Version 1.1, July 2017

Insecticide Resistance Action Committee

Insecticide resistance management guidelines for insect pests of corn, soybean and cotton in Brazil

IRAC Brazil & IRAC International

IRAC Insecticide Resistance Management Guidelines – Corn, Brazil (Condensed Version)

NOTE: In the following document the word 'insecticide(s)' refers to chemical & biological insecticides which are applied as either foliar, soil or seed treatments. It does not include plant incorporated proteins (PIP) which have insecticidal activity.

- **Only apply insecticides at economic pest thresholds**
  Follow locally established economic pest thresholds for the application of foliar insecticides in order to optimize insecticide use. Always use labeled rates and water volumes.
- **Use windows of insecticide application**
  Use windows of application to minimize exposure of sequential generations of an insect pest species to the same insecticide modes of action. Each window should be approximately 30 days to coincide with a single generation of the target insects.
- **Rotate insecticides with different modes of action.**
  If more than one insecticide application is required during an application window then it is recommended to use an insecticide which has a different mode of action. However, multiple applications of insecticides with the same mode of action within a single window are acceptable as long as combined effects (residual activity) of the applications do not exceed the 30-day window.
- **Insecticide seed treatments**
  Seeds which have been treated with an insecticide seed coating may not provide control of insect pests for the duration of window 1 (30 days). If an additional foliar insecticide application is required in the window it is strongly recommended that the foliar insecticide be applied no later than 25 days after seeding and for best IRM practice belong to a different mode of action group to the insecticide seed coating. Insecticides with the same mode of action as the seed coating should not be used for at least 30 days after the end of the first window.
- **Preserve non-target & beneficial organisms**
  The use of selective insecticides with reduced impact on non-target and beneficial organisms is recommended whenever possible.
- **Insecticide mixtures**
  Insecticide mixtures may offer benefits for pest control and/or IRM when appropriately incorporated into rotation strategies with additional modes of action, but generally a single mixture should not be relied upon alone.
- **Avoid insecticides which have existing resistance problems**
  Consult with local experts to determine which insecticides are affected by resistance in your locality. A preference to insecticides which are not affected by resistance should be given.

- **Manage crop post-harvest stubble & volunteers**
  Scout the field during pre-sowing burn down with a herbicide and if insects are observed in the remaining crop residues, the use of foliar applied insecticides is recommended for their control.
- **Rotate crops**
  It is recommended that subsequent or parallel crop sowings be of a different crop type. Sequential planting of the same crop can significantly increase both pest populations and the risk of resistance. Polyphagous insect pest species (e.g. *Spodoptera frugiperda*, *Helicoverpa armigera*) are particularly at risk from being exposed to insecticides and insecticidal proteins with the same mode of action across different crop plantings and special attention should be paid to minimize their exposure to insecticides and insecticidal proteins with the same mode of action.

Recommendations specific to corn expressing Bt proteins

•Refuge
The sowing/planting of a minimum 10% area of corn refuge (Non-Bt) within 800m of the Bt corn is considered mandatory. An in-field strip refuge is recommended for maximum effectiveness.

•Use of foliar insecticides in the refuge should be minimised
In the refuge, an insecticide application should be considered when the percent damaged plants reaches 30% (Davis Scale 3). The number of sprays in the refuge should not exceed 2 sprays and should be made before V6 (Up to 60 days post-sowing). When the refuge is sprayed, the Bt field should also be scouted and sprayed at the same time as the refuge if the level of damage in the Bt field exceeds the threshold provided by the seed supplier"

•Follow seed suppliers guidelines on the foliar spray thresholds in the Bt crop and the refuge.
Under high pest pressure the application of insecticides may be necessary in both the Bt crop and the refuge crop. It is recommended to follow the seed suppliers recommendations on the appropriate foliar spray thresholds.

•Rotate crops
It is recommended that subsequent or parallel crop sowings be either a non-host crop or a conventional variety of corn, whenever feasible.

Examples: Corn Application Windows (Condensed Version)

Foliar application of insecticides at locally agreed pest threshold.
Do not to use same insecticide MoA used in previous window and subsequent crop sowing

	Pre-Planting Window	Window 1 VE-V2	Window 2 V3-V6	Window 3 V7-VT	Window 4 R1-R3
Conventional Corn – Lepidoptera	Foliar Insecticide MoA X	Insecticide Seed Treatment (MoA Y); Seed Treatment or Foliar; Foliar Insecticide MoA Y	Foliar Insecticide MoA Z	Foliar Insecticide MoA R; Foliar Insecticide MoA R	Foliar Insecticide MoA Z
Conventional Corn – Stink Bug		Foliar insecticide MoA Q+W	Foliar Insecticide MoA X		
Bt Bt Corn **MAIN CROP** – Lepidoptera	Foliar Insecticide MoA X	Insecticide Seed Treatment (MoA Y); Seed treatment or Foliar; Foliar Insecticide MoA Y; Bt toxin (single or stacked): MoA Group 11			
Bt Bt Corn **MAIN CROP** – Stink Bug		Foliar insecticide MoA Q+W	Foliar Insecticide MoA X		
Bt Bt Corn **REFUGE** – Lepidoptera	Foliar Insecticide MoA X	Insecticide Seed Treatment (MoA Y); Seed Treatment or Foliar; Foliar Insecticide MoA Y			
Bt Bt Corn **REFUGE** – Stink Bug		Foliar insecticide MoA Q+W	Foliar Insecticide MoA X		

Pre-Planting (dessecação)	Planting /Sowing	Vegetative	Reprodutive

IRAC Insecticide Resistance Management Guidelines – Soybean, Brazil (Condensed Version)

NOTE: In the following document the word 'insecticide(s)' refers to chemical & biological insecticides which are applied as either foliar, soil or seed treatments. It does not include plant incorporated proteins (PIP) which have insecticidal activity.

- **Only apply insecticides at economic pest thresholds**
  Follow locally established economic pest thresholds for the application of foliar insecticides in order to optimize insecticide use. Always use labeled rates and water volumes.
- **Use windows of insecticide application**
  Use windows of application to minimize exposure of sequential generations of an insect pest species to the same insecticide modes of action. Each window should be approximately 30 days to coincide with a single generation of the target insects.
- **Rotate insecticides with different modes of action.**
  If more than one insecticide application is required during an application window then it is recommended to use an insecticide which has a different mode of action. However, multiple applications of insecticides with the same mode of action within a single window are acceptable as long as combined effects (residual activity) of the applications do not exceed the 30-day window.
- **Insecticide seed treatments**
  Seeds which have been treated with an insecticide seed coating may not provide control of insect pests for the duration of window 1 (30 days). If an additional foliar insecticide application is required in the window it is strongly recommended that the foliar insecticide be applied no later than 25 days after seeding and for best IRM practice belong to a different mode of action group to the insecticide seed coating. Insecticides with the same mode of action as the seed coating should not be used for at least 30 days after the end of the first window.
- **Insecticide mixtures**
  Insecticide mixtures may offer benefits for pest control and/or IRM when appropriately incorporated into rotation strategies with additional modes of action, but generally a single mixture should not be relied upon alone.
- **Preserve non-target & beneficial organisms**
  The use of selective insecticides with reduced impact on non-target and beneficial organisms is recommended whenever possible.
- **Avoid insecticides which have existing resistance problems**
  Consult with local experts to determine which insecticides are affected by resistance in your locality. A preference to insecticides which are not affected by resistance should be given.

- **Manage crop post-harvest stubble & volunteers**
  Scout the field during pre-sowing burn down with a herbicide and if insects are observed in the remaining crop residues, the use of foliar applied insecticides is recommended for their control.
- **Rotate crops**
  It is recommended that subsequent or parallel crop sowings be of a different crop type. Sequential planting of the same crop can significantly increase both pest populations and the risk of resistance. Polyphagous insect pest species (e.g. *Spodoptera frugiperda*, *Helicoverpa armigera*) are particularly at risk from being exposed to insecticides and insecticidal proteins with the same mode of action across different crop plantings and special attention should be paid to minimize their exposure to insecticides and insecticidal proteins with the same mode of action.

Recommendations specific to soybean expressing Bt proteins

•Refuge
The sowing/planting of a minimum 20% area of soybean refuge (Non-Bt)within 800m of the Bt soybean is considered mandatory. An in-field strip refuge is recommended for maximum effectiveness.

•Use of foliar insecticides in the refuge should be minimised
The application of insecticides to the non-Bt refuge can reduce the resistance management benefits of sowing the refuge. Therefore it is recommended to minimize the use of insecticides applied to the refuge.

•Follow seed suppliers guidelines on the foliar spray thresholds in the Bt crop and the refuge.
Under high pest pressure the application of insecticides may be necessary in both the Bt crop and the refuge crop. It is recommended to follow the seed suppliers recommendations on the appropriate foliar spray thresholds.

•Rotate crops
It is recommended that subsequent or parallel crop sowings be either a non-host crop or a conventional variety of soybean, whenever feasible.

Examples: Soybean Application Windows (Condensed Version)

Foliar application of insecticides at locally agreed pest threshold.
Do not to use same insecticide MoA used in previous window and subsequent crop sowing

	Pre-Planting Window	Window 1 (VE-V5)	Window 2 (V6-R1)	Window 3 (R2-R4)	Window 4 (R5-R6)
Conventional Soybean – Lepidoptera	Foliar Insecticide MoA W	Insecticide Seed Treatment (MoA Y) Seed treatment or foliar	Foliar Insecticide MoA Z Foliar Insecticide MoA Z	Foliar Insecticide MoA X	Foliar Insecticide MoA Z
Conventional Soybean – Stink Bug			Foliar insecticide MoA Q	Foliar Insecticide MoA X	
Conventional Soybean – Whitefly			Foliar insecticide MoA Q		
Bt Bt Soybean MAIN CROP – Lepidoptera	Foliar Insecticide MoA W	Foliar Insecticide (MoA Y) Foliar Insecticide (MoA Y) Seed treatment or foliar	Foliar Insecticide MoA Z Bt toxin (single or stacked): MoA Group 11		
Bt Bt Soybean MAIN CROP – Stink Bug			Foliar insecticide MoA Q	Foliar Insecticide MoA X	
Bt Bt Soybean MAIN CROP – Whitefly			Foliar insecticide MoA Q		
Bt Bt Soybean REFUGE – Lepidoptera	Foliar Insecticide MoA W	Insecticide Seed Treatment (MoA Y) Seed treatment or foliar	Foliar Insecticide MoA Z		
Bt Bt Soybean REFUGE – Stink Bug			Foliar insecticide MoA Q	Foliar Insecticide MoA X	
Bt Bt Soybean REFUGE – Whitefly			Foliar insecticide MoA Q		

Pre-Planting (dessecação)	Plan ting	Vegetative	Reproductive	Harvest

IRAC Insecticide Resistance Management Guidelines – Cotton, Brazil (Condensed Version)

NOTE: In the following document the word 'insecticide(s)' refers to chemical & biological insecticides which are applied as either foliar, soil or seed treatments. It does not include plant incorporated proteins (PIP) which have insecticidal activity.

- **Only apply insecticides at economic pest thresholds**
  Follow locally established economic pest thresholds for the application of foliar insecticides in order to optimize insecticide use. Always use labeled rates and water volumes.
- **Use windows of insecticide application**
  Use windows of application to minimize exposure of sequential generations of an insect pest species to the same insecticide modes of action. Each window should be approximately 30 days to coincide with a single generation of the lepidopteran target insects. 15 day windows should be used for weevils, mites and aphids
- **Rotate insecticides with different modes of action.**
  If more than one insecticide application is required during an application window then it is recommended to use an insecticide which has a different mode of action. However, multiple applications of insecticides with the same mode of action within a single window are acceptable as long as combined effects (residual activity) of the applications do not exceed the 30-day window.
- **Insecticide seed treatments**
  Seeds which have been treated with an insecticide seed coating may not provide control of insect pests for the duration of window 1 (30 days). If an additional foliar insecticide application is required in the window it is strongly recommended that the foliar insecticide be applied no later than 25 days after seeding and for best IRM practice belong to a different mode of action group to the insecticide seed coating. Insecticides with the same mode of action as the seed coating should not be used for at least 30 days after the end of the first window.
- **Insecticide mixtures**
  Insecticide mixtures may offer benefits for pest control and/or IRM when appropriately incorporated into rotation strategies with additional modes of action, but generally a single mixture should not be relied upon alone.
- **Preserve non-target & beneficial organisms**
  The use of selective insecticides with reduced impact on non-target and beneficial organisms is recommended whenever possible.
- **Avoid insecticides which have existing resistance problems**
  Consult with local experts to determine which insecticides are affected by resistance in your locality. A preference to insecticides which are not affected by resistance should be given.

- **Manage crop post-harvest stubble & volunteers**
  Scout the field during pre-sowing burn down with a herbicide and if insects are observed in the remaining crop residues, the use of foliar applied insecticides is recommended for their control.
- **Rotate crops**
  It is recommended that subsequent or parallel crop sowings be of a different crop type. Sequential planting of the same crop can significantly increase both pest populations and the risk of resistance. Polyphagous insect pest species (e.g. *Spodoptera frugiperda*, *Helicoverpa armigera*) are particularly at risk from being exposed to insecticides and insecticidal proteins with the same mode of action across different crop plantings and special attention should be paid to minimize their exposure to insecticides and insecticidal proteins with the same mode of action.

Recommendations specific to cotton expressing Bt proteins

•Refuge
The sowing/planting of a minimum 20% area of cotton refuge (non-Bt) within 800m of the Bt cotton is considered mandatory. An in-field strip refuge is recommended for maximum effectiveness.

•Use of foliar insecticides in the refuge should be minimised
The application of insecticides to the non-Bt refuge can reduce the resistance management benefits of sowing the refuge. Therefore it is recommended to minimize the use of insecticides applied to the refuge.

•Follow seed suppliers guidelines on the foliar spray thresholds in the Bt crop and the refuge.
Under high pest pressure the application of insecticides may be necessary in both the Bt crop and the refuge crop. It is recommended to follow the seed suppliers recommendations on the appropriate foliar spray thresholds.

•Rotate crops
It is recommended that subsequent or parallel crop sowings be either a non-host crop or a conventional variety of cotton, whenever feasible.

Examples: Cotton Application Windows (Condensed Version)

Foliar application of insecticides at locally agreed pest threshold.
Do not to use same insecticide MoA used in previous window and subsequent crop sowing

Pre-Planting Window	Window 1 (Seeding to 10 days PE)	Window 2 (10-40 days PE)	Window 3 (40-70 days PE)	Window 4 (70-100 days PE)	Window 5 (100-130 days PE)

Conventional Cotton

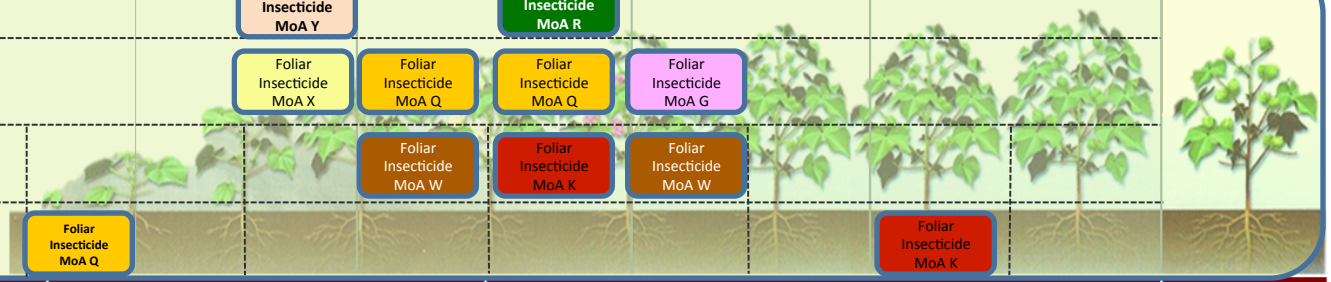
	Pre-Planting Window	Window 1 (Seeding to 10 days PE)	Window 2 (10-40 days PE)	Window 3 (40-70 days PE)	Window 4 (70-100 days PE)	Window 5 (100-130 days PE)
Lepidoptera	Foliar Insecticide MoA Z			Foliar Insecticide MoA Y	Foliar Insecticide MoA Y	Foliar Insecticide MoA X / Foliar Insecticide MoA R
Whitefly			Foliar Insecticide MoA X	Foliar Insecticide MoA Q	Foliar Insecticide MoA Q	Foliar Insecticide MoA G
Boll Weevil				Foliar Insecticide MoA W	Foliar Insecticide MoA K	Foliar Insecticide MoA W
Aphids & mites		Foliar Insecticide MoA Q				Foliar Insecticide MoA K

Bt Bt Cotton **MAIN CROP**

	Pre-Planting Window	Window 1 (Seeding to 10 days PE)	Window 2 (10-40 days PE)	Window 3 (40-70 days PE)	Window 4 (70-100 days PE)	Window 5 (100-130 days PE)
Lepidoptera	Foliar Insecticide MoA Z	Bt toxin (single or stacked): MoA Group 11	Foliar Insecticide MoA Y			
Whitefly			Foliar Insecticide MoA X	Foliar Insecticide MoA Q	Foliar Insecticide MoA Q	Foliar Insecticide MoA G
Boll Weevil				Foliar Insecticide MoA W	Foliar Insecticide MoA K	Foliar Insecticide MoA W
Aphids & mites		Foliar Insecticide MoA Q				Foliar Insecticide MoA K

Bt Bt Cotton **REFUGE**

	Pre-Planting Window	Window 1 (Seeding to 10 days PE)	Window 2 (10-40 days PE)	Window 3 (40-70 days PE)	Window 4 (70-100 days PE)	Window 5 (100-130 days PE)
Lepidoptera	Foliar Insecticide MoA Z		Foliar Insecticide MoA Y	Foliar Insecticide MoA R		
Whitefly			Foliar Insecticide MoA X	Foliar Insecticide MoA Q	Foliar Insecticide MoA Q	Foliar Insecticide MoA G
Boll Weevil				Foliar Insecticide MoA W	Foliar Insecticide MoA K	Foliar Insecticide MoA W
Aphids & mites		Foliar Insecticide MoA Q				Foliar Insecticide MoA K



Pre-Planting	Planting /Sowing	Vegetative	Reproductive	Desication

Version 1.1, July 2017

Insecticide Resistance Action Committee

Insecticide resistance management guidelines for insect pests of corn, soybean and cotton in Brazil

Supplemental Information

Contents:

Introduction:

- The following IRM recommendations have been developed by IRAC Brazil & IRAC International and in consultation with leading local experts on Brazilian agriculture and resistance management.

- The recommendations contained within the document are based on resistance management principles, whilst also considering the need to provide economical pest control.

- The documents provided are intended to provide the basis for developing an effective pest management program that minimizes the risk of insecticide resistance evolution.

- Although this document provides the basis for developing a pest management strategy, local variations in agronomic practice, pest spectrum, crop growth dynamics, pest susceptibility.....etc, mean that **adaptation to local condition is necessary**.

Building a pest management program which incorporates resistance management.

The basis for an effective pest management strategy is:

- Plan ahead by considering when insect control may be needed during the crop cycle and ensuring that a variety of insect control options are available.
- Build a pest management plan for the individual crop, but also take into account pests which may transfer to and from other crops.
- Make effective use of the insect control options available by using locally approved pest management thresholds.
- Rotate insecticides with different modes of action, to avoid resistance development.
- Always follow manufacturers and seed producers recommendations on sowing a refuge, insecticide label rates and using appropriate application equipment.
- Avoid the parallel or sequential sowing of host crops which are hosts to the same insect pests

Version 1.1, July 2017

Insecticide Resistance Action Committee

Insecticide resistance management guidelines for insect pests of corn in Brazil

IRAC Insecticide Resistance Management Guidelines – Corn, Brazil (Part I)

NOTE: In the following document the word 'insecticide(s)' refers to chemical & biological insecticides which are applied as either foliar, soil or seed treatments. It does not include plant incorporated proteins (PIP) which have insecticidal activity.

- In cropping systems which require multiple applications of insecticides, it is recommended that windows* of application are utilized in order to minimize exposure of sequential generations of the insect pests to the same insecticide modes of action**.
- The main pests of corn (fall armyworm, corn earworm, stink bugs) all have approximately a 30 day generation time. By establishing application windows which are approximatley 30 days in length, the chances of sequential generations of the target insect being exposed to the same insecticide mode of action will be decreased and the risk of resistance development will be reduced.
- Follow locally established economic pest thresholds for the application of foliar insecticides in order to optimize insecticide use.
- If more than one insecticide application is required during a 30-day window then it is preferred that each insecticide has a different mode of action. Multiple applications of the same mode of action within a single window is acceptable as long as combined effects of the applications do not exceed the 30 day window duration.
- Application windows for pre-sowing (burn-down period) and seed treatment insecticide applications should be included in a window strategy.
- Seeds which have been treated with an insecticide seed coating may not provide control of insect pests for the duration of window 1 (30 days). If an additional foliar insecticide application is required in the window it is strongly recommended that the foliar insecticide be applied no later than 25 days after seeding and for best IRM practice belong to a different mode of action group to the insecticide seed coating. Insecticides with the same mode of action as the seed coating should not be used for at least 30 days after the end of the first window.

*Also known as 'block applications'
** Insecticide modes of action can be identified either by the mode of action classification number on the label or by the various mode of action classification documents provided by IRAC.

IRAC Insecticide Resistance Management Guidelines – Corn, Brazil (Part II)

- Insecticide pre-mixtures can provide benefits for the control of multiple pests simultaneously or hard to control pests. Insecticide mixtures may offer benefits for IRM when appropriately incorporated into rotation strategies with additional mode(s) of action, but generally a single mixture should not be relied upon alone*.

- The use of selective insecticides with reduced impact on non-target and beneficial organisms is recommended when possible. By selecting insecticides with minimal impact on predatory/parasitic organisms, the need for insecticide sprays will be reduced and as a result the risk of resistance will be reduced.

- The following resistance has been reported in Brazilian populations. Those implementing a pest management program should consult with local experts to determine if products containing these insecticides are considered to provide effective pests control of the target pests. In the absence of information on the insect susceptibility to these insecticides, alternative modes of action which are not affected by resistance should be given preference.

    - Fall Armyworm (*Spodoptera frugiperda*): Carbamates/Organophosphates (G1), Pyrethroids (G3) & Benzoyl ureas (G15)
    - Cotton Bollworm (*Helicoverpa armi*gera) : Carbamates/Organophosphates (G1), Cyclodienes (G2), Pyrethroids (G3).

- The management of crop remnants/volunteers (both prior to planting/sowing and after harvest) is strongly recommended. Scout the field during pre-sowing burn down with herbicides (30 days before planting/sowing) and if insects are observed in the remaining crop residues, the use of foliar applied insecticides is recommended for their control.

- It is recommended that subsequent or parallel crop sowings be of a different crop type. Sequential planting of the same crop can significantly increase both pest populations and the risk of resistance. Polyphagous insect pest species (e.g. *Spodoptera frugiperda*, *Helicoverpa armigera*) are particularly at risk from being exposed to insecticides and insecticidal proteins with the same mode of action across different crop plantings and special attention should be paid to minimize their exposure to insecticides and insecticidal proteins with the same mode of action.

* See IRAC position statement on the use of insecticide mixtures for IRM purposes.
G# = IRAC Mode of Action Classification Group

Additional IRM Recommendations for Bt corn & the associated refuge

- Corn hybrids which express two or more plant incorporated proteins (PIP) which both control a single target pest are preferred for resistance management purposes over varieties which express either single PIP's or two or more PIP targeting different species.

- The sowing of a minimum of 10% of a non- Bt corn refuge within 800m of the Bt corn is considered mandatory for managing resistance to plant incorporated Bt-toxins

- An in-field strip refuge is recommended for maximum effectiveness, although other refuge design options are available.

- The application of insecticides to the refuge can reduce the resistance management benefits of sowing/planting the structured refuge. Therefore under low pest pressure conditions it is recommended not to apply or at least minimize the use of insecticides applied to the refuge.

- Under high pest pressure the application of insecticides may be necessary in both the Bt crop and the refuge in order to maintain the crop. The following pest thresholds are recommended to minimize the number of insects in the traited crop, whilst maximizing the productivity of the refuge (both yield & susceptible insect production).

- Conventional corn = Insecticide application at a minimum of 20% plant damage at Davis scale 3
- Bt corn = See seed producers recommendations for unexpected damage. Recommendations range from 4% to 20% plant damage.
- Refuge corn = Maximum of two foliar insecticide applications targeting lepidoptera prior to V6 stage (up to 60 days after sowing). Insecticide application at a minimum of 30% plant damage at Davis scale 3.

- The use of *Bacillus thuringiensis* based foliar insecticide sprays is not recommended in the refuge.

- It is recommend that subsequent crop sowings be either a non-host crop or a conventional variety of corn, whenever feasible

* See Manufacturers recommendation, the recommended threshold will depend on the proteins expressed in the selected seed varieity. .

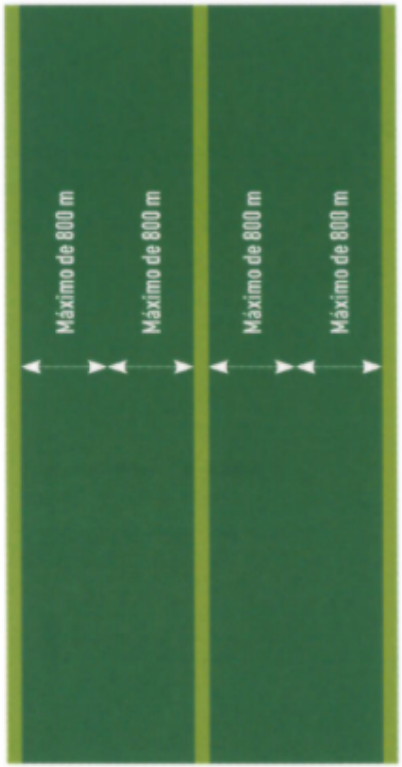
Structured Refuge Options

- Different options for the mandatorys sowing of a minimum of 10% area of a corn refuge (Non-Bt) within 800m of the Bt corn. An in-field strip refuge is recommended for maximum effectiveness.

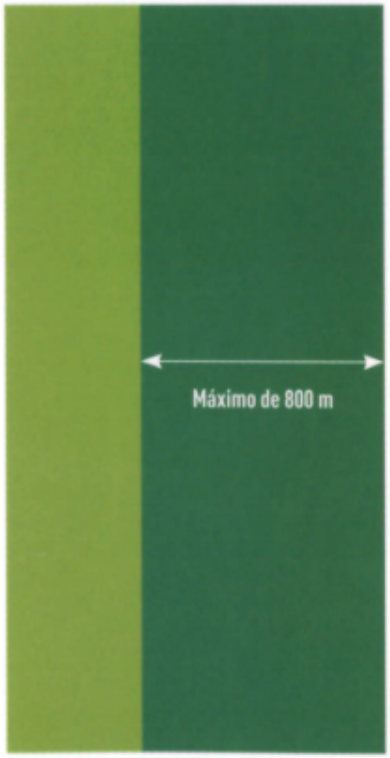
Refuge area (Non-Bt)

Transgenic plants area (Bt)

In-field strip refuge



Block refuge



Border refuge

Davis Damage Scale for Corn (1-9)

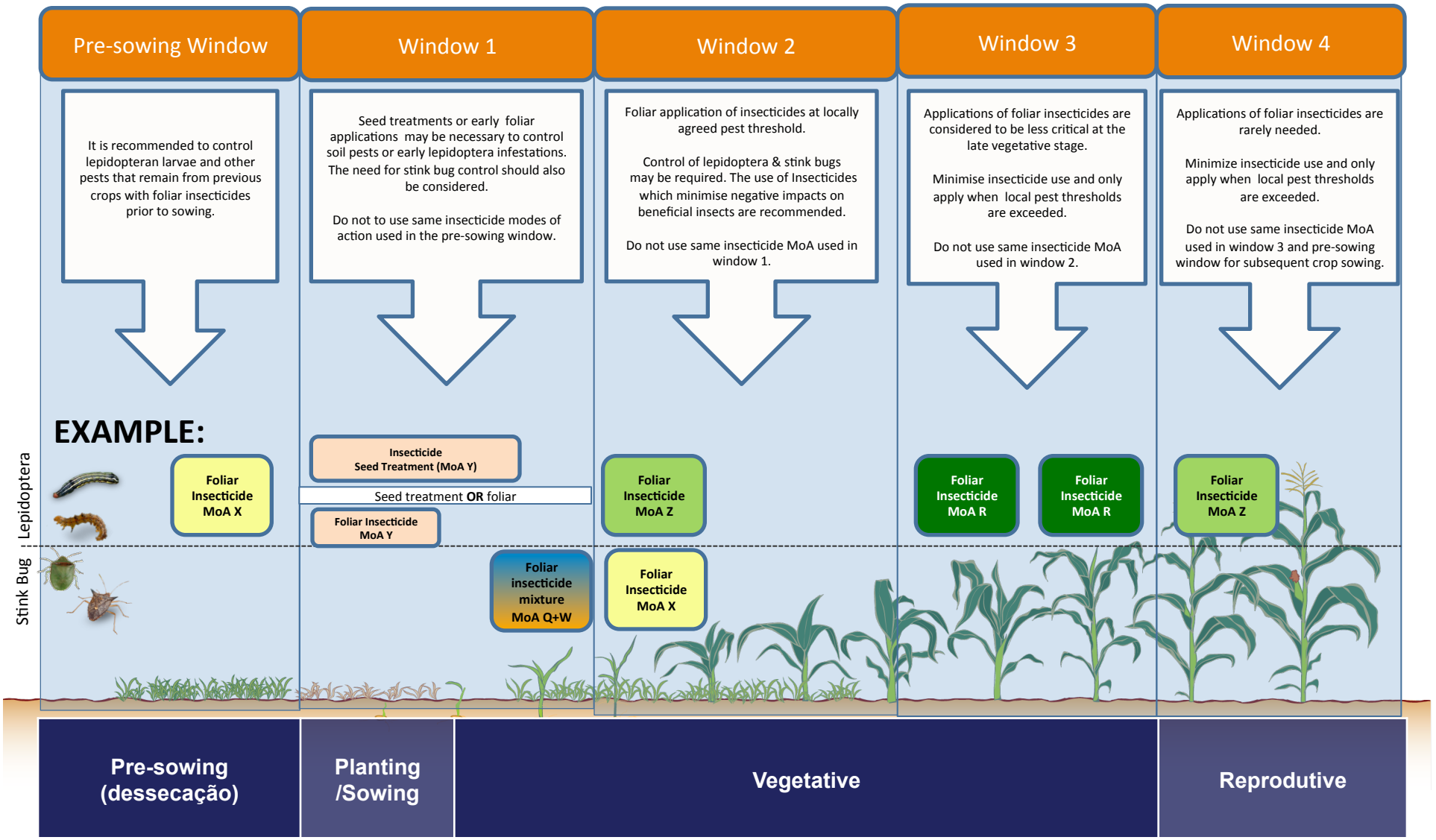
Photos supplied by DuPont-Pioneer

Insecticide Resistance Action Committee

Pest management strategy examples: Corn

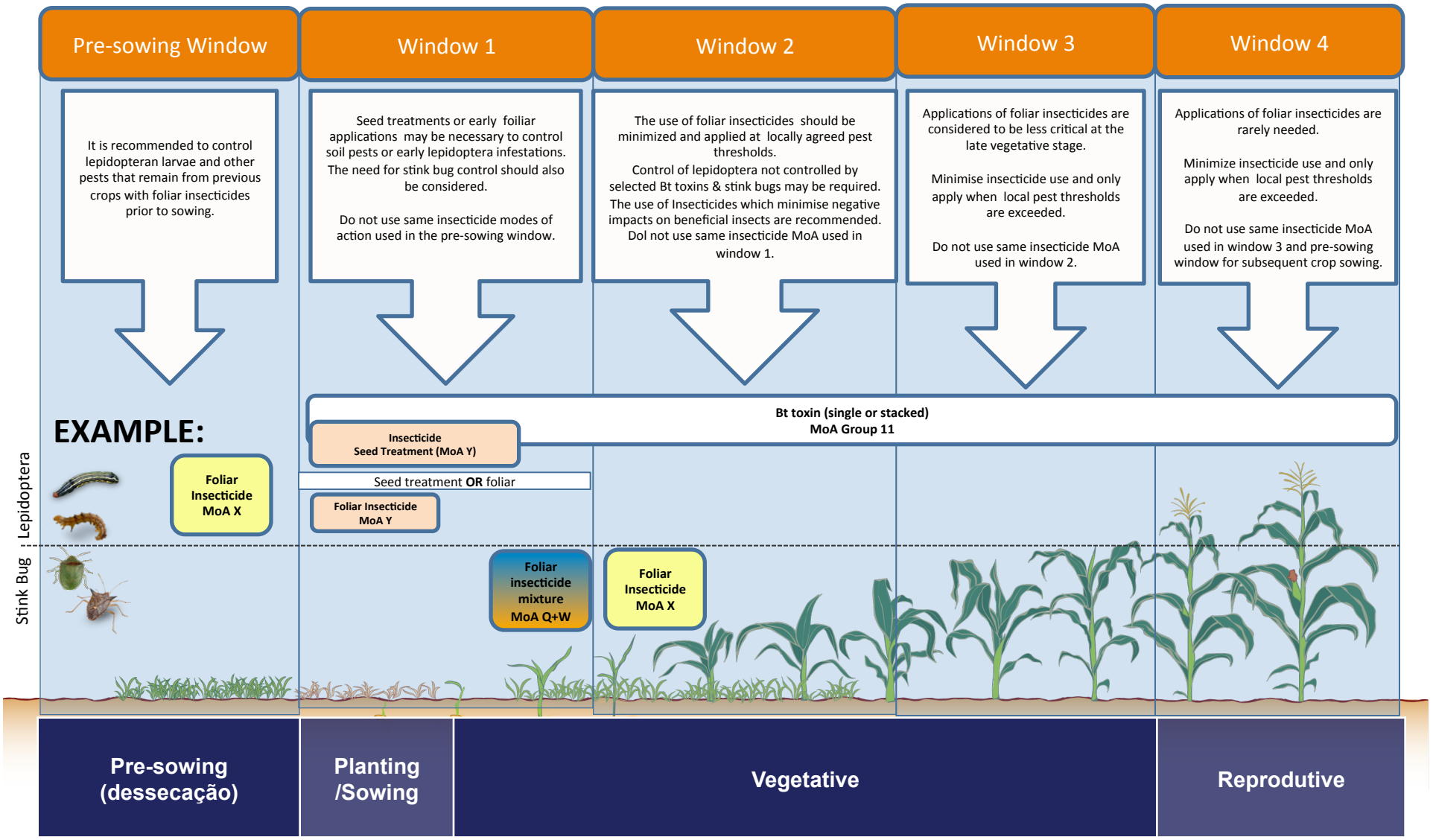
IRAC Insecticide Resistance Management Guidelines – Corn, Brazil

Application Windows for Conventional Corn



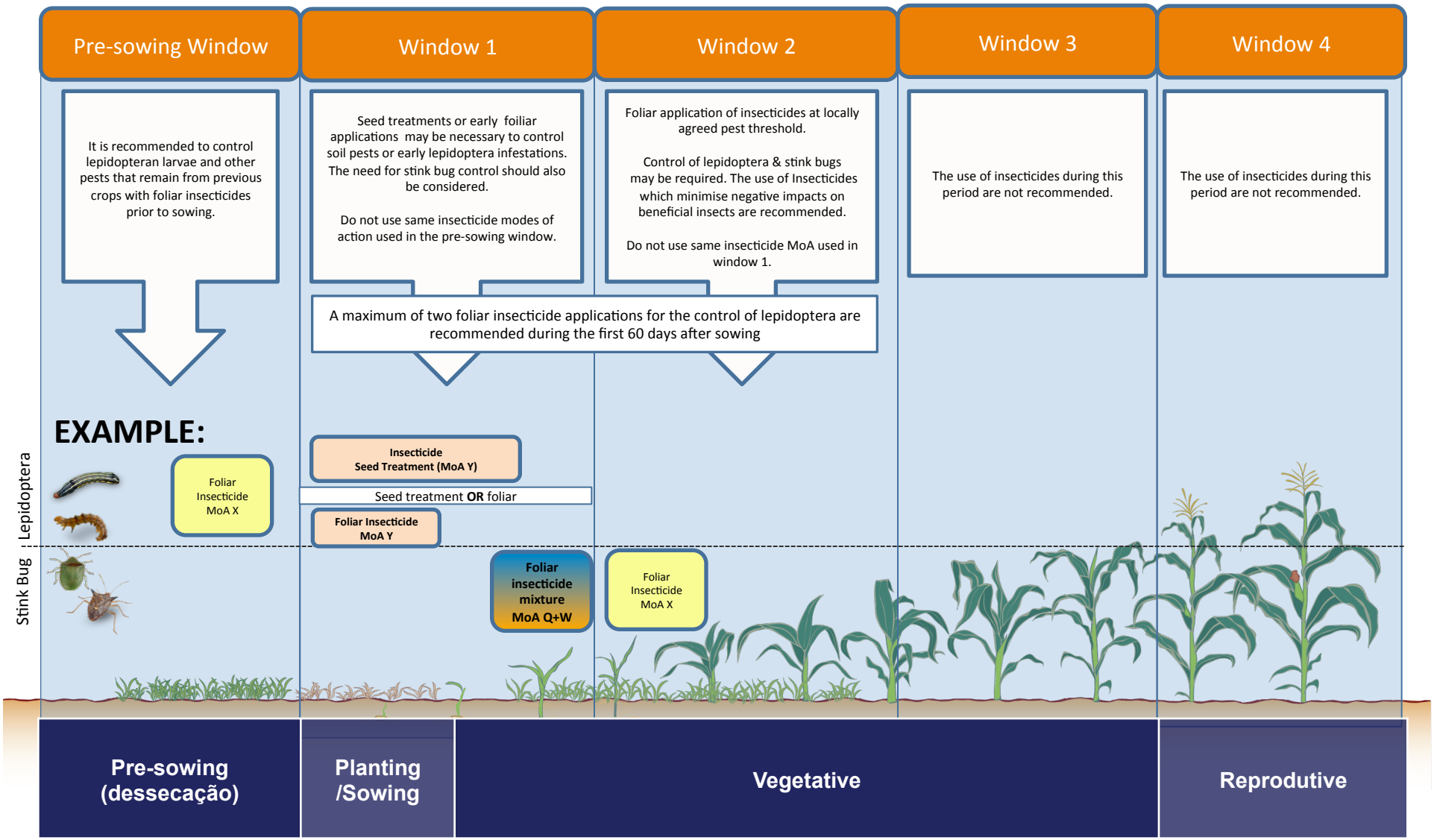
IRAC Insecticide Resistance Management Guidelines – Corn, Brazil

Application Windows for Bt Corn MAIN CROP



IRAC Insecticide Resistance Management Guidelines – Corn, Brazil

Application Windows for Bt Corn REFUGE



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Insecticide Resistance Action Committee

Insecticide resistance management guidelines for insect pests of soybean in Brazil

IRAC Insecticide Resistance Management Guidelines – Soybean, Brazil (Part I)

NOTE: In the following document the word 'insecticide(s)' refers to chemical & biological insecticides which are applied as either foliar, soil or seed treatments. It does not include plant incorporated proteins (PIP) which have insecticidal activity.

- In cropping systems which require multiple applications of insecticides, it is recommended that windows* of application are utilized in order to minimize exposure of sequential generations of the insect pests to the same insecticide modes of action**.
- The main pests of soybean (soybean looper, armyworms, bollworm, stink bugs, tobacco whitefly) all have approximately a 30-40 day generation time. By establishing application windows which are approximately 30 days in length, the chances of sequential generations of the target insect being exposed to the same insecticide mode of action will be decreased and the risk of resistance development will be reduced.
- Follow locally established economic pest thresholds for the application of foliar insecticides in order to optimize insecticide use.
- If more than one insecticide application is required during a 30-day window then it is preferred that each insecticide has a different mode of action. Multiple applications of the same mode of action within a single window is acceptable as long as combined effects of the applications do not exceed the 30 day window duration.
- Application windows for pre-sowing (burn-down period) and seed treatment insecticide applications should be included in a window strategy.
- Seeds which have been treated with an insecticide seed coating may not provide control of insect pests for the duration of window 1 (30 days). If an additional foliar insecticide application is required in the window it is strongly recommended that the foliar insecticide be applied no later than 25 days after seeding and for best IRM practice belong to a different mode of action group to the insecticide seed coating. Insecticides with the same mode of action as the seed coating should not be used for at least 30 days after the end of the first window.

*Also known as 'block applications'
** Insecticide modes of action can be identified either by the mode of action classification number on the label or by the various mode of action classification documents provided by IRAC.

IRAC Insecticide Resistance Management Guidelines – Soybean, Brazil (Part II)

- Insecticide pre-mixtures can provide benefits for the control of multiple pests simultaneously or hard to control pests. Insecticide mixtures may offer benefits for IRM when appropriately incorporated into rotation strategies with additional mode(s) of action, but generally a single mixture should not be relied upon alone*.

- The use of selective insecticides with reduced impact on non-target and beneficial organisms is recommended when possible. By selecting insecticides with minimal impact on predatory/parasitic organisms, the need for insecticide sprays will be reduced and as a result the risk of resistance will be reduced.

- The following resistance has been reported in Brazilian populations. Those implementing a pest management program should consult with local experts to determine if products containing these insecticides are considered to provide effective pests control of the target pests. In the absence of information on the insect susceptibility to these insecticides, alternative modes of action which are not affected by resistance should be given preference.

- Black cutworm (Agrotis ipsilon): Cyclodiene (G2)
- Fall Armyworm (Spodoptera frugiperda): Carbamates/Organophosphates (G1), Pyrethroids (G3) & Benzoyl ureas (G15)
- Soybean Looper (Chrysodiexis includens): Carbamates/Organophosphates (G1), Pyrethroids (G3)
- Velvetbean Catapillar (Anticarsia gemmatalis): Nuclear Polyhedrosis Virus (NPV)
- Cotton Bollworm (Helicoverpa armigera) : Carbamates/Organophosphates (G1), Cyclodienes (G2), Pyrethroids (G3).
- Tobacco Whitefly (Bemisia tabaci): Carbamates/Organophosphates (G1), Cyclodienes (G2), Pyrethroids (G3), Neonicotinoids (G4), Pymetrozine (G9).

- The management of crop remnants/volunteers (both prior to sowing and after harvest) is strongly recommended. Scout the field during pre-sowing burn down with herbicides (20 days before sowing) and if insects are observed in the remaining crop residues, the use of foliar applied insecticides is recommended for their control.

- It is recommended that subsequent or parallel crop sowings be of a different crop type. Sequential planting of the same crop can significantly increase both pest populations and the risk of resistance. Polyphagous insect pest species (e.g. Spodoptera frugiperda, Helicoverpa armigera) are particularly at risk from being exposed to insecticides and insecticidal proteins with the same mode of action across different crop plantings and special attention should be paid to minimize their exposure to insecticides and insecticidal proteins with the same mode of action.

* See IRAC position statement on the use of insecticide mixtures for IRM purposes.
G# = IRAC Mode of Action Classification Group

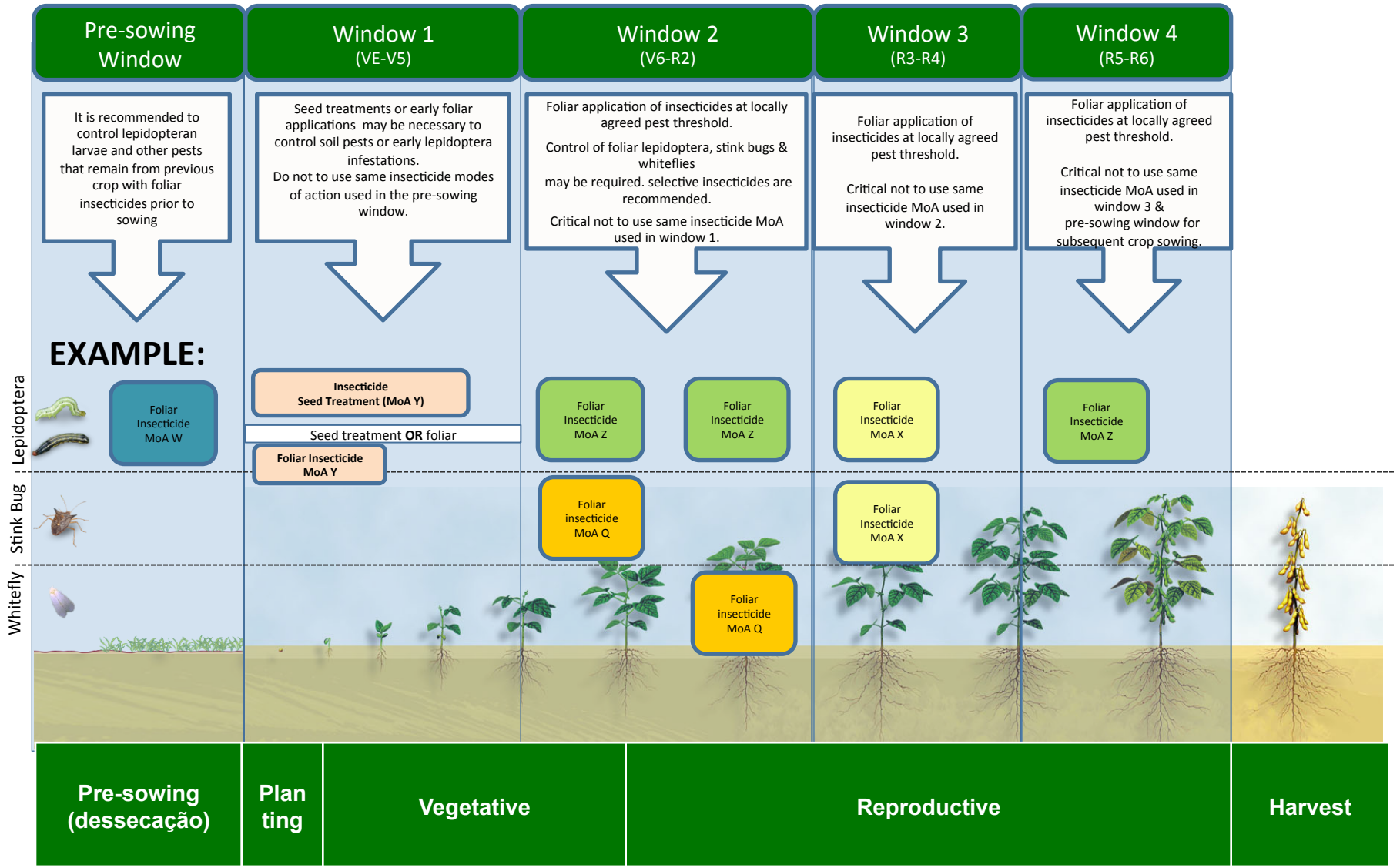
Additional IRM Recommendations for Bt soybean & the associated refuge

- The sowing of a minimum of 20% of a soybean refuge (non- Bt) which is planted within 800m of the Bt soybean is considered mandatory for managing resistance to plant incorporated Bt-toxins
- An in-field strip refuge is recommended for maximum effectiveness, although other refuge design options are available.
- The application of insecticides to the refuge can reduce the resistance management benefits of sowing the structured refuge. Therefore under low pest pressure conditions it is recommended not to apply or at least minimize the use of insecticides applied to the refuge.
- Under high pest pressure the application of insecticides may be necessary in both the Bt crop and the refuge in order to maintain the crop. It is recommended to follow locally recommended pest thresholds and minimizing the use of foliar applied insecticides in the refuge.
- The use of Bacillus thuringiensis based foliar insecticide sprays is not recommended in the refuge.
- It is recommend that subsequent crop sowings be either a non-host crop or a conventional variety of soybean, whenever feasible.

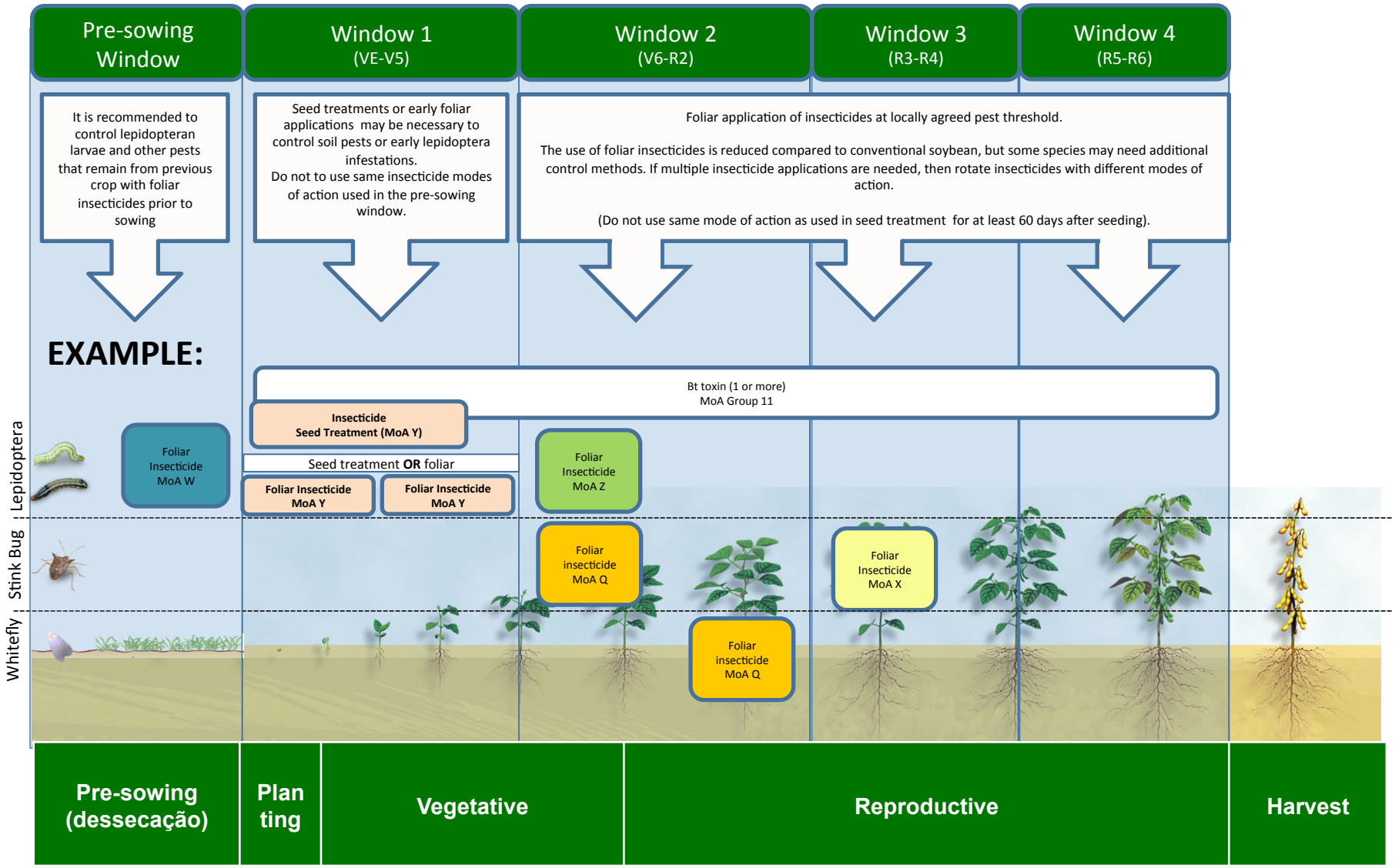
Insecticide Resistance Action Committee

Pest management strategy examples: Soybean

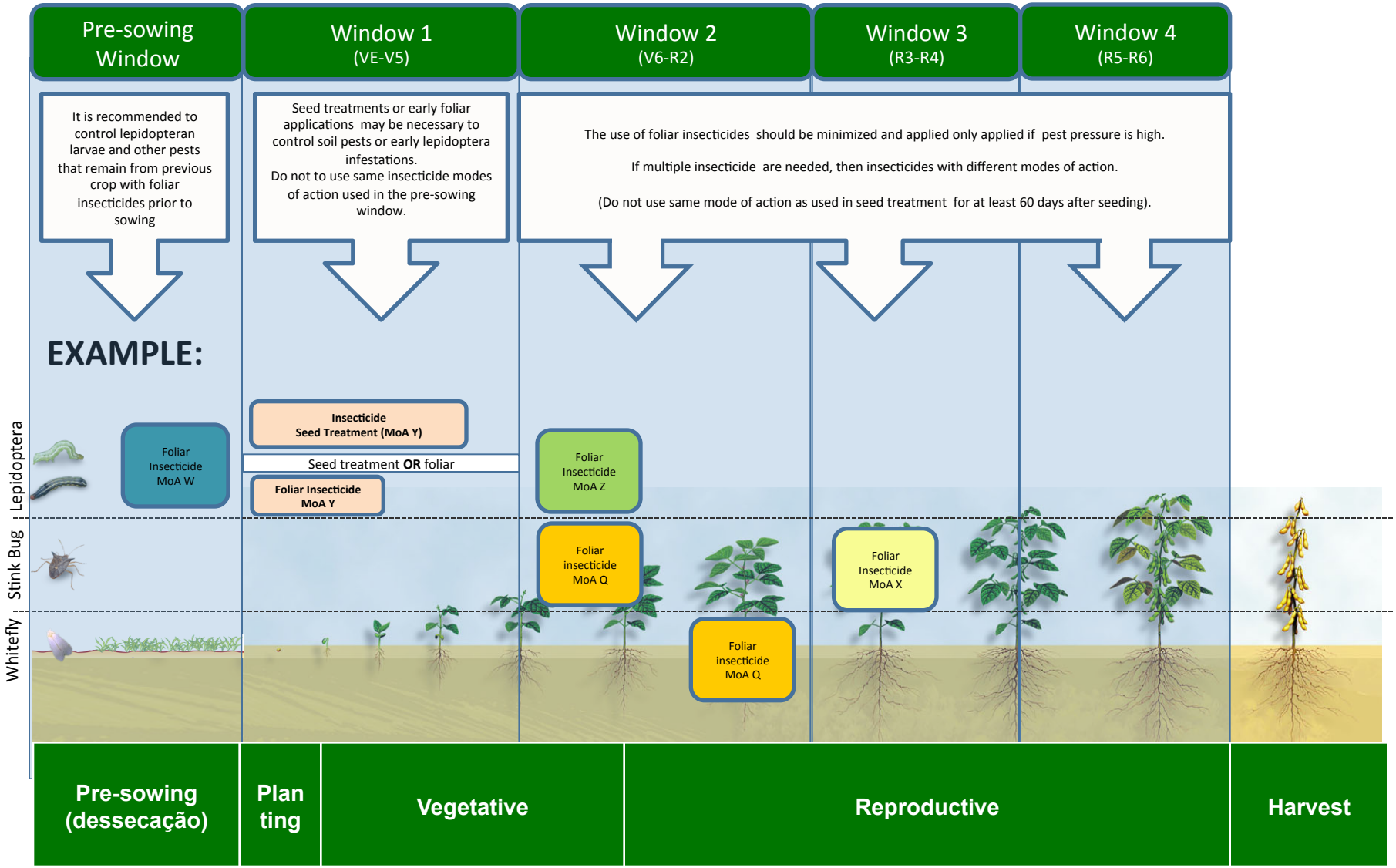
Application Windows for Conventional Soybean



Application Windows for Bt Soybean (MAIN CROP)



Application Windows for Bt Soybean (REFUGE)



Version 1.1, July 2017

Insecticide Resistance Action Committee

Insecticide resistance management guidelines for insect pests of cotton in Brazil

IRAC Insecticide Resistance Management Guidelines – Cotton, Brazil (Part I)

NOTE: In the following document the word 'insecticide(s)' refers to chemical & biological insecticides which are applied as either foliar, soil or seed treatments. It does not include plant incorporated proteins (PIP) which have insecticidal activity.

- In cropping systems which require multiple applications of insecticides, it is recommended that windows* of application are utilized in order to minimize exposure of sequential generations of the insect pests to the same insecticide modes of action**.
- The main pests of cotton can be divided into different groups based on the duration of their lifecycle. Lepidopteran pests, whiteflies and stink bugs have a generation time of approximatley 30 days, whilst the cotton boll weevil, aphids and mites all have shorter generation times (15-20 days). By establishing application windows which are approximately 30 days in length for lepidoptera, stink bugs and whiteflies and 15 day windows for weevils, mites and aphids, the chances of sequential generations of the target insect being exposed to the same insecticide mode of action will be decreased and the risk of resistance development will be reduced.
- Follow locally established economic pest thresholds for the application of foliar insecticides in order to optimize insecticide use.
- If more than one insecticide application is required for during a day window then it is preferred that each insecticide has a different mode of action. Multiple applications of the same mode of action within a single window is acceptable as long as combined effects of the applications do not exceed the window duration.
- Application windows for pre-sowing (burn-down period) and seed treatment insecticide applications should be included in a window strategy.
- Seeds which have been treated with an insecticide seed coating may not provide control of insect pests for the duration of window 1 (30 days). If an additional foliar insecticide application is required in the window it is strongly recommended that the foliar insecticide be applied no later than 25 days after seeding and for best IRM practice belong to a different mode of action group to the insecticide seed coating. Insecticides with the same mode of action as the seed coating should not be used for at least 30 days after the end of the first window.

*Also known as 'block applications'
** Insecticide modes of action can be identified either by the mode of action classification number on the label or by the various mode of action classification documents provided by IRAC.

IRAC Insecticide Resistance Management Guidelines – Cotton, Brazil (Part II)

- Insecticide pre-mixtures can provide benefits for the control of multiple pests simultaneously or hard to control pests. Insecticide mixtures may offer benefits for IRM when appropriately incorporated into rotation strategies with additional mode(s) of action, but generally a single mixture should not be relied upon alone*.

- The use of selective insecticides with reduced impact on non-target and beneficial organisms is recommended when possible. By selecting insecticides with minimal impact on predatory/parasitic organisms, the need for insecticide sprays will be reduced and as a result the risk of resistance will be reduced.

- The following resistance has been reported in Brazilian populations. Those implementing a pest management program should consult with local experts to determine if products containing these insecticides are considered to provide effective pests control of the target pests. In the absence of information on the insect susceptibility to these insecticides, alternative modes of action which are not affected by resistance should be given preference.

    - Cotton Leafworm (*Alabama argillacea*): Cyclodiene (G2)
    - Soybean Looper (*Chrysodiexis includens*): Carbamates/Organophosphates (G1), Pyrethroids (G3)
    - Cotton Bollworm (*Helicoverpa armi*gera) : Carbamates/Organophosphates (G1), Cyclodienes (G2), Pyrethroids (G3).
    - Tobacco Budworm (*Heliothis virescens*): Carbamates/Organophosphates (G1), Cyclodienes (G2), Pyrethroids (G3).
    - Tobacco Whitefly (*Bemisia tabaci*): Carbamates/Organophosphates (G1), Cyclodienes (G2), Pyrethroids (G3), Neonicotinoids (G4), Pymetrozine (G9).
    - Two-Spotted Spider Mite (*Tetranychus urticae*): Carbamates/Organophosphates (G1), Chlorfenaypr (G13)
    - Cotton aphid (*Aphis gossypii*): Carbamates/Organophosphates (G1), Pyrethroids (G3)

- The management of crop remnants/volunteers (both prior to sowing and after harvest) is strongly recommended. Scout the field during pre-sowing burn down with herbicides (30 days before sowing) and if insects are observed in the remaining crop residues, the use of foliar applied insecticides is recommended for their control.

- It is recommended that subsequent or parallel crop sowings be of a different crop type. Sequential planting of the same crop can significantly increase both pest populations and the risk of resistance. Polyphagous insect pest species (e.g. Spodoptera frugiperda, Helicoverpa armigera) are particularly at risk from being exposed to insecticides and insecticidal proteins with the same mode of action across different crop plantings and special attention should be paid to minimize their exposure to insecticides and insecticidal proteins with the same mode of action.

* See IRAC position statement on the use of insecticide mixtures for IRM purposes.
G# = IRAC Mode of Action Classification Group

Additional IRM Recommendations for Bt cotton & the associated refuge

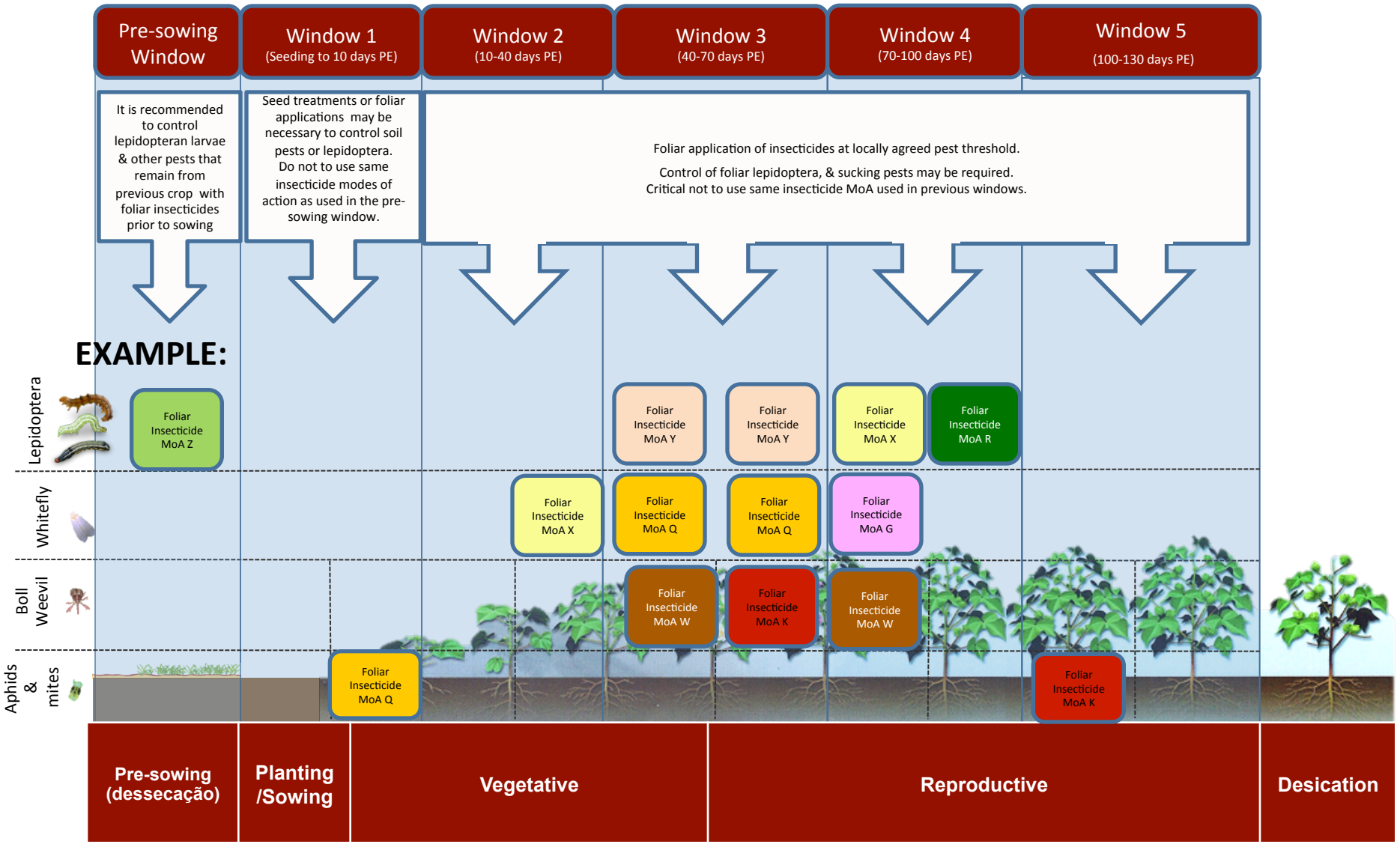
- Cotton varieties which express two or more plant incorporated proteins (PIP) which both control a single target pest are preferred for resistance management purposes over varieties which express either single PIP's or two or more PIP targeting different species.
- The sowing of a minimum of 20% of a cotton refuge (non-Bt) which is planted within 800m of the Bt cotton is considered mandatory for managing resistance to plant incorporated Bt-toxins
- An in-field strip refuge is recommended for maximum effectiveness, although other refuge design options are available.
- The application of insecticides to the refuge can reduce the resistance management benefits of sowing the structured refuge. Therefore under low pest pressure conditions it is recommended not to apply or at least minimize the use of insecticides applied to the refuge.
- Under high pest pressure the application of insecticides may be necessary in both the Bt crop and the refuge in order to maintain the crop. It is recommended to follow locally recommended pest thresholds and minimizing the use of foliar applied insecticides in the refuge.
- The use of *Bacillus thuringiensis* based foliar insecticide sprays is not recommended in the refuge.
- It is recommended that subsequent crop sowings be either a non-host crop or a conventional variety of cotton, whenever feasible.

Insecticide Resistance Action Committee

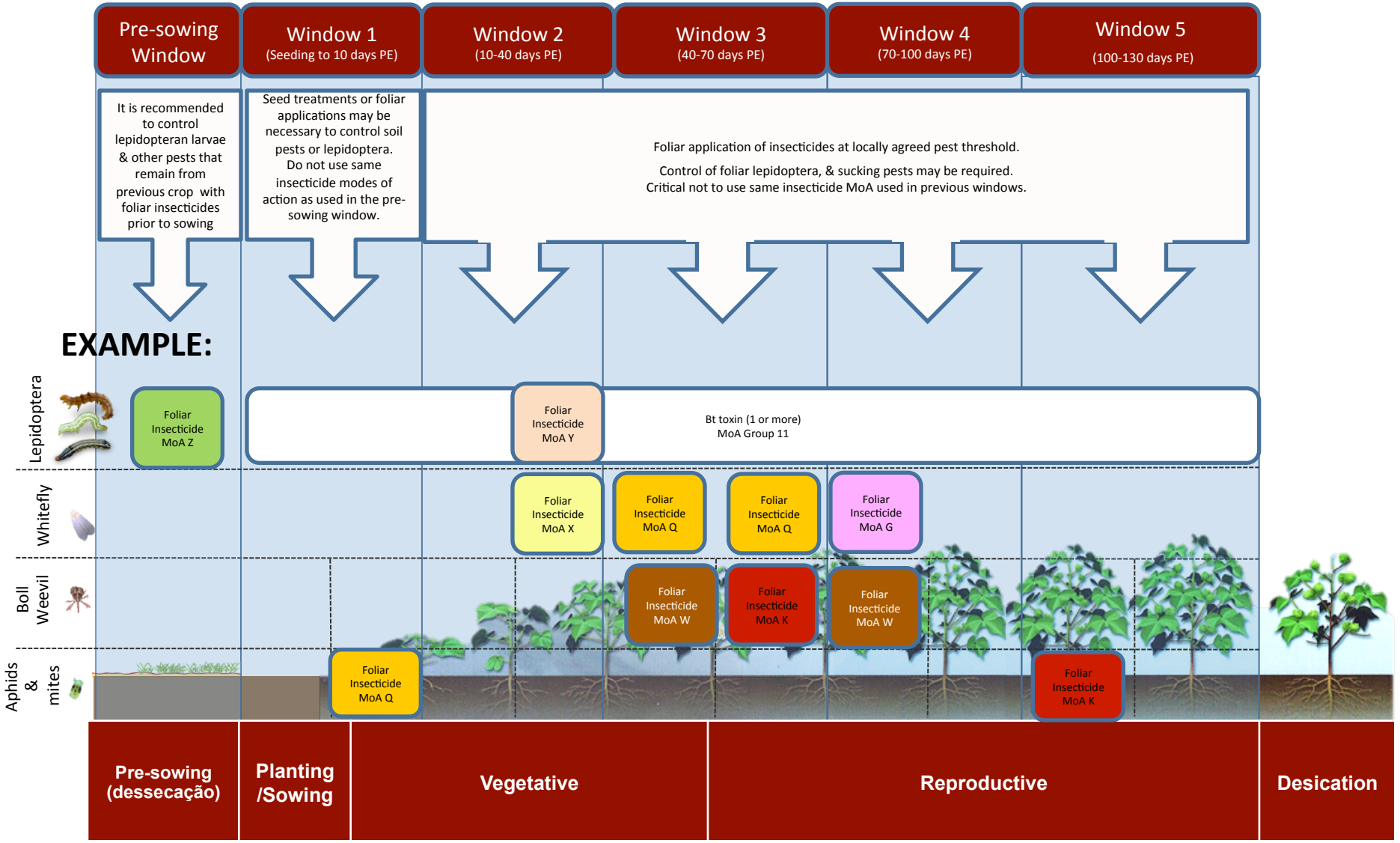
Pest management strategy examples: Cotton

IRAC Insecticide Resistance Management Guidelines – Cotton, Brazil

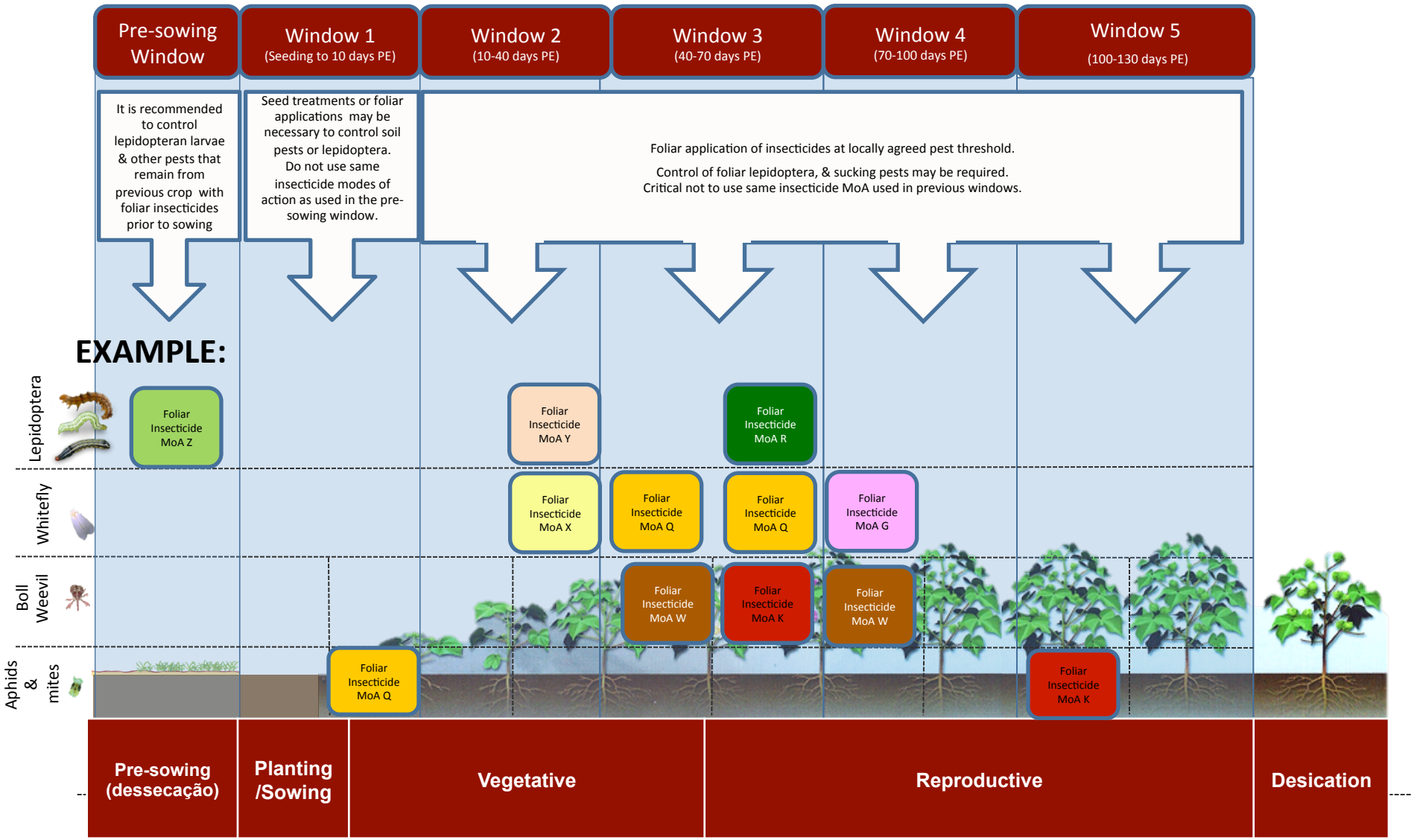
Application Windows for Conventional Cotton



Application Windows for Bt Cotton (MAIN CROP)



Application Windows for Bt Cotton (REFUGE)



Insecticide Resistance Action Committee

Area-Wide & Cross-Crop Pest Management in Brazil

Cross-Crop Resistance Management

- Cotton, Soybean & Corn are hosts to several polyphagous pest species, which are capable of moving between the different crops. Key pest of concern are armyworms (*Spodoptera* spp.), cotton bollworm (*Helicoverpa armigera*) and the neotropical brown stinkbug (*Euschistus heros*).

- Sequential or parallel sowings of host crops can increase the risk of exposure to the same insecticide modes of action (chemical, biological & trait) and therefore increase the risk of resistance.

- It is recommended that growers minimize the potential transfer of insects between crops by implementing the following practices.

    - Manage crop remnants/volunteers both prior to sowing and after harvest.
    - Scout the field during pre-sowing burn down with herbicides and if insects are observed in the remaining crop residues use insecticides for their control.
    - Consider a 'host-plant free window' between crops by either leaving areas unplanted or sowing non-host crops.
    - If parallel or sequential host crops are planted, then consider using insecticide with a different mode of action on each crop and/or choosing Bt host crops which express different proteins.

Area Wide Resistance Management

- Insecticide resistance management programs are most effective when conducted over as much of the cropping area as possible.
- In the large cropping landscapes of Brazil, this naturally means that pest management and insecticide resistance management are not in the hands of any one individual.
- The benefits of implementing best pest management practice are most apparent when growers can co-ordinate and communicate activities via an area-wide resistance management program.
- In the absence of a coordinated resistance management program, significant benefits can still be achieved through individual implementation of IRM.
- Non-compliance of best IRM practice can have a detrimental impact on resistance management, through the selection of resistant pests. Therefore communication and bi-lateral communication of best practice to neighboring growers promotes stronger IRM benefits.
- IRAC recommends that growers not only implement good resistance management practices, but also communicate with other growers in surrounding areas to promote best practice. Where possible IRM tactics should be co-ordinated to provide maximum benefits.