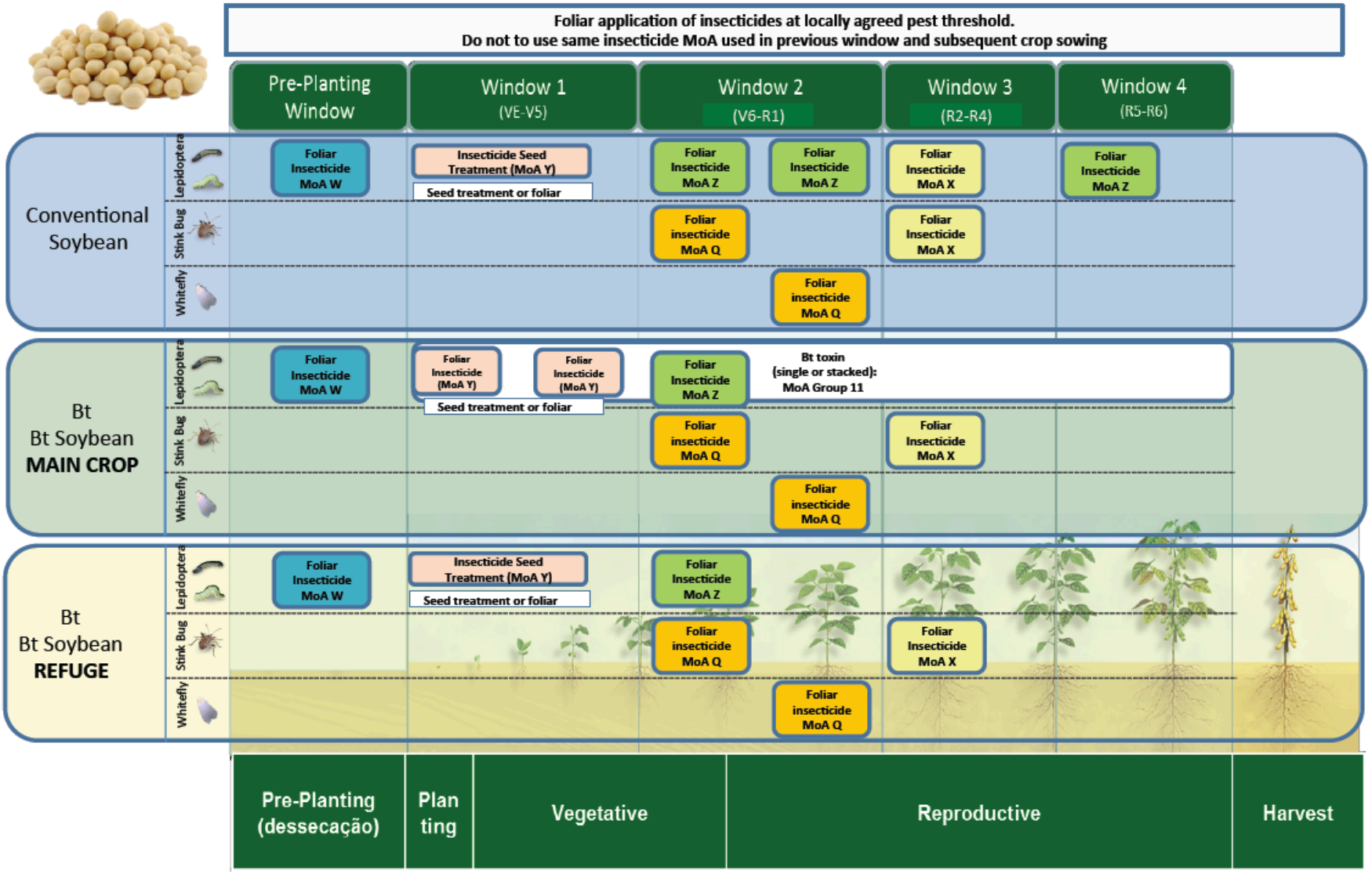
Consecutive generations are not exposed to same MoA. Break in selection pressure between generations allows recovery of susceptible population.

***Rotation within and between generations***

Ideal situation with lower selection pressure. Not often practical with available MoA

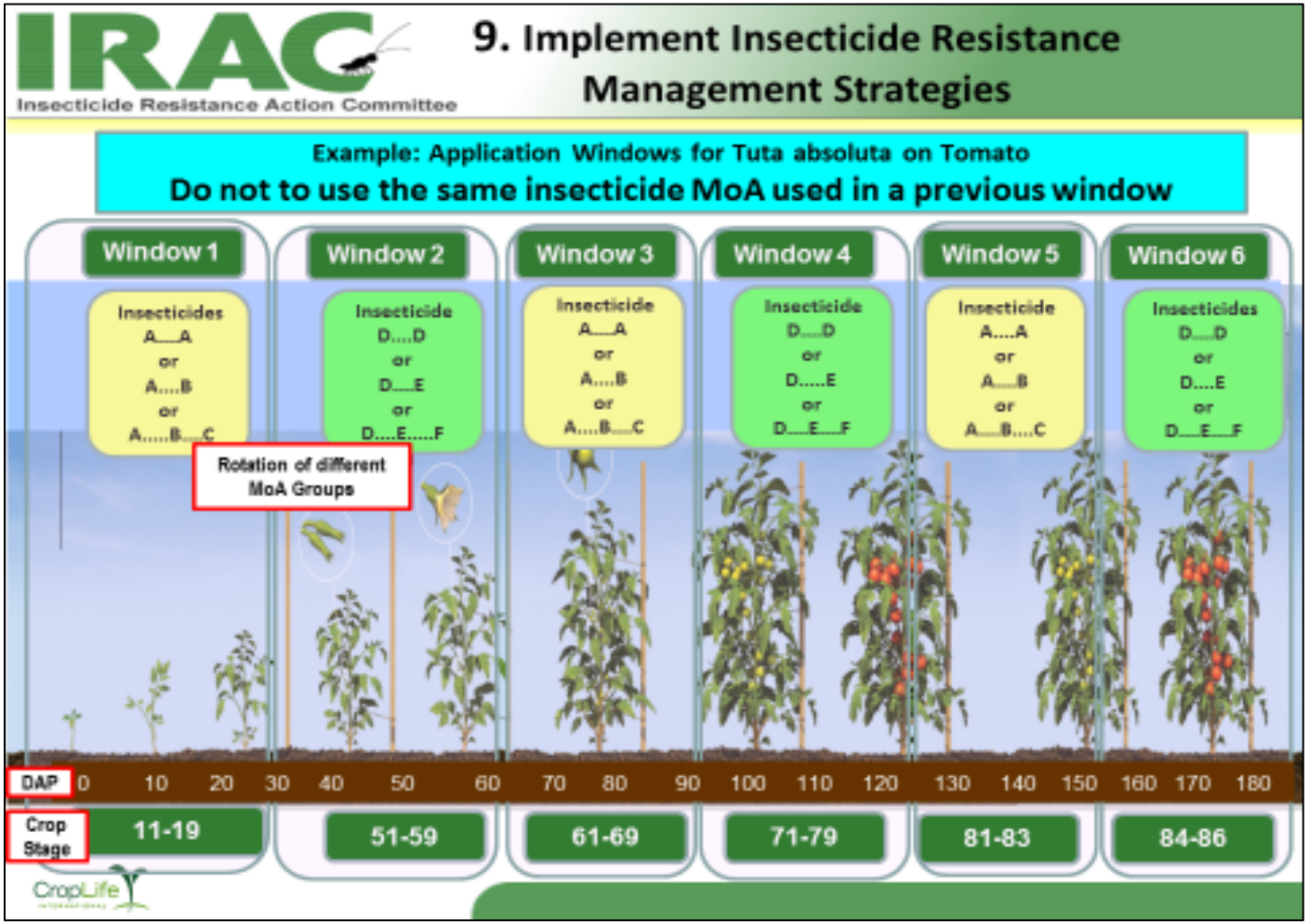
## 4. Examples of IRM rotation strategy

**A. Brazil:** IRM-compliant rotation of seed and foliar-applied insecticides for control of pests of conventional, Bt-soybean main crop, and Bt-soybean refuge.



**B. Europe, Middle East, Africa Greenhouse Crops (solanaceous).**

IRAC Mode of Action rotation strategy recommended for foliar products applied on greenhouse crops attacked by *Tuta absoluta*.



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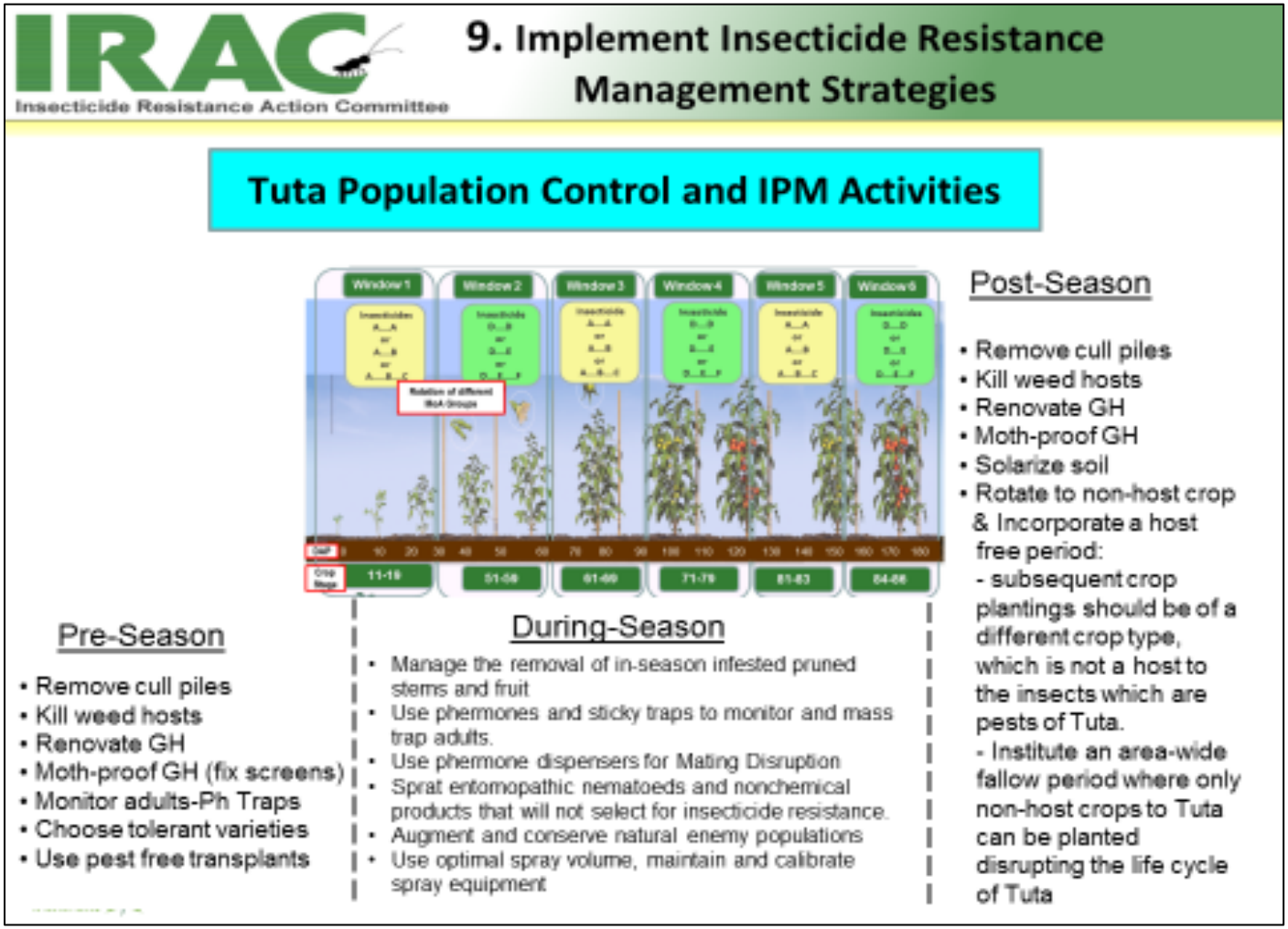
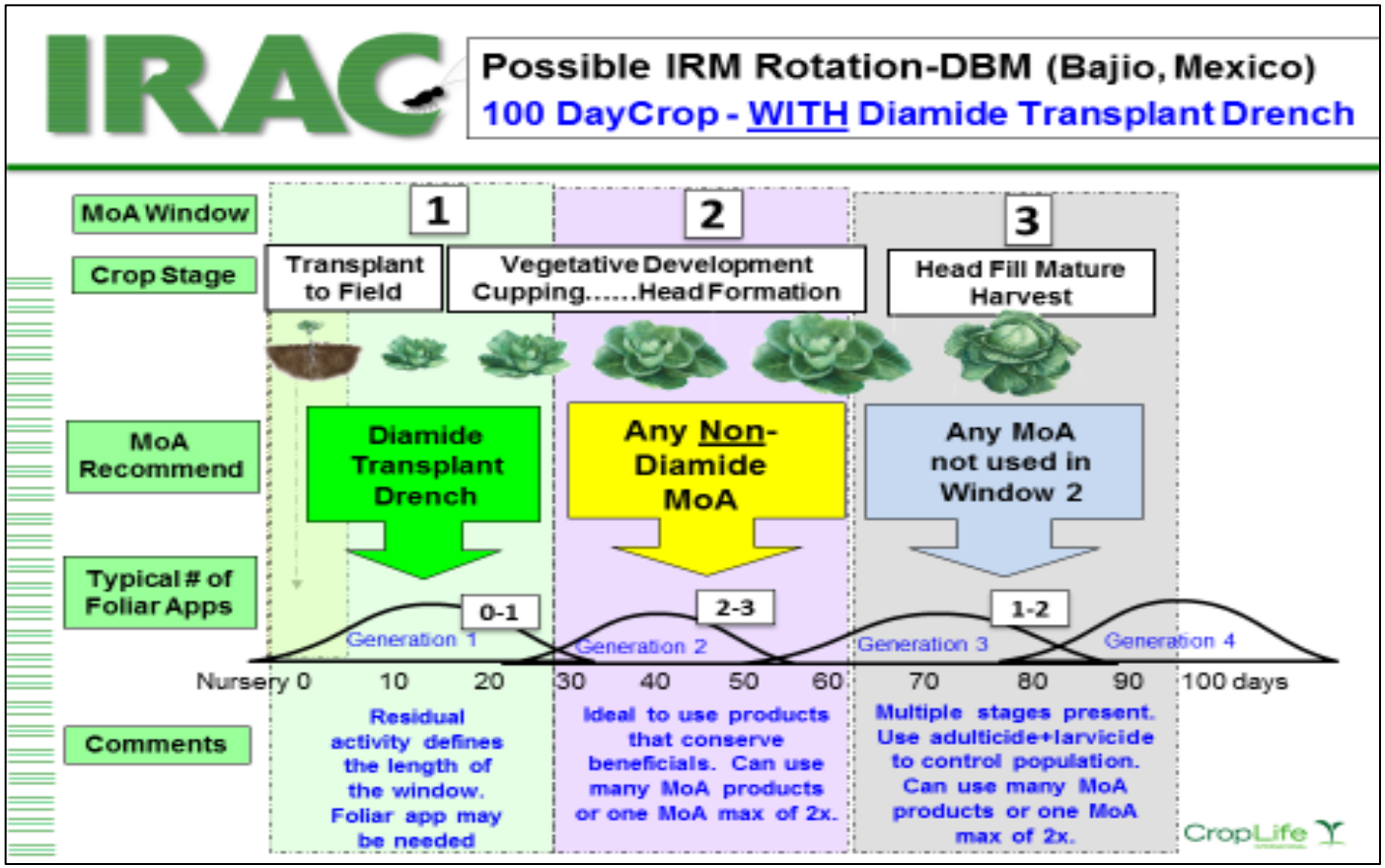


**C. Bajio, Mexico Brassica Crops.**

IRAC Mode of Action rotation strategies recommended for foliar and drench applications on cauliflower and broccoli to control Diamondback moth, *Plutella xylostella*.



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