Integrated Pest Management (IPM) & Insect Resistance Management (IRM) for Fall Armyworm in South African Maize

Compiled by IRAC South Africa, May 2018

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1 Introduction

Fall Armyworm (*Spodoptera frugiperda*), FAW, is endemic to tropical and subtropical regions of North & South America. Larvae feed on more than 80 plant species, including maize, rice, sorghum, millet, sugarcane, vegetable crops and cotton. FAW can cause significant yield losses if not well managed. Multiple generations per year occur and under favourable conditions, adults can fly up to 100 km per night.
FAW was first detected in Central and Western Africa in early 2016 (Benin, Nigeria, Sao Tome and Principe, and Togo) and further reported and confirmed in the whole of mainland Africa (except Lesotho and the Island States), in Burkina Faso, Cabo Verde, Cameroon, Gambia, Ghana, Guinea Bissau, Niger, Senegal, and Ethiopia, Burundi, Kenya, Rwanda, South Sudan, Uganda (FAO Briefing Note on FAW, Oct 2017). In South Africa it was first detected in the summer of 2016, and identification confirmed in February 2017 (IPPC Feb 2017 report).

Although Bt GM maize has been proven to be an efficient and reliable technology against FAW in America and other parts of the world, a singular reliance on Bt-technology will not be sufficient to manage this pest in South Africa. Some reports of FAW resistance to Bt-technology have been recorded (Fatoretto et al, 2017). Integrated Pest Management programmes will be required to ensure continued high maize productivity, as well as manage the risk for resistance development against Bt-technologies in South Africa. Bt-technologies are widely used in commercial maize production in South Africa and an efficient system of structured refugia has been adopted with an approx. 90% compliance by growers to reduce the risk of resistance development in Busseola fusca, the African Maize Stalk Borer. Current IRM plans for Busseola fusca and Chilo partellus require growers to plant either a minimum 5% unsprayed or minimum 20% sprayed refuge.

In South Africa, it will be critically important to have a harmonised approach to IRM for FAW across the industry and across technologies. This approach should combine a clear and simple structured refuge policy which does not confuse growers between the requirements for FAW and maize stalk borers in South Africa, and which enables a high grower compliance. There are several commercialised Bt-products in South Africa which are very similar. This approach is in the best interests of the seed industry, growers and South African consumers.
Map of areas affected by Fall Armyworm (as of 1 October 2017)

2 The Need for Integrated Pest Management to deliver effective FAW control

Although Bt-technologies in maize offer a very good control option for FAW, it is clear that this on its own will not deliver durable and sustainable options into the future. It is important that transgenic technologies be coupled with effective insecticide programmes to ensure a workable and lasting solution for FAW, which is likely to remain a significant pest of not only maize, but many other row and vegetable crops in South Africa.

The proposed FAW IPM working group, residing under IRAC and Crop Life SA, offers one of the best avenues to develop a sustainable set of IPM recommendations to align the industry and ensure high adoption of the same, while also ensuring durability of control systems.

3 Control of FAW with Bt

Several Bt-technologies have been approved for commercial cultivation in maize in South Africa. These are the following events:

1. MON810 YieldGard Monsanto
2. MON89034 YieldGard II Monsanto
3. Bt11 AgriSure Syngenta

These events express combinations of Cry1 and Cry2 proteins, which have varying levels of efficacy against FAW.

Bt-technologies are widely used in maize production in South Africa and a sophisticated system of structured refugia has been adopted by growers to reduce the risk of resistance development in *Busseola fusca*, the African Maize Stalk Borer. Current IRM requires growers to plant either a minimum 5% unsprayed or minimum 20% sprayed refuge. Compliance is very high in the order of 90%.

The SANSOR Innovation committee has recently aligned IRM recommendations for FAW and other maize stalk borers for Bt-maize production in South Africa. The purpose of this document was to expand these recommendations to include an insecticide component in the control
programmes for maize stalk borers and FAW. A harmonised approach to IRM is expected to prolong the efficacy of all Bt-technologies and registered insecticides in maize in South Africa.

4 IRM Recommendations for Bt-Maize (from SANSOR)

- **Planting either a minimum of 5% unsprayed or 20% sprayed non-Bt maize refuge within 400m of the transgenic maize is considered mandatory for managing resistance to plant incorporated Bt-toxins**
- The application of insecticides to the non-transgenic refuge can either neutralise or reduce the resistance management benefits of planting the structured refuge. Therefore, under low pest pressure conditions it is recommended not to apply insecticides to the refuge.
- The initial period (first 30 days) after seeding is considered the most critical period for plant protection from insects. Seed treatment or early use of foliar insecticides can provide early pest control and help crop establishment in both the transgenic crop and the refuge.
- Under high pest pressure the application of insecticides may be necessary in both the transgenic crop and the refuge in order to maintain the crop.
- The following action thresholds are recommended to minimise the number of insects in the traited crop, whilst maximising the productivity of the refuge (both yield & susceptible insect production).
  - For *Busseola fusca* and *Chilo partellus*
    - Transgenic maize: Insecticide application when 5-10% of the plants exhibit *Busseola/Chilo* damage. (5% preventative, 10% action threshold)
    - Refuge maize / non-Bt maize: 5% Refuge – no spraying, 20% refuge insecticide application when 10% of the plants exhibit *Busseola/Chilo* damage.
  - For *Spodoptera frugiperda* (FAW)
    - Transgenic maize: Insecticide application when 5-10% of the plants exhibit plant damage at Davis scale 3 & above (5% preventative, 10% action threshold)
    - Refuge maize / non-Bt maize: 5% Refuge – no spraying, 20% Refuge - Insecticide application when 20% of the plants exhibit damage at Davis scale 3 or more.
  - **For *Spodoptera frugiperda* only: Under conditions of extreme infestation (> 20% of the plants infested at a Davis rating of 3 or more) in the 5% unsprayed**
refuge, it may be necessary to control FAW by applying insecticides. Should the refuge be sprayed in these circumstances, the Bt field should be sprayed as well

- The use of *Bacillus thuringiensis* based foliar insecticide sprays is not allowed in the refuge.
- All the associated refuge requirements for maize borers should be adhered to (Industry proposal August 2017).
- Only insecticides that have been registered under Act 36 should be used when controlling FAW in South Africa.
- Furthermore, it is recommended that an Integrated Pest Management approach be developed to combat FAW and to prolong the efficacy of Bt-technologies in maize in South Africa.
5 Davis Visual Rating Scale

Types of lesions caused by FAW (Davis 1992)

Figure 1. Types of lesions caused by fall armyworm larval feeding on leaves (a, pin-hole; b, small circular; c₁, small elongated; c₂, medium-sized elongated; c₃, large elongated; d₁, small uniform to irregular shaped; d₂, medium-sized uniform to irregular shaped; d₃, large uniform to irregular shaped; and e, shot-hole) and f, leaf sheath.
Visual guide of Davis Scale (Source: DuPont Pioneer, Brazil)
6 Insecticides & Insecticide programs for FAW control

General

1. Application windows are recommended where multiple insecticide applications are required.
2. FAW has an approximately 30-day generation period – establish application windows that are approximately 30 days apart to ensure that sequential generations of FAW are not exposed to the same insecticide Mode Of Action (MOA) in sequential insecticide applications.
3. Multiple applications of the same MOA in a single window period should be avoided.
4. Seeds treated with an insecticide may not provide effective control for the duration of the first window. If additional foliar applications are required in the first window, they should be of a different MOA, and should be applied no later than 25 days after planting.
5. The use of selective insecticides with reduced impact on non-target and beneficial insects should be used where possible.
6. Management of crop residues /volunteer plants before planting and after harvest is critical – burn down to remove host plants/weeds before planting, and apply insecticides post-harvest if FAW is observed.
7. Sequential maize plantings will increase the local populations of FAW.
8. Learn which insecticides have the same MOA / belong to the same groups, and make sure different MOA are used in each window period. See Tables 1-11, and also the Diagrams on pages 18-20 for examples of Window applications.

Known insecticide resistance in FAW

Resistance has been reported in the following groups: Carbamates (1A), Organophosphates (1B), Pyrethroids (3), Bt’s (11A) (IRAC. Strategies for Sustainable Control of Fall Armyworm, *Spodoptera frugiperda* www.irac-online.org).
Insecticides and MOA groups registered for FAW in South Africa (refer to http://www.irac-online.org/modes-of-action/ )

Nerve & Muscle Targets

1. Group 1: Acetylcholine esterase (AChE) inhibitors: 1A: Carbamates, 1B: Organophosphates
2. Group 3: Sodium channel modulators: 3A: Pyrethrins & Pyrethroids
3. Group 5: Nicotinic acetylcholine receptor (nAChR) allosteric modulators: Spinosyns
4. Group 6: Chloride channel activators: Avermectins
5. Group 14: Nicotinic acetylcholine receptor (nAChR) blockers: Cartap hydrochloride
7. Group 28: Ryanodina receptor modulators: Diamides

Midgut Targets

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

Growth & Development Targets

1. Group 15: Inhibitors of chitin biosynthesis: Benzolureas: e.g. Flufenoxuron, Lufenuron, Novaluron
2. Group 18: Ecdysone receptor antagonists: Diacylhydrazines e.g. Methoxyfenozide

Unknown Mode of Action

1. UND: Compounds with unknown MOA: Pyridalyl
**FAW Resistance management** ([http://www.irac-online.org/](http://www.irac-online.org/))

To prevent the development of insecticide resistance, use a combination of all available pest management and resistance management tools to decrease FAW exposure to insecticides.

- Always follow the label directions of each product.

- Consult product label or IRAC’s website (www.irac-online.org) to determine the MOA of each product.

- Do not treat successive generations with products of the same MOA.

- Follow the “treatment windows” approach:
  
  A “treatment window” is the period of residual activity provided by single or sequential applications of products with the same mode of action. This “treatment window” should not exceed approximately 30 days (generally used as the length of an insect pest generation) but can be less and should not exceed more than 2 applications of products from the same MoA.

- Generally, the total exposure period of products representing a single MOA applied throughout the crop cycle (from seedling to harvest) should not exceed approximately 50% of the crop cycle or exceed 50% of the total number of insecticide applications targeted at the same pest species.

- Apply insecticides only when needed based on economic thresholds.

- Choose products from Tables 1-11, making sure not to apply products from the same Table (MOA) in the same window. Ensure 60 days between applications of the same MOA, according to IRAC guidelines.
Table 1: IRAC Group 1 agrochemicals registered to control FAW in South Africa

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spitfire 900 SP</td>
<td>L8197</td>
<td>Methomyl</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1A</td>
<td>Maize</td>
</tr>
<tr>
<td>Avi Klorpirifos</td>
<td>L4318</td>
<td>Chlorpyrifos</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1B</td>
<td>Maize</td>
</tr>
<tr>
<td>Cyplamyl 90 SP</td>
<td>L3436</td>
<td>Methomyl</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1A</td>
<td>Maize</td>
</tr>
<tr>
<td>Masta 900 SP</td>
<td>L9449</td>
<td>Methomyl</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1A</td>
<td>Maize and potatoes</td>
</tr>
<tr>
<td>Agropyrifos</td>
<td>L4888</td>
<td>Chlorpyrifos</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1B</td>
<td>Maize, pastures and Potatoes</td>
</tr>
<tr>
<td>Pyrinex 480 EC</td>
<td>L4673</td>
<td>Chlorpyrifos</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1B</td>
<td>Maize</td>
</tr>
<tr>
<td>Methomex 900 SP</td>
<td>L5254</td>
<td>Methomyl</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1A</td>
<td>Maize</td>
</tr>
<tr>
<td>Methomex 200 SL</td>
<td>L5253</td>
<td>Methomyl</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1A</td>
<td>Maize</td>
</tr>
<tr>
<td>Mylomex 900 SP</td>
<td>L4383</td>
<td>Methomyl</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1A</td>
<td>Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts), maize, tobacco, sorghum, wheat, lupins, lucerne, veld and grazing</td>
</tr>
<tr>
<td>Methomate 200 SL</td>
<td>L8123</td>
<td>Methomyl</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1A</td>
<td>Maize, cotton , sorghum and veld grazing</td>
</tr>
<tr>
<td>Methomyl 200 SL</td>
<td>L7100</td>
<td>Methomyl</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1A</td>
<td>Maize, cotton , sorghum and veld grazing</td>
</tr>
<tr>
<td>Avi-Merkaptophtion DP</td>
<td>L4278</td>
<td>Mercaptothion</td>
<td>Stomach and contact insecticide</td>
<td>1</td>
<td>1B</td>
<td>Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts), Sorghum, groundnuts, maize, cotton, sugarcane,</td>
</tr>
<tr>
<td>Cropchem Chlorpyrifos EC</td>
<td>L5867</td>
<td>Chlorpyrifos</td>
<td>Contact insecticide</td>
<td>1</td>
<td>1B</td>
<td>Maize, Pastures and Potatoes</td>
</tr>
<tr>
<td>Marshal 48 EC</td>
<td>L3314</td>
<td>Carbosulfan</td>
<td>Systemic insecticide</td>
<td>1</td>
<td>1A</td>
<td>Maize</td>
</tr>
</tbody>
</table>
Table 2: IRAC Group 3 agrochemicals registered to control FAW in South Africa

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akito</td>
<td>L6709</td>
<td>Beta-cypermethrin</td>
<td>Stomach and contact insecticide</td>
<td>3</td>
<td>3A</td>
<td>maize, sorghum, sweetcorn, wheat, tomatoes, peas, lupins, lucerne, groundnuts and Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts)</td>
</tr>
</tbody>
</table>

Table 3: IRAC Group 4 agrochemicals registered to control FAW in South Africa

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag-Tap 500 SP</td>
<td>L7550</td>
<td>Cartap hydrochloride</td>
<td>Contact and systemic action insecticide</td>
<td>14</td>
<td>4C</td>
<td>Barley, cabbage, canola, maize, onions, potatoes, sorghum, soy beans, sugarcane, sunflower, sweetcorn, and wheat</td>
</tr>
</tbody>
</table>

Table 4: IRAC Group 5 agrochemicals registered to control FAW in South Africa

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delegate 250 WG</td>
<td>L8392</td>
<td>Spinetoram</td>
<td>contact and stomach insecticide</td>
<td>5</td>
<td>5A</td>
<td>Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts), maize, sweetcorn and sorghum</td>
</tr>
</tbody>
</table>
### Table 5: IRAC Group 6 agrochemicals registered to control FAW in South Africa

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emma</td>
<td>L9022</td>
<td>Emamectin benzoate</td>
<td>Stomach transaminin insecticide</td>
<td>6</td>
<td>6</td>
<td>Maize, sweetcorn and potatoes</td>
</tr>
<tr>
<td>Proclaim</td>
<td>L7581</td>
<td>Emamectin benzoate</td>
<td>Stomach transaminin insecticide</td>
<td>6</td>
<td>6</td>
<td>Barley, beans, groundnuts, peas, maize , sweetcorn , sorghum, sunflower, soy bean, dry bean, wheat</td>
</tr>
<tr>
<td>Promec 20 EW</td>
<td>L9729</td>
<td>Emamectin benzoate</td>
<td>Stomach transaminin insecticide</td>
<td>6</td>
<td>6</td>
<td>Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts), maize, sweetcorn,</td>
</tr>
<tr>
<td>Vitex 50</td>
<td>L9525</td>
<td>Emamectin benzoate</td>
<td>Stomach transaminin insecticide</td>
<td>6</td>
<td>6</td>
<td>Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts), maize, sweetcorn,</td>
</tr>
<tr>
<td>Warlock 19.2 EC</td>
<td>L9872</td>
<td>Emamectin benzoate</td>
<td>Stomach transaminin insecticide</td>
<td>6</td>
<td>6</td>
<td>Maize and sweetcorn</td>
</tr>
<tr>
<td>Lepidex</td>
<td>L7977</td>
<td>Emamectin benzoate</td>
<td>Stomach transaminin insecticide</td>
<td>6</td>
<td>6</td>
<td>Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts), maize</td>
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### Table 6: IRAC Group 11 agrochemicals registered to control FAW in South Africa

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops:</th>
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</thead>
<tbody>
<tr>
<td>Delfin</td>
<td>L9761</td>
<td>Bacillus thuringiensis var kurstaki Strain SA-11</td>
<td>Bioinsecticide</td>
<td>11</td>
<td>11</td>
<td>Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts), barley, cotton, maize, sorghum, soybean and wheat.</td>
</tr>
<tr>
<td>Eco-Bb</td>
<td>L8469</td>
<td>Beauveria bassiana</td>
<td>Bioinsecticide</td>
<td>11</td>
<td>11</td>
<td>Cruciferae (cabbage, broccoli, cauliflower and brussels sprouts) Maize, sweetcorn, soybean, tomatoes and sorghum</td>
</tr>
<tr>
<td>Florbac WG</td>
<td>L5531</td>
<td>Bacillus thuringiensis var. aizawai</td>
<td>Bioinsecticide</td>
<td>11</td>
<td>11</td>
<td>Maize and sweetcorn</td>
</tr>
</tbody>
</table>
### Table 7: IRAC Group 15 agrochemicals registered to control FAW in South Africa

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorba</td>
<td>L5343</td>
<td>Lufenuron</td>
<td>Insect growth inhibitor (IGI)</td>
<td>15</td>
<td>15</td>
<td>Barley, beans, dry bean, cruciferae(cabbage, broccoli, cauliflower and brussels sprouts), groundnuts, maize, peas, sweetcorn, sunflower, soy bean, sorghum, and wheat</td>
</tr>
<tr>
<td>Judge</td>
<td>L9927</td>
<td>Lufenuron</td>
<td>insect growth inhibitor (IGI)</td>
<td>15</td>
<td>15</td>
<td>Maize, sweetcorn and potatoes</td>
</tr>
<tr>
<td>Dimilin 25 WP</td>
<td>L5483</td>
<td>Diflubenzuron</td>
<td>Contact insecticide</td>
<td>15</td>
<td>15A</td>
<td>Maize, sweetcorn, and potatoes</td>
</tr>
<tr>
<td>Dimilin SC 48</td>
<td>L7140</td>
<td>Diflubenzuron</td>
<td>Contact insecticide</td>
<td>15</td>
<td>15A</td>
<td>Maize, sweetcorn and potatoes</td>
</tr>
</tbody>
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### Table 8: IRAC Group 22 agrochemicals registered to control FAW in South Africa

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops</th>
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</thead>
<tbody>
<tr>
<td>Steward</td>
<td>L8435</td>
<td>Indoxacarb</td>
<td>Stomach and contact insecticide</td>
<td>22</td>
<td>22A</td>
<td>Cotton, lettuce, maize, peppers, sorghum, soy bean, sweetcorn, potatoes and sugarcane</td>
</tr>
<tr>
<td>Advance</td>
<td>L9147</td>
<td>Indoxacarb</td>
<td>Stomach and contact insecticide</td>
<td>22</td>
<td>22A</td>
<td>Cotton, maize and sorghum, veld and grazing</td>
</tr>
<tr>
<td>Addition</td>
<td>L9146</td>
<td>Indoxacarb</td>
<td>Stomach and contact insecticide</td>
<td>22</td>
<td>22A</td>
<td>Cotton maize, sorghum, veld and grazing</td>
</tr>
<tr>
<td>Doxstar Flo</td>
<td>L9884</td>
<td>Indoxacarb</td>
<td>Stomach and contact insecticide</td>
<td>22</td>
<td>22A</td>
<td>cruciferae(cabbage, broccoli, cauliflower and brussels sprouts), maize, peppers and sweetcorn,</td>
</tr>
<tr>
<td>Steward</td>
<td>L6332</td>
<td>Indoxacarb</td>
<td>Stomach and contact insecticide</td>
<td>22</td>
<td>22A</td>
<td>Cotton, lettuce, maize, sweetcorn, soy beans, sorghum, and potatoes</td>
</tr>
</tbody>
</table>
Table 9: IRAC Group 28 agrochemicals registered to control FAW in South Africa

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coragen</td>
<td>L8529</td>
<td>chlorantraniliprole</td>
<td>Stomach and contact insecticide</td>
<td>28</td>
<td>28</td>
<td>Cotton, maize, sorghum, sweetcorn, sugarcane and potatoes</td>
</tr>
<tr>
<td>Belt</td>
<td>L8860</td>
<td>Flubendiamide</td>
<td>Non systemic</td>
<td>28</td>
<td>28</td>
<td>Endive, lettuce, maize, spinach and maize</td>
</tr>
<tr>
<td>Prevathon</td>
<td>L9150</td>
<td>Chlorantraniliprole</td>
<td>Stomach and contact insecticide</td>
<td>28</td>
<td>28</td>
<td>Maize, sweetcorn, and sorghum</td>
</tr>
</tbody>
</table>

Table 10: Products with UNKNOWN MOA registered to control FAW in South Africa.

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sumipleo SC</td>
<td>L8377</td>
<td>Pyridalyl</td>
<td>Stomach &amp; contact insecticide</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Maize and sweetcorn</td>
</tr>
</tbody>
</table>
Table 11: Products with multiple IRAC Group agrochemicals registered to control FAW in South Africa. Use of these products in one window disqualifies the use of the second MOA in the product in the same window.

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Registration Number</th>
<th>Active ingredients</th>
<th>Type</th>
<th>Resistance Group (IRAC)</th>
<th>Resistance sub Group (IRAC)</th>
<th>Registered for Use on the Following Crops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oncol Super 220 EC</td>
<td>L7649</td>
<td>Benfuracarb/ fenvalerate</td>
<td>Systemic &amp; contact insecticide</td>
<td>1 3</td>
<td>1A and 3</td>
<td>Maize, sweetcorn, and sorghum</td>
</tr>
<tr>
<td>Cyperfos 500 EC</td>
<td>L7606</td>
<td>Chlorpyrifos/ Cypermethrin</td>
<td>Stomach &amp; contact insecticide</td>
<td>1 3</td>
<td>1B and 3B</td>
<td>Maize, wheat and sorghum</td>
</tr>
<tr>
<td>Plemax</td>
<td>L10246</td>
<td>Indoxacarb/ novaluron</td>
<td>Chitin inhibition, Stomach &amp; contact insecticide</td>
<td>22 15</td>
<td>22A and 15</td>
<td>Maize and sweetcorn</td>
</tr>
<tr>
<td>Ampligo</td>
<td>L8685</td>
<td>Chlorantraniliprole/ lambda-cyhalothrin</td>
<td>Stomach &amp; contact insecticide</td>
<td>3 28</td>
<td>3 and 28</td>
<td>Barley, canola, maize, sweetcorn, groundnuts, soy bean, sunflower, and wheat</td>
</tr>
<tr>
<td>Uphold 360 SC</td>
<td>L10164</td>
<td>Spinetoram/ methoxyfenozide</td>
<td>Contact &amp; stomach insecticide</td>
<td>5 18</td>
<td>5A and 18</td>
<td>Maize, sweetcorn, and sorghum</td>
</tr>
<tr>
<td>Denim Fit</td>
<td>L9978</td>
<td>Emamectin benzoate/ lufenuron</td>
<td>stomach &amp; insect growth inhibitor</td>
<td>6 15</td>
<td>6 and 15</td>
<td>Maize, legume vegetables, soybeans, sorghum, sunflower, dry beans, groundnuts, barley and sweetcorn</td>
</tr>
</tbody>
</table>
Application Windows & Example MOA's for Bt-Maize main crop

Application of a broad spectrum insecticide is recommended to control large lepidopteran larvae that may remain from previous crop planting.

Most critical period for controlling pests. Seed treatments & early foliar applications to control soil pests or early lepidopteran infestations. Critical not to use same insecticide modes of action used in the pre-planting window.

Reduce insecticide use. Control Lepidoptera not controlled by Bt-toxins. Use insecticides with low impact on beneficial insects. Critical not to use same insecticide MOA used in window 1.

Minimise insecticide use and only apply when local pest thresholds are exceeded. Critical not to use same insecticide MOA used in window 3 and Pre-plant window.

**Fall Armyworm Control Windows**

1. Pre-plant
   1st Spray: MOA: Group 1A, 1B, 3 & 3B *

2. Critical insect control period
   1st Spray: MOA: Group 5, 6, 15 & 22
   2nd Spray: MOA: Group 4, 28

3. Late vegetative
   1st Spray: MOA: Group 1A, 1B, 3 & 3B

4. Reproductive
   Bt-Maize (single or stacked) MOA: Group 11

**Application Windows & Example MOA's for Bt-Maize main crop**

**1. Pre-plant**
- Dry seed
- VE
- V1
- V3
- V6
- V12
- VT
- R1
- R3 - R4
- R6

**Vegetative Growth stages**
- Growth tip and tassel below surface, plant about 25 cm high

**Reproductive Growth stages**
- Last branch of tassel visible / 2 days before silking starts.
- Pollen shed begins
- Silks are visible outside the husk
- Milk & Dough stages
- Physiological Maturity. Max dry weight achieved

NB: Group 11 insecticides may also be applied on Bt-maize, * Choice of MOA groups for example purposes
Application Windows & Example MOA's for non-Bt-Maize refuge

Application of a broad spectrum insecticide is recommended to control large lepidopteran larvae that may remain from previous crop planting.

Most critical period for controlling pests. Seed treatments & early foliar applications to control soil pests or early lepidopteran infestations. Critical not to use same insecticide modes of action used in the pre-planting window.

Reduce insecticide use. Control Lepidoptera not controlled by Bt-toxins. Use insecticides with low impact on beneficial insects. Critical not to use same insecticide MOA used in window 1.

Minimise insecticide use and only apply when local pest thresholds are exceeded. Critical not to use same insecticide MOA used in window 3 and Pre-plant window.

**Fall Armyworm Control Windows**

1. Pre-plant
2. Critical insect control period
3. Late vegetative
4. Reproductive

1st Spray: MOA: Group 1A, 1B, 3 & 3B

2nd Spray: MOA: Group 4, 28

1st Spray: MOA: Group 5, 6, 15 & 22

1st Spray: MOA: Group 1A, 1B, 3 & 3B

Days after emergence

0 10 25 44 56 70 90 120

Pre-plant. Dry seed VE V1 V3 V6 V12 VT R1 R3 - R4 R6

Vegetative Growth stages

Growth tip and tassel below surface, plant about 25 cm high

Reproductive Growth stages

Last branch of tassel visible / 2 days before silking starts. Pollen shed begins

Silks are visible outside the husk

Milk & Dough stages

Physiological Maturity. Max dry weight achieved

NB: Group 11 insecticides may not be applied on non-Bt maize refugia, * Choice of MOA groups for example purposes
Application Windows & Example MOA’s for Conventional Maize Crop

Application of a broad spectrum insecticide is recommended to control large lepidopteran larvae that may remain from previous crop planting.

Most critical period for controlling pests. Seed treatments & early foliar applications to control soil pests or early lepidopteran infestations. Critical not to use same insecticide modes of action used in the pre-planting window.

Reduce insecticide use. Control Lepidoptera not controlled by Bt-toxins. Use insecticides with low impact on beneficial insects. Critical not to use same insecticide MoA used in window 1.

Minimise insecticide use and only apply when local pest thresholds are exceeded. Critical not to use same insecticide MoA used in window 3 and Pre-plant window.

**Fall Armyworm Control Windows**

1. Pre-plant
   - 1st Spray: MOA: Group 1A, 1B, 3, 3B & 11 *

2. Critical insect control period
   - 1st Spray: MOA: Group 5, 6, 15 & 22
   - 2nd Spray: MOA: Group 4, 28

3. Late vegetative
   - 1st Spray: MOA: Group 1A, 1B, 3 & 3B

4. Reproductive

Days after emergence:

<table>
<thead>
<tr>
<th>0</th>
<th>10</th>
<th>25</th>
<th>44</th>
<th>56</th>
<th>70</th>
<th>90</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-plant</td>
<td>Dry seed</td>
<td>VE V1</td>
<td>V3</td>
<td>V6</td>
<td>V12</td>
<td>VT</td>
<td>R1</td>
</tr>
</tbody>
</table>

**Vegetative Growth stages**

Growth tip and tassel below surface, plant about 25 cm high

**Reproductive Growth stages**

Last branch of tassel visible/2 days before silking starts.
Pollen shed begins
Silks are visible outside the husk
Milk & Dough stages
Physiological Maturity. Max dry weight achieved

* Choice of MOA groups for example purposes
7 Additional Resources & References

- Davis, F. M. 1992. Visual Rating Scales for Screening Whorl-stage Corn for Resistance to Fall Armyworm. Mississippi Agricultural & Forestry Experiment Station, Technical Bulletin 186, Mississippi State University, MS39762, USA.

- A list of insecticides registered for use against FAW may be found at [http://www.daff.gov.za/daffweb3/Branches/Agricultural-Production-Health-Food-Safety/Food-Import-Export-standards/Fall-armyworm](http://www.daff.gov.za/daffweb3/Branches/Agricultural-Production-Health-Food-Safety/Food-Import-Export-standards/Fall-armyworm)

- Phil Abrahams; Melanie Bateman; Tim Beale; Victor Clottey; Matthew Cock; Yelitza Colmenarez; Natalia Corniani; Roger Day; Regan Early; Julien Godwin; Jose Gomez; Pablo Gonzalez Moreno; Sean T. Murphy; Birgitta Oppong-Mensah; Noah Phiri; Corin Pratt; Gareth Richards; Silvia Silvestri; Arne Witt, 2017, Fall Armyworm: Impacts and Implications for Africa, Evidence Note (2), September 2017, CABI. [http://www.invasive-species.org/Uploads/InvasiveSpecies/Fall%20Armyworm%20Evidence%20Note%20September%202017.pdf](http://www.invasive-species.org/Uploads/InvasiveSpecies/Fall%20Armyworm%20Evidence%20Note%20September%202017.pdf)

- Erasmus, A, 2017, The Invasion of the Fall Armyworm in South Africa. [http://www.arc.agric.za/Agricultural%20Sector%20News/The%20invasion%20of%20the%20fall%20armyworm%20in%20South%20Africa.pdf#search=Fall%20armyworm](http://www.arc.agric.za/Agricultural%20Sector%20News/The%20invasion%20of%20the%20fall%20armyworm%20in%20South%20Africa.pdf#search=Fall%20armyworm)


- IRAC. Strategies for Sustainable Control of Fall Armyworm, *Spodoptera frugiperda*. [www.irac-online.org](http://www.irac-online.org)


- IPPC report Feb 2017 [https://www.ippc.int/static/media/files/pestreport/2017/02/10/First_detection_of_TAC.pdf](https://www.ippc.int/static/media/files/pestreport/2017/02/10/First_detection_of_TAC.pdf)