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

IRAC Brazil & IRAC International
• **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.

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### 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. 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.

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These guidelines are for educational purposes only. Details are accurate to the best of our knowledge but IRAC and its member companies cannot accept responsibility for how this information is used or interpreted. Advice should always be sought from local experts or advisors and health and safety recommendations followed.
• 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.
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### Examples: Soybean Application Windows (Condensed Version)

<table>
<thead>
<tr>
<th>Pre-Planting Window</th>
<th>Window 1 (VE-V5)</th>
<th>Window 2 (V6-R1)</th>
<th>Window 3 (R2-R4)</th>
<th>Window 4 (R5-R6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional Soybean</strong></td>
<td><strong>Bt Soybean MAIN CROP</strong></td>
<td><strong>Bt Soybean REFUGE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foliar Insecticide MoA W</td>
<td>Foliar Insecticide MoA Z</td>
<td>Foliar Insecticide MoA Z</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed treatment or foliar</td>
<td>Foliar Insecticide MoA Q</td>
<td>Foliar Insecticide MoA Q</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foliar Insecticide (MoA Y)</td>
<td>Foliar Insecticide (MoA Y)</td>
<td>Foliar Insecticide (MoA Y)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foliar Insecticide MoA W</td>
<td>Foliar Insecticide MoA Z</td>
<td>Foliar Insecticide MoA Z</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bt toxin (single or stacked): MoA Group 11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foliar Insecticide MoA Q</td>
<td>Foliar Insecticide MoA Q</td>
<td>Foliar Insecticide MoA Q</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 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 (dessecação)
- Planting
- Vegetative
- Reproductive
- Harvest

- Whitefly
- Lepidoptera
- Foliar Insecticide (MoA W)
- Foliar Insecticide (MoA Z)
- Foliar Insecticide (MoA Q)
- Foliar Insecticide (MoA X)
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. 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

<table>
<thead>
<tr>
<th>Pre-Planting Window</th>
<th>Window 1 (Seeding to 10 days PE)</th>
<th>Window 2 (10-40 days PE)</th>
<th>Window 3 (40-70 days PE)</th>
<th>Window 4 (70-100 days PE)</th>
<th>Window 5 (100-130 days PE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Cotton</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bt Cotton MAIN CROP</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bt Cotton REFUGE</td>
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Insecticide resistance management guidelines for insect pests of corn, soybean and cotton in Brazil

Supplemental Information
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• Introduction

• IRM recommendations for Corn
  • Corn expressing Bt-toxins
  • Refuge corn
  • Conventional corn

• IRM recommendations for soybean
  • Soybean expressing Bt-toxins
  • Refuge corn
  • Conventional soybean

• IRM recommendations for cotton
  • Cotton expressing Bt-toxins
  • Refuge corn
  • Conventional cotton

• IRM practice in a multi-crop environment
  • Post-harvest/Pre-sowing IRM
  • Area wide resistance management

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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.

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Insecticide resistance management guidelines for insect pests of corn in Brazil
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 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.
• 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 armigera*): 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 treated 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 variety.
Structured Refuge Options

- Different options for the mandatory 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)
IRAC Insecticide Resistance Management Guidelines — Corn, Brazil

Davis Damage Scale for Corn (1-9)

1
2
3
4
5
6
7
8
9

Photos supplied by DuPont-Pioneer

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Pest management strategy examples: Corn
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### Application Windows for Conventional Corn

<table>
<thead>
<tr>
<th>Window</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-sowing Window</strong></td>
<td>It is recommended to control lepidopteran larvae and other pests that remain from previous crops with foliar insecticides prior to sowing.</td>
</tr>
<tr>
<td><strong>Window 1</strong></td>
<td>Seed treatments or early foliar applications may be necessary to control soil pests or early lepidoptera infestations. The need for stink bug control should also be considered. Do not use same insecticide modes of action used in the pre-sowing window.</td>
</tr>
<tr>
<td><strong>Window 2</strong></td>
<td>Foliar application of insecticides at locally agreed pest threshold. Control of lepidoptera &amp; stink bugs may be required. The use of Insecticides which minimise negative impacts on beneficial insects are recommended. Do not use same insecticide MoA used in window 1.</td>
</tr>
<tr>
<td><strong>Window 3</strong></td>
<td>Applications of foliar insecticides are considered to be less critical at the late vegetative stage. Minimise insecticide use and only apply when local pest thresholds are exceeded. Do not use same insecticide MoA used in window 2.</td>
</tr>
<tr>
<td><strong>Window 4</strong></td>
<td>Applications of foliar insecticides are rarely needed. Minimize insecticide use and only apply when local pest thresholds are exceeded. Do not use same insecticide MoA used in window 3 and pre-sowing window for subsequent crop sowing.</td>
</tr>
</tbody>
</table>

**EXAMPLE:**

- **Foliar Insecticide MoA X**
- **Seed Treatment (MoA Y)**
- **Foliar Insecticide MoA Y**

**Insecticide**

- **Seed treatment OR foliar**

**Foliar insecticide mixture MoA Q+W**

**Foliar Insecticide MoA X**

**Foliar Insecticide MoA Z**

**Lepidoptera**

**Stink Bug**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-sowing (dessecação)</td>
<td></td>
</tr>
<tr>
<td>Planting /Sowing</td>
<td></td>
</tr>
<tr>
<td>Vegetative</td>
<td></td>
</tr>
<tr>
<td>Reproductive</td>
<td></td>
</tr>
</tbody>
</table>
IRAC Insecticide Resistance Management Guidelines — Corn, Brazil

Application Windows for Bt Corn MAIN CROP

**Pre-sowing Window**
- It is recommended to control lepidopteran larvae and other pests that remain from previous crops with foliar insecticides prior to sowing.

**Window 1**
- Seed treatments or early foliar applications may be necessary to control soil pests or early lepidoptera infestations.
- The need for stink bug control should also be considered.
- Do not use the same insecticide modes of action used in the pre-sowing window.

**Window 2**
- The use of foliar insecticides should be minimized and applied at locally agreed pest thresholds.
- Control of lepidoptera not controlled by selected Bt toxins & stink bugs may be required.
- The use of Insecticides which minimise negative impacts on beneficial insects are recommended.
- Do not use the same insecticide MoA used in window 1.

**Window 3**
- Applications of foliar insecticides are considered to be less critical at the late vegetative stage.
- Minimise insecticide use and only apply when local pest thresholds are exceeded.
- Do not use the same insecticide MoA used in window 2.

**Window 4**
- Applications of foliar insecticides are rarely needed.
- Minimize insecticide use and only apply when local pest thresholds are exceeded.
- Do not use the same insecticide MoA used in window 3 and pre-sowing window for subsequent crop sowing.

**EXAMPLE:**
- Bt toxin (single or stacked)
  - MoA Group 11

**Seed Treatment (MoA Y)**
- Foliar Insecticide MoA X
- Insecticide

**Foliar Insecticide MoA Y**
- Foliar Insecticide mixture MoA Q+W
- Foliar Insecticide MoA X

**Planting /Sowing**
- Pre-sowing (dessecação)
- Vegetative
- Reproductive

**Stink Bug | Lepidoptera**
- Foliar Insecticide MoA X

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Insecticide resistance management guidelines for insect pests of soybean in Brazil
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 (Chrysodeixis includens): Carbamates/Organophosphates (G1), Pyrethroids (G3)
• Velvetbean Catapillar (Anticarsia gemmatalis): Nuclear Polyhedrosis Virus (NPV)
• Cotton Bollworm (Helicoverpa armigera) : Carbamates/Organophosphates (G1), Cyclodiene (G2), Pyrethroids (G3).
• Tobacco Whitefly (Bemisia tabaci): Carbamates/Organophosphates (G1), Cyclodiene (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
IRAC Insecticide Resistance Management Guidelines — Soybean, Brazil

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.
Pest management strategy examples: Soybean
These guidelines are for educational purposes only. Details are accurate to the best of our knowledge but IRAC and its member companies cannot accept responsibility for how this information is used or interpreted. Advice should always be sought from local experts or advisors and health and safety recommendations followed.
Application Windows for Bt Soybean (MAIN CROP)

Pre-sowing Window
- It is recommended to control lepidopteran larvae and other pests that remain from previous crop with foliar insecticides prior to sowing.

Window 1 (VE-V5)
- Seed treatments or early foliar applications may be necessary to control soil pests or early lepidoptera infestations. Do not to use same insecticide modes of action used in the pre-sowing window.

Window 2 (V6-R2)
- Foliar application of insecticides at locally agreed pest threshold. The use of foliar insecticides is reduced compared to conventional soybean, but some species may need additional control methods. If multiple insecticide applications are needed, then rotate insecticides with different modes of action.

Window 3 (R3-R4)

Window 4 (R5-R6)

EXAMPLE:
- Bt toxin (1 or more) MoA Group 11

Foliar Insecticide MoA W
- Foliar Insecticide MoA Y
- Foliar Insecticide MoA Z
- Foliar Insecticide MoA X
- Foliar Insecticide MoA Q

Pre-sowing (dessecação) | Pre-planting | Vegetative | Reproductive | Harvest
--- | --- | --- | --- | ---
Whitefly | Stink Bug | Lepidoptera

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These guidelines are for educational purposes only. Details are accurate to the best of our knowledge but IRAC and its member companies cannot accept responsibility for how this information is used or interpreted. Advice should always be sought from local experts or advisors and health and safety recommendations followed.
Insecticide resistance management guidelines for insect pests of cotton in Brazil
**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 approximately 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.
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 (*Chrysodixis includens*): Carbamates/Organophosphates (G1), Pyrethroids (G3)
- Cotton Bollworm (*Helicoverpa armigera*): 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), Chlorfenapyr (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

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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.
Pest management strategy examples: Cotton
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IRAC Insecticide Resistance Management Guidelines — Cotton, Brazil

Application Windows for Bt Cotton (MAIN CROP)

Pre-sowing 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)

It is recommended to control lepidopteran larvae & other pests that remain from previous crop with foliar insecticides prior to sowing.

Seed treatments or foliar applications may be necessary to control soil pests or lepidoptera. Do not use same insecticide modes of action as used in the pre-sowing window.

Foliar application of insecticides at locally agreed pest threshold.
Control of foliar lepidoptera, & sucking pests may be required.
Critical not to use same insecticide MoA used in previous windows.

EXAMPLE:

Lepidoptera

Foliar Insecticide MoA Y

Bt toxin (1 or more)
MoA Group 11

Whitefly

Seed treatments or foliar applications may be necessary to control soil pests or lepidoptera. Do not use same insecticide modes of action as used in the pre-sowing window.

Foliar Insecticide MoA X

Foliar Insecticide MoA Q

Foliar Insecticide MoA K

Foliar Insecticide MoA W

Boll Weevil

Foliar Insecticide MoA X

Foliar Insecticide MoA W

Foliar Insecticide MoA K

Aphids & mites

Foliar Insecticide MoA Q

Foliar Insecticide MoA W

Planting /Sowing

Vegetative

Reproductive

Desication

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IRAC Insecticide Resistance Management Guidelines – Cotton, Brazil

Application Windows for Bt Cotton (REFUGE)

**Pre-sowing Window** (Seeding to 10 days PE)
- It is recommended to control lepidopteran larvae & other pests that remain from previous crop with foliar insecticides prior to sowing.

**Window 1** (10-40 days PE)
- Seed treatments or foliar applications may be necessary to control soil pests or lepidoptera. Do not use same insecticide modes of action as used in the pre-sowing window.

**Window 2** (40-70 days PE)

**Window 3** (70-100 days PE)

**Window 4** (100-130 days PE)
- Foliar application of insecticides at locally agreed pest threshold.
- Control of foliar lepidoptera, & sucking pests may be required.
- Critical not to use same insecticide MoA used in previous windows.

**EXAMPLE:**
- Foliar Insecticide MoA Z
- Foliar Insecticide MoA Y
- Foliar Insecticide MoA X
- Foliar Insecticide MoA Q
- Foliar Insecticide MoA R
- Foliar Insecticide MoA G
- Foliar Insecticide MoA W
- Foliar Insecticide MoA K

**Foliar Insecticide MoA:**

**Aphids & mites**
- Foliar Insecticide MoA Q

**Lepidoptera**

**Whitefly**

**Boll Weevil**

**Desication**

**Vegetative**

**Reproductive**

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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.