Native Genetic Resistance in Maize to Spodoptera frugiperda

B.M. Prasanna* and Felix San Vicente

CIMMYT Global Maize Program
& CGIAR Research Program MAIZE
Email: b.m.prasanna@cgiar.org
The Pest (*Spodoptera frugiperda*)

- Wide host range (>80 plant species) but with major preference for maize
- Short life cycle: 1-2 months (depending on weather)
- Rapid proliferation (>1000 eggs per female)
- Strong migratory capacity of moths: 500 km before oviposition; with suitable wind >1000 km
Invasion by **FAW** in Africa: 44 Countries

**January 2016**

**February 2017**

**January 2018**

- Detecte and officially reported
- Detected awaiting official reporting
CABI estimates that 13.5 m tonnes of maize worth US$ 3 billion in SSA at risk from FAW in 2017-2018

Fall Armyworm in Africa
Key lessons learnt so far

- FAW poses a serious threat to food security and livelihoods of millions of smallholders in Africa. The pest is unfortunately here to stay for a long-term!
- We still do not know all the answers about the pest and its dynamics in Africa. However, we can certainly learn a lot from countries which have been dealing with this pest for several decades.
- Indiscriminate and extensive use of highly toxic pesticides must stop. We need to adopt ecologically and environmentally-friendly and IPM-based technologies/management practices for sustainable control.
- Need for well-coordinated and rapid responses at the national, regional and continental levels.
How can we effectively tackle a complex pest like Fall Armyworm in Africa?

Not just by one or two tools, but with an array of relevant tools from a tool box!

- Biological Control
- Biorational Pesticides
- Conventional Resistance
- Transgenic Resistance
- Cultural Control
- Habitat Management
The FAW IPM Guide for Africa

- Effective monitoring, surveillance and scouting
- Host plant resistance
- Biological control and biorational pesticides
- Cultural control and sustainable agro-ecological management
- Environmentally safer pesticides
Conventional Breeding for Insect Resistance

- Has, in general, lagged behind disease resistance
- However, there is germplasm with resistance to insect-pests, including FAW
- Breeding for insect-pest resistance requires good knowledge of the biology of the host as well as the pest
- Effectiveness depends upon:
  - Available diversity of germplasm
  - Efficient insect rearing technique
  - Efficient artificial infestation of the host
  - Breeding techniques employed
CIMMYT’s Earlier Work on Conventionally-derived Resistance to Insect-pests

CIMMYT-Mexico: During the 1980s and 1990s, an array of populations as well as elite inbred lines with native genetic resistance to FAW derived, mainly from the Caribbean maize germplasm.

CIMMYT-Africa: Insect-resistant maize lines, hybrids and OPVs developed and released under IRMA (Insect Resistant Maize for Africa) Project
### Potential sources of native genetic resistance to FAW

#### CIMMYT-derived maize germplasm:

- Pop. 304; Pop. 392; Pop. FAW-CGA; Pop. FAW-Tuxpeno; Pop. FAW-Non-Tuxpeno
- CMLs/hybrids/OPVs based on insect-resistant maize germplasm, etc.

#### USDA-Mississippi temperate maize inbreds:

Mp496; Mp701-Mp708, Mp713; Mp714; Mp716

#### Embrapa-Brazil maize germplasm:

CMS14C; CMS23 (Antigua x Republica Dominica); CMS24; MIRT (Multiple Insect Resistance Tropical) race Zapalote Chico, Sintetico Spodoptera, Caatingueiro Spodoptera, and Assum Preto Spodoptera
Several elite CIMMYT-derived drought-tolerant lines are highly susceptible to FAW attack. Need for rapid conversion of the FAW-susceptible lines into resistant versions.
Screening of CIMMYT maize inbred lines under FAW infestation in Kakamega, Kenya

Susceptible

Resistant

Susceptible (CML444)

Resistant

Susceptible

Resistant
Intensive screening of CIMMYT Tropical Maize Germplasm against FAW under artificial infestation in Kiboko, Kenya
What is the basis for conventional resistance to FAW?

- **Mp708 and FAW7050** (resistant): elevated defensive proteins following insect herbivory (greater conversion of photosynthates to defensive proteins); higher amino acid and glucose contents; constitutive accumulation of jasmonic acid.

- **Susceptibility of Ab24E to S. frugiperda** was due to a high P/C ratio (protein-to-total non-structural carbohydrates) and a low level of induced defensive compounds.
(E)-β-caryophyllene, a terpenoid associated with resistance, is released constitutively in Mp708.

FAW-fed samples of both Mp708 (resistant) and Tx601 (susceptible) showed high transcript number of \( \text{tps23} \), the gene responsible for the synthesis of \( (E)\)-β-caryophyllene.

FAW larvae show a preference for Tx601 whorl tissue over Mp708 tissue; dosage of Tx601 whorl with (E)-β-caryophyllene repels the FAW!
The toxic protein RIP2, induced by caterpillar feeding, is one of a potential suite of proteins that can defend maize against chewing herbivores.
Antibiosis was detected in the sorghum landrace accessions from Honduras -- San Bernardo III, Hilate-179, Piña-61, and Lerdo-104.

A hypothesis, based on differential selection and increased selection pressure brought about through intercropping with maize, was presented to explain the development of antibiosis in these landrace populations.
Bt Maize against FAW – a proven technology!

• Several different cry genes are available – e.g., cry1A, cry1Ab, and cry1F – and have been deployed in commercial Bt maize varieties globally for over 20 years.

• Bt also produces another class of lepidopteran-specific proteins termed Vegetative Insecticidal Proteins (VIP). These VIPs are encoded by vip genes, the most notable of which is the vip3A gene used to confer FAW resistance.

• Numerous GM maize hybrids, including various combinations of cry and vip genes, are commercially available in Brazil and North America, where over 80% of the total maize production area is cultivated with Bt maize.
Bt Maize in Africa

• In Africa, Bt maize is currently commercially available only in South Africa, where regulatory authorities have overseen multiple approvals, with more than 15 years of deployment of such products.

• Two GM products are available that provide protection against FAW:
  - MON810 event → intended to control stem borer but also confers partial resistance to FAW; cultivated in South Africa since 1997.
  - MON89034 event → demonstrated efficacy for control of both FAW and stem borer; cultivated in South Africa since 2010. MON89034 is particularly recommended for FAW control due to its high efficacy against the pest, as well as anticipated durability of control over time due to its incorporation of “stacked” or “pyramided” insect-resistance traits.
Bt Maize: Partial but Significant FAW Control
(Confined Field Trials in Uganda, January 2017)
Preliminary CFT results: Stacked TELA hybrids in Kenya, Mozambique, and Uganda out-yielded isogenic hybrids by 9–98% under FAW + Stem borer.
Performance of *Bt* Maize under Natural Stem-borers and FAW Infestation in Uganda, March 2018

*Bt* maize (*Left*) vs. non-*Bt* version (*Right*) against FAW and Stem borers
Presently, Most Commercial Maize Varieties in Africa

Some of the CIMMYT Maize Germplasm with Conventional / Native Resistance to FAW

Bt Maize vs Native Resistance

- Resistant
- Partially Resistant
- Susceptible
- Highly Susceptible

Presently, Most Commercial Maize Varieties in Africa
Recommendations:

- Using locally-adapted germplasm that contain native *Spodoptera* resistance
- A robust education program to teach end-users about the insect-resistance management
- Appropriate crop stewardship
- Resistance monitoring
- Pyramided trait products to delay resistance development
In Conclusion...

- Insufficient attention has been given to the integration of conventionally-derived resistance with other IPM tactics in effective management of insect-pests of crops in general.

- We need to **effectively utilize and quantify the benefits of host plant resistance** in multi-tactic IPM programs.

- **Keys to overcoming the barriers:**
  - Systematic analysis of compatibility and possible synergies between host plant resistance with other IPM approaches (e.g., biological and chemical control) with regard to FAW in Africa
  - Increased application of modern genetic tools in accelerating breeding for improved Africa-adapted varieties with FAW resistance and other farmer-preferred traits.
Thanks!

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