Fall Armyworm (FAW) and Insecticide Resistance Management (IRM)

John A. Fajardo, MSc.
Corn Agronomic System Manager
Southeast Asia Pakistan
Bayer Crop Science

22nd October 2020
Topics

• What & Why IRM?
• FAW IRM Strategy
• Best Practices & Resources
• How to ensure IRM successful?
Insecticide Resistance Management (IRM)

“IRM refers to the strategies for delaying or suppressing increase in the pest population to overcome intended effects of a product such as insecticide or Plant Incorporated Protectant (PIP)”
How does insecticide resistance become a problem?

Insect with resistance mutation

Susceptible insect

Insecticide NOT affected by mutation

Insecticide is 76% efficient

Insecticide affected by mutation

Insecticide is 44% efficient

Insecticide is 5% efficient

Source: IRAC
Mechanisms of Resistance

1. Target Site Resistance
   • Insect can modify the shape of the protein and prevent the insecticide from interacting at the site of action when a mutation occurs in the receptor protein, causing resistance. Insecticides have specific site of action within an insect, usually a receptor protein.

2. Metabolic Resistance
   • Insect enzymes that break down unwanted molecules are either significantly increased in amount or modified to become more efficient to break down the insecticide.

3. Physical Adaptation
   • Insect adapt physically by protecting itself from the insecticide like thicker cuticle, extra waxy covering, or faster excretion of waste. Does not offer much protection but becomes more effective with other mechanisms.

4. Behavioral Adaptation
   • Insect behaviors changes like reduced exposure to the insecticide and allowing it to survive although not common.

Source: IRAC
IRM Prolongs the Effectiveness of an Insecticide or PIP

• As industry, … ensure the product works effectively the longest possible time due to significant investments; product development/ introduction costs millions of dollars & takes ~10 years

• As regulator, … ensure effective and safe product is available

• As researcher/ extension agent, … ensure safe & effective product is available for recommendations

• As farmer, … ensure that crop is protected from pests, i.e. FAW

Source: IRAC
Elements of IRM

Integrated Pest Management (IPM)

Education and Training

Insecticide Resistance Management (IRM)

Resistance Monitoring and Remedial Actions

Conventional (white corn, sweet corn, OPV) & PIP corn

Different Mode of Action (MoAs); Follow label use

Suitable Bt protein expression in plant

Refuge for susceptible insects

PIP or Bt Corn

Source: Bayer Crop Science
How IRM be achieved?
The goals of IRM are dependent on pre-existing resistance at high frequencies within field populations or if it is being considered upon introduction of a new technology.

- **Remove Resistance Alleles or reduce fitness**
  - Increase dose, treat vulnerable stages, use AIs that confer low level of resistance, Use synergists, Mixtures with different Mode of Action (MoAs)

- **Preserving susceptible genotypes**
  - Reliance on thresholds, reduced application rates, NO persistent products, untreated refuges, treat only specific stages

- **Redundant killing**
  - Redundant killing through mixtures or sequential applications of different MoAs

Source: Bayer Crop Science
## Conventional Corn: Use Insecticides with Multiple Mode of Action

Fertilizer and Pesticide Authority Approved Insecticides against FAW Including Mode of Action

<table>
<thead>
<tr>
<th>No.</th>
<th>ACTIVE INGREDIENT</th>
<th>Mode of Action (IRAC)</th>
<th>MoA Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>THIODICARB</td>
<td>1. ACETYLCHOLINESTERASE (ACHE) INHIBITORS</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>CARBOSULFAN</td>
<td>1. ACETYLCHOLINESTERASE (ACHE) INHIBITORS</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>SPINETORAM</td>
<td>5. NICOTINIC ACETYLCHOLINE RECEPTOR (NACHR) ALLOSTERIC MODULATORS - SITE I</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>EMAMECTIN BENZOATE</td>
<td>6. GLUTAMATE-GATED CHLORIDE CHANNEL (GLUCL) ALLOSTERIC MODULATORS</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>BACILLUS THURINGIENSIS VAR. KURSTAKI</td>
<td>11. MICROBIAL DISRUPTORS OF INSECT MIDGUT MEMBRANES</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>BACILLUS THURINGIENSIS VAR. AIZAWAI</td>
<td>11. MICROBIAL DISRUPTORS OF INSECT MIDGUT MEMBRANES</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>LUFENURON</td>
<td>15. INHIBITORS OF CHITIN BIOSYNTHESIS AFFECTING CHS1</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>INDOXACARB</td>
<td>22. VOLTAGE-DEPENDENT SODIUM CHANNEL BLOCKERS</td>
<td>22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No.</th>
<th>ACTIVE INGREDIENT</th>
<th>Mode of Action (IRAC)</th>
<th>MoA Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>CHLORANTRANILIPROLE</td>
<td>28. RYANODINE RECEPTOR MODULATORS</td>
<td>28</td>
</tr>
<tr>
<td>10</td>
<td>CYANTRANILIPROL</td>
<td>28. RYANODINE RECEPTOR MODULATORS</td>
<td>28</td>
</tr>
<tr>
<td>11</td>
<td>TETRANILIPROLE</td>
<td>28. RYANODINE RECEPTOR MODULATORS</td>
<td>28</td>
</tr>
<tr>
<td>12</td>
<td>CHLORANTRANILIPROLE + THIAMETHOXAM</td>
<td>28. RYANODINE RECEPTOR MODULATORS &amp; 4. NICOTINIC ACETYLCHOLINE RECEPTOR (NACHR) COMPETITIVE MODULATORS</td>
<td>28 &amp; 4</td>
</tr>
<tr>
<td>13</td>
<td>PYRIDALYL</td>
<td>UN COMPOUNDS OF UNKNOWN OR UNCERTAIN MOA</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>(Z)-9-TETRADECENYL ACETATE</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>(Z9,E12) 9,12-TETRADECADIEN-1-OL</td>
<td>Unknown</td>
<td></td>
</tr>
</tbody>
</table>

Sources:
Fertilizer and Pesticide Authority, list of approved insecticides as of Oct. 2020
IRAC, MoA group
Example of Spray Program

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Mode of Action Group (IRAC)</th>
<th>MoA</th>
</tr>
</thead>
<tbody>
<tr>
<td>TETRANILIPROLE</td>
<td>28. RYANODINE RECEPTOR MODULATORS</td>
<td>1</td>
</tr>
<tr>
<td>CHLORANTRANILIPROLE</td>
<td>28. RYANODINE RECEPTOR MODULATORS</td>
<td>1</td>
</tr>
<tr>
<td>CYANTRANILIPROLE</td>
<td>28. RYANODINE RECEPTOR MODULATORS</td>
<td>1</td>
</tr>
<tr>
<td>SPINETORAM</td>
<td>5. NICOTINIC ACETYLCHOLINE RECEPTOR (NACHR) ALLOSTERIC MODULATORS - SITE I</td>
<td>2</td>
</tr>
<tr>
<td>THIODICARB</td>
<td>1. ACETYLYCHOLINESTERASE (ACHE) INHIBITORS</td>
<td>2</td>
</tr>
</tbody>
</table>

- Always follow label recommendations
- Start early applications/ based on threshold
- Use different MoA
- ~7 Days Spray interval under high infestation, depending on product

Sources:
- Fertilizer and Pesticide Authority for list of insecticides
- IRAC for Mode of Action
- Bayer Crop Science for Corn Growth Stage

110 days

Window 1 (0-30 days)  Window 2 (30-60 days)  Window 3 (60-90 days)
In PIP (Bt Corn): Use Multiple Mode of Action and effective dose to remove resistance alleles

- Resistance allele frequency for Bt A $\text{R} = 1$ in a thousand
- Resistance allele frequency for Bt B $\text{R} = 1$ in a thousand

These are all controlled by a plant expressing effective doses of Bt A and Bt B

- Resistance allele frequency for Bt A $\text{R} = 1$ in a million $1 \times 10^{-6}$
- Resistance allele frequency for Bt A $\text{R} = 1$ in a billion $1 \times 10^{-9}$
- Resistance allele frequency for Bt A $\text{R} = 1$ in a trillion $1 \times 10^{-12}$

Refuge must be adequate for one-in-a-trillion survivor

Source: Bayer Crop Science
In PIP (Bt Corn) : Use refuge or non-Bt corn to preserve susceptible insects

- Maintain a population of insect pests not exposed to Bt proteins
- Lack of exposure to Bt proteins allows susceptible insects to mate with rare resistant insects that may emerge
- Susceptibility to Bt technology passed on to offspring, helping preserve long-term effectiveness Bt corn

Source: Bayer Crop Science
## Case: Philippines IRM Strategy for PIP Bt Corn, focused on Asian Corn Borer (ACB)

| Dose, refuge, Two MoAs | // Dual mode of action and effective dose drives excellent to good control against target pests  
<table>
<thead>
<tr>
<th></th>
<th>// Refuge, Refuge In Bag (RIB) ensures refuge compliance</th>
</tr>
</thead>
</table>
| Resistance Monitoring | // Sentinel sites planted annually to monitor pest damage besides other non-targets  
| | // Resistance monitoring assays done annually and reports submitted to BPI  
| | // F2 studies – investigate non-recessive resistance in ACB |
| Surveys and outreach | // National IRM surveys – every two years (Cross-Industry effort)  
| | // Outreach – Crop Life Philippines, IRAC Asia/CLA, BCP  
| | // Protocols, guidelines review, annual activities |
| Next gen Tech and modeling | // Resistance Modeling for enhanced IRM plan – refuge increase in RIB  
| | // Next generation technology advancement in progress |
Enhanced IRM Strategies being discussed by various stakeholders through seminars and workshops


Bureau of Plant Industry & Fertilizer and Pesticide Authority Workshop on the Harmonization of Guidelines on February 11-13, 2020

Source: http://biotech.da.gov.ph
Resources

1. Insecticide Resistance Action Committee
   https://irac-online.org/

2. CABI  www.cabi.org/isc

3. CropLife Philippines
   https://www.croplife.org.ph/

4. Department of Agriculture, Provincial/
   City/ Municipal Agriculture Offices

5. Research agencies, universities, and
   extension offices

6. Industry or company resource/
   representatives
Recommendations for Successful IRM

1. IRM Strategy should be holistic and enhanced by relevant stakeholders
   • should cover insecticides and Plant Incorporated Protectant in corn
   • focus can be identified based on risk assessment of pest biology/ habits & products

2. Information dissemination and tracking can be intensified, i.e. digital tools

3. Farmers should follow the IRM recommendations

Thank you.

For further information, feel free to contact:

- e john.fajardo@bayer.com; ea_croplife@pltdsl.net
- w www.croplife.org.ph
- t +63 8772 3992
- a Unit 5E Mapfre Bldg. Acacia Ave. Madrigal Business Park, Ayala, Alabang, Muntinlupa City