Increasing Genetic Gains in Maize through Breeding for Insect Resistance

Anani Bruce, Lewis Machida, Yoseph Beyene, Stephen Mugo

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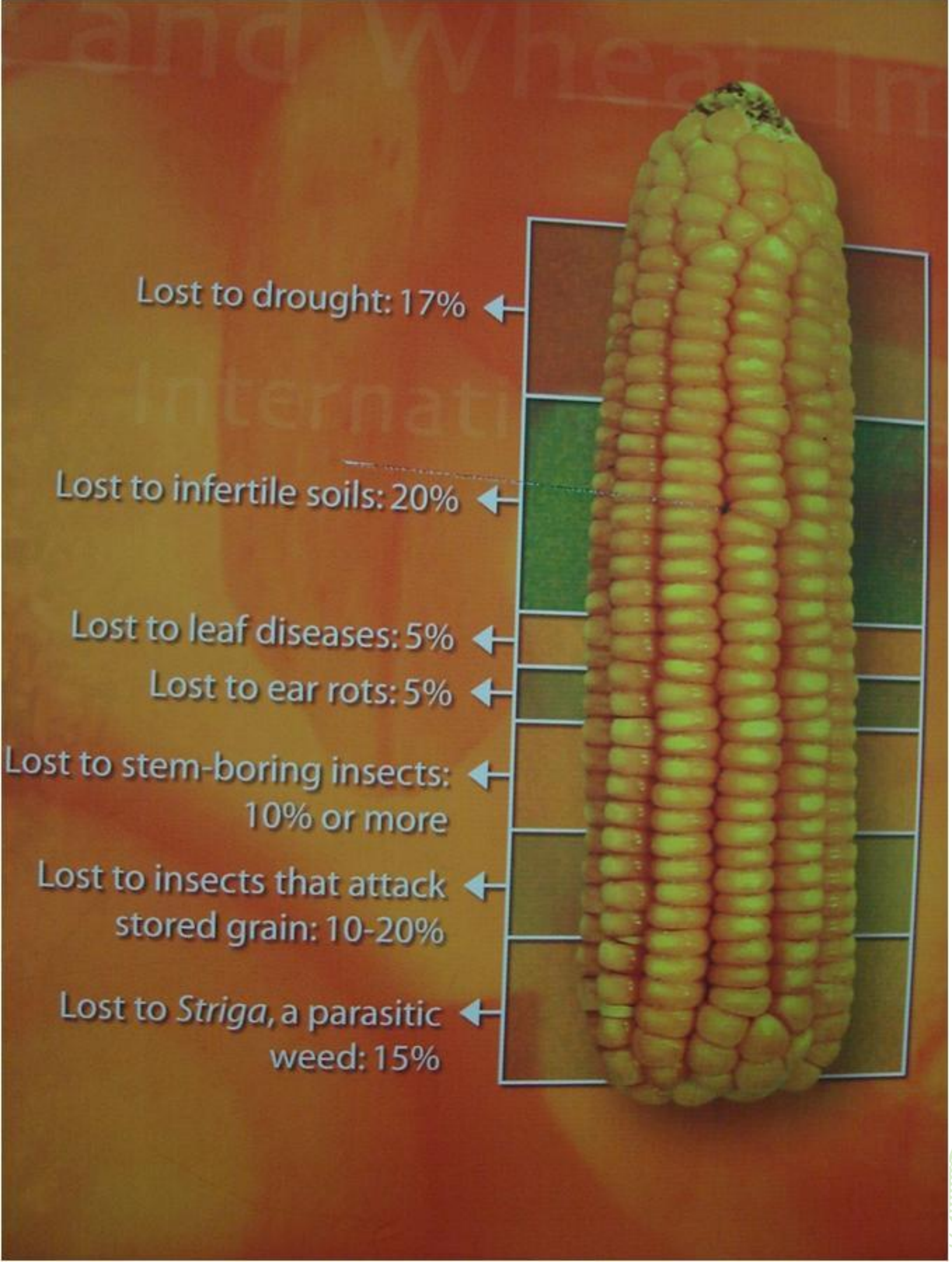
Outline

- Insect pests globally and in SSA
- Management of stemborer pests
- Fall armyworm: a new maize pest in Africa
- Use of Bt maize for stemborer and FAW Control
- Management of postharvest pests
- Concluding remarks

Insect pests globally and in SSA



Lost to stem borers	= >10%
Lost to post harvest pests	= >15%
Total	**= >25%**

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Introduction

Insect pest problem:

- Part of agricultural ecosystems
- Affects 46% of global maize growing area
- Insect pests causes 25% world maize loss annually
  - Field pests causes 14.5% world loss annually
  - Storage pests causes 10% world loss annually
- 52 million MT of grains valued at $5.7 billion
- 60% of maize loss is in the tropics
- US$550 M worth of insecticide used annually to control insect pests in crops

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Insect pests in maize production and storage in various agro-ecologies

			Upper wet MA	Lower wet MA	Dry MA	Wet lowlands	Dry lowlands	Global†	Importance	Hot Spots
Insects	***Busseola fusca***	1.5	1.5	2.8	3.8	5.0	4.8	3.2	M	TZ, Highlands,
	Chilo partellus	4.5	3.5	2.6	2.8	1.8	2.1	2.9	M	LLT: Africa,
	Cutworm	4.7	4.7	4.7	3.9	3.7	3.8	4.3	L	
	Diabrotica spp	4.5	4.3	2.4	2.9	3.5	3.8	3.5	L	
	Diatraea spp	3.4	3.1	3.4	2.8	2.7	2.8	3.0	M	
	Eldana saccharina	.	4.0	5.0	5.0	2.5	3.5	4.0	L	
	Sesamia spp.	4.0	.	4.0	3.0	3.0	3.0	3.4	L	Africa,
	Ostrinia furnicalis	.	3.0	2.0	.	2.0	2.0	2.3	H	
	Heliothis spp.	2.0	3.0	4.0	4.0	4.0	4.0	3.5	L	of LA
	Spodoptera spp.	4.5	3.8	3.8	3.8	2.0	2.6	3.4	L	
	Aphids	4.0	4.8	4.8	4.7	4.5	4.3	4.5	L	
	Leaf/plant hoppers	4.7	3.3	3.3	2.9	3.3	3.3	3.5	L	
	Grasshoppers	5.0	5.0	5.0	3.3	4.2	3.3	4.3	L	
	Flea beetles	3.7	4.8	4.8	4.9	5.0	4.7	4.6	L	
	Spider mites	4.7	4.8	4.7	2.8	4.8	3.7	4.2	L	Arid environments
	Termites	4.0	4.0	3.5	2.8	4.0	2.0	3.4	L	
	Phyllophaga spp	3.9	3.9	3.0	3.9	3.0	3.0	3.5	L	Minimium tillage
	Wireworms	3.9	3.9	2.9	3.9	3.2	3.2	3.5	L	Minimium tillage
	Sitotroga cerealella	4.9	5.0	5.0	4.0	5.0	5.0	4.8	L	
	Plodia interpuctella	4.9	5.0	5.0	4.0	5.0	5.0	4.8	L	
	Prostephanus truncatus	3.8	2.3	1.8	2.3	1.6	2.0	2.3	H	C. ,
	Sitophilus spp	3.3	2.3	1.8	3.1	1.7	2.4	2.4	H	Humid environment

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Importance of stress factors/breeding goals in various maize mega-environments in Sub-Saharan Africa.

			Abiotic stress			Diseases									Pests				
	Africa	Need for earlier germplasm	Low N	Drought	Low pH	MSV	E. turc	GLS	P.sorghi	PLS	P. polisora	H. maydis	DMR	Ear rots	Striga	Chilo partellis	Busseola fusca	Prostephanus	Sitophilus spp
	Highlands	2.0	2.8	4.3	3.0	3.5	1.0	1.3	1.3	1.3	4.3	5.0	5.0	1.8	4.0	4.5	1.5	3.8	3.0
	Upper humid mid-altitudes	3.0	2.0	3.8	2.8	2.3	1.0	1.0	2.3	1.3	4.3	4.8	5.0	1.0	3.0	3.5	1.5	2.0	1.8
	Lower humid mid-altitudes	3.0	1.3	2.3	4.0	2.5	2.3	2.5	2.8	3.0	3.5	3.8	4.3	2.8	2.3	3.3	2.8	1.3	1.8
	Dry mid-altitudes	1.3	1.0	1.0	4.3	3.5	4.5	4.3	4.0	5.0	4.5	4.3	5.0	3.3	3.8	2.8	3.8	2.5	3.0
	Humid Lowlands	3.0	2.3	3.3	3.0	2.0	4.5	4.8	4.8	5.0	2.5	1.8	2.0	2.3	2.3	1.0	5.0	1.0	1.8
	Dry lowlands	1.0	1.5	1.0	5.0	1.8	4.5	4.8	4.3	4.8	3.8	2.8	3.0	3.5	2.3	1.3	4.8	2.0	2.5

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Management of stemborer pests in maize

Important stemborer species in SSA

Busseola fusca

Sesamia calamistis

Chilo partellus

Eldana saccharina

Window

Dead heart

Stem tunneling

Stem breakreage

Mycotoxin' contamination

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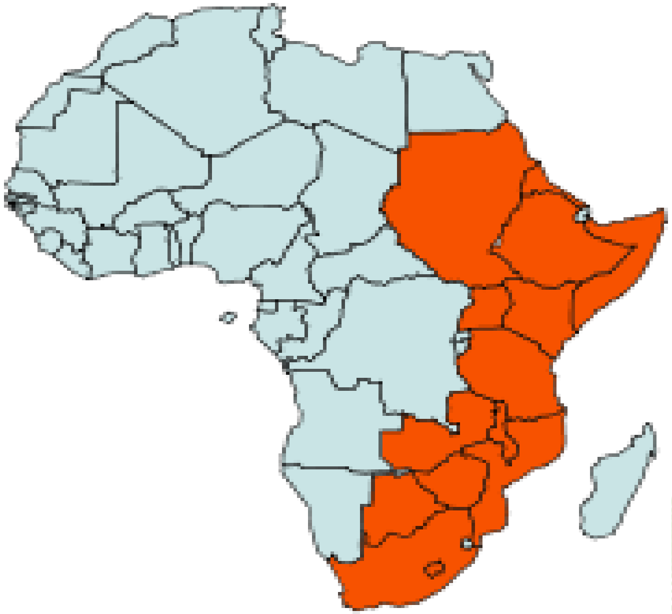
Chilo partellus = the spotted stem borer

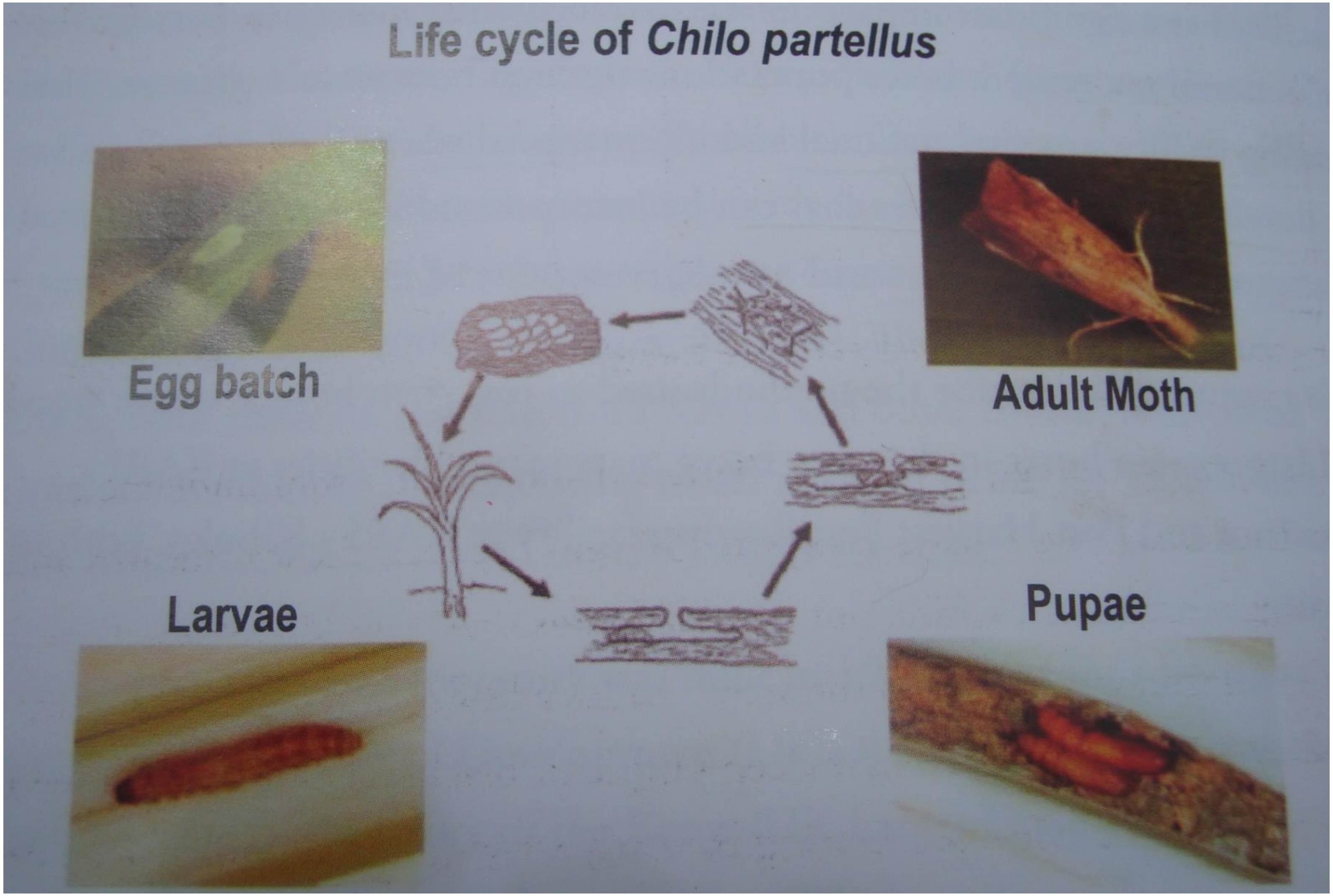
- **Nature of damage**
  - Cause rows of oval perforations in leaf whorl
  - Damage the growing point: dead-heart
  - Severe in the lowlands

Geographical distribution

- Introduced to Africa
- Australia, Africa, Southeast Asia



Life cycle of *Chilo partellus*



Busseola fusca = African maize stem borer

Nature of damage

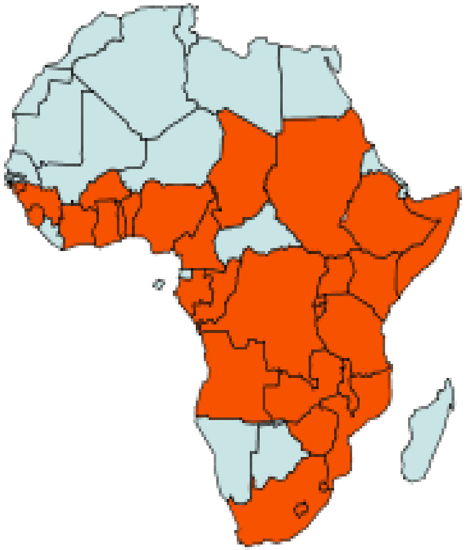
- The larvae migrate to the leaf whorl for feeding
- Causes dead-hearts
- 2nd generation larvae feed on tassels, ears, stems

Description

- Larvae grayish body
- Adult is dark brown moth

Geographical distribution

- Sub-Saharan Africa, 500-2500m



Life cycle of *B. fusca*

Sesamia calamistis = The pink stem borer

Nature of damage

- Similar to *C. partellus* and *B. fusca*

Description

- **Pinkish larvae, 3-4 cm long**
- **Adult is light brown**

Distribution

- **Warmer coastal areas of Africa**

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Some wild habitat stemborers

Busseola segeta

Busseola phaia

Sesamia oriaula

Scimesa piscator

Sesamia poaphaga

Sesamia penniseti

Sesamia sp5

Manga melanodonta

Manga nubifera

Yield loss in maize due to stemborers

Country	Species	Yield loss (%)
South Africa	*B. fusca*	10-100
South Africa	*C. partellus*	50
Lesotho	*B. fusca*	0.4-36.6
Kenya and Tanzania	*C. partellus*	13-18
Kenya and Tanzania	*B. fusca*	12
Kenya and Tanzania	*E. saccharina*	15-28
Guinea	*E. saccharina*	14-27
Burundi	*E. saccharina*	12-15
Burundi	*E. saccharina*	30-50

How to Control stemborers?

1. Chemical control
   - Broad-spectrum insecticides
   - Bio-pesticide
2. Cultural control
3. **Host plant resistance**
4. Biological control using
   - Parasitoids
   - Predators
   - Pathogens

Pupa parasitoids

Larva parasitoids

Egg parasitoids

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Control methods for stemborers

- Stem borers are difficult to control, largely because of the nocturnal habits of the adult moth and the cryptic behavior of the immature stages (Seshu Reddy and Sum 1992).
- IPM is based on information of insect population dynamics, pest monitoring and integration of several compatible control measures.
- In Africa, a combination of cultural, chemical and biological control of maize stem borer measures are practiced. Various control techniques have been tried, some with partial success, but all have limitations and none has provided a complete solution.

Chemical control for stemborers

- Chemical control using synthetic insecticides provides only protection against early attacks but not against borers feeding inside the ear
- It requires pest monitoring and training of farmers but in most countries appropriate training capacities do not exist.
- The inappropriate use may affect human health and interfere with natural control by predators and parasitoids leading to outbreaks of secondary pests.
  - Borers are difficult to control with insecticides
  - Stem borers are cryptic feeders-late instars (3rd instars)
  - Early (1st, 2nd) larval instars- leaf whorl feeders

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Cultural Control for stemborers

- Manipulation of the environment in such a way as to render it unfavorable to the pest (the **crop** and the **land)**
  - Crop manipulation (intercropping, destruction of residues, planting dates)
  - Land manipulation (crop rotation, tillage)

- Most relevant and feasible pest control for African farmers

Pros and cons of cultural control for stemborers

Pros

- Readily available to the farmers
- Don’t entail extra investment in equipment to apply
- Little adverse effect on the environment

Cons

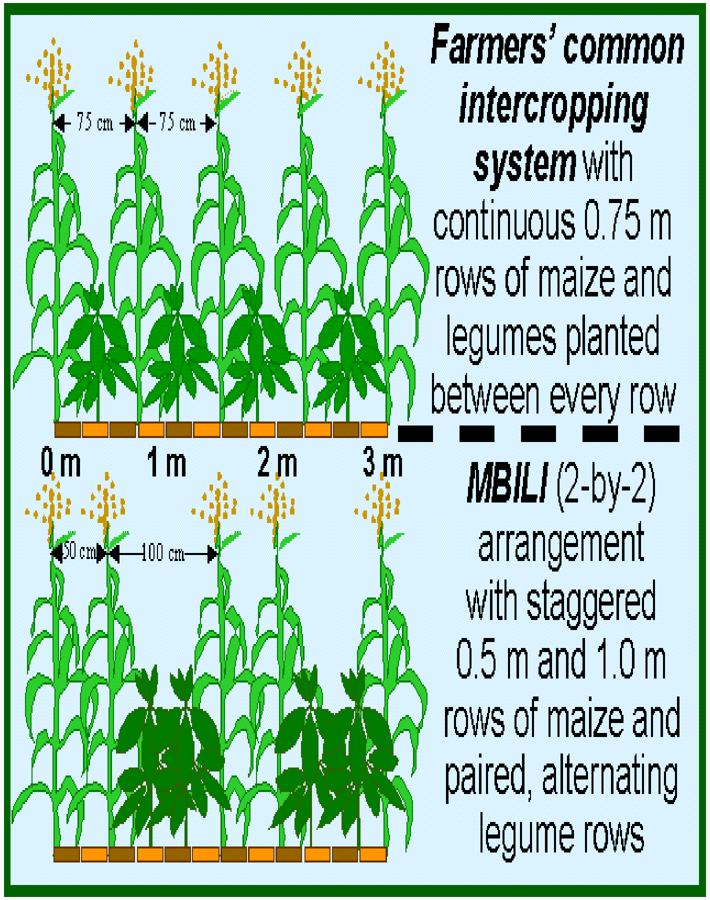
- Labor intensive
- Knowledge of biology & ecology of the pest
- Requires cooperation among farmers

Habitat management strategy

- **Intercropping**
- Single row, double row, strip intercropping:

- **Maize-legume -** reduced infestation
- of stem borers
  - Maize-cowpea
  - Maize-common bean
  - Maize-legume trees

- **Maize-cereals -** intensified infestation
- of stem borers
  - Maize-sorghum
  - Maize-millet



Maize-sorghum
Maize-millet

Habitat management

- Utilization of biodiversity for management of cereal stem borers
- Benefits from grasses and legumes in cultivation of maize
- Combined use of trap and repellent plants
- Called the **Push-Pull** strategy

Plants used in the push-pull system

Trap plants = Pull (attractants)

Repellent plants = Push

Legume silver leaf (*Desmodium uncinatum*)

Napier grass (*Pennisetum purpureum*)

Pull (attractants)

Challenges:
seeds availability
adoptability and land shortage

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Fungi

- Entomopathogenic fungi produce toxins
- *Metarhizium anisopliae* and *Beauveria bassiana*
- Collection and characterization of isolates

Biological control

- Classical BC has been attempted against the invasive *Chilo partellus* using the parasitoid *Cotesia flavipes*
- Redistribution of parasitoids – i.e. the geographic expansion of a parasitoid species or population beyond their native range – has been attempted against *B. fusca* introducing Kenyan populations of *C. sesamiae* in western Africa and the West African egg parasitoid *Telenomus isis* into Kenya.
- However, in most cases BC achieves only partial control of the pest and has to be combined with other control techniques.

Parasitoids of stem borers

Telenomus sp.

Trichogramma bournieri

Cotesia flavipes

Pediobus fuvus

Host plant resistance

- HPR maize breeding programs by CIMMYT and IITA have focused on lepidopteran and coleopteran pests.
- Antibiosis from hydroxamic acids and flavonoid glycosides in maize has been key for managing pests.
- Because many traits related to maize resistance to insects are multigenic incorporating them into breeding populations has been difficult.
- However, the use of marker-assisted selection can facilitate breeding once genes for these traits are identified.
- One option to enhance maize HPR and transgenic insect-resistance includes efforts to combine natural traits with transgenic traits for maximum effectiveness

Breeding for insect Resistance

1. Has lagged behind disease resistance
2. Requires knowledge on the biology of maize and the pest
3. Dependent upon:
   - The insect pest,
   - Efficient insect rearing technique,
   - Efficient artificial infestation of maize plants,
   - Genetic techniques, and
   - Plant breeding techniques

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Genetic control of resistance to insect pests

Stem borers

- Resistance to stem borers is available
- Resistance is controlled mainly by many nuclear genes (polygenic) genes with additive effects

Functional Modalities of Insect Resistance

1. Non-preference (Antixenosis)
    - Non Suitable of the maize plant as a host
2. Antibiosis
    - Adverse affects on the pest
3. Tolerance
    - The reaction of the plant to insect attack

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Status of Breeding Programs for Insect in SSA

Few maize improvement programs include breeding for host plant resistance

1. Genetic challenges posed by the screening and selection for resistance

   - Polygenic control and quantitatively inheritance

2. Logistical challenges in screening and selection

   - Expensive insect rearing

Farmers rely on other non-genetic methods: Chemical, cultural, biological or no control

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Measured Traits for Stem Borer Resistance

1. Loss of photosynthetic leaf area
   - Leaf area damage score
2. Dead hearts
   - Simple counts
3. Lodging from damaged stems
   - Stem lodging
   - Number of exit holes / Cumulative tunnel length
   - Tunnel length: plant height ratio
4. Increased ear rots & mycotoxins
   - Number of rotten ears - with borer damage
5. Reduced grain yields
   - Grain yield
   - Grain yield loss = Protected Yield–Infested yield

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SBR Variety Testing Protocol

- Alpha lattice designs were used
- Artificial infestation and natural infestation are used in different trials
- In both cases each and every plot is divided into two:

  a) infested area (artificial or natural);

  b) protected area
- Data is collected separately for infested area and for protected area

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SBR Variety Testing Protocol

- Collected data included:
  - Dead hearts
  - Stem borer leaf damage rating
  - Number of exit holes on stems/stalks
  - Number and cumulative length of stem borer tunnels after splitting of stems
  - Standard agronomic trial data

Field Infestation: Stem Borers (Larvae)

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Maize Leaf Damage

Dead Hearts and Stem Damage

Tunnel Length of Insect Resistant Maize

Stem Borer Resistant and Checks

2011 SBR Results

Entry	Pedigree	BLUE Yield (t/ha)	Yield Rank	Days to 50% Anthesis (days)	No. Exit Holes (#)	Stem Borer Damage (1-9)	Tunnel Length (cm)	Tunnel Length/Plant Height (#)
8	CKIR11009	5.30	1	64.6	1.7	2.6	6.0	0.022
3	CKIR11004	5.22	2	63.6	1.8	2.4	7.0	0.029
2	CKIR11003	5.10	3	64.2	2.0	2.5	7.6	0.031
15	CKIR11019	5.06	4	63.7	1.5	2.3	6.2	0.025
23	CKIR11027	5.06	4	64.1	0.9	2.5	3.3	0.013
25	CKIR11031	5.03	6	65.2	1.9	2.4	4.7	0.017
13	CKIR11016	5.01	7	65.4	1.5	2.7	3.9	0.016
24	CKIR11029	5.00	8	65.6	0.9	2.4	3.4	0.013
14	CKIR11018	4.98	9	63.1	1.2	2.2	6.4	0.024
21	CKIR11025	4.97	10	63.9	1.3	2.3	4.6	0.018
30	Local Check 2	4.71	19	63.4	1.7	2.1	5.3	0.022
28	WH505	4.62	24	65.0	2.0	3.0	5.5	0.023
29	Local Check 1	4.57	26	63.1	1.7	2.5	5.4	0.021
	nlocs	16		19	5	8	6	6
	Grand_Mean	4.80		64.2	1.5	2.4	4.9	0.020
	LSD	0.52		1.26	0.84	0.74	2.06	0.01
	CV %	5		1	28	16	21	22
	Heritability	0.43		0.78	0.33	0.00	0.59	0.55

Conclusion

- Stem borers are economically the most important pest There are a number of control measures against stem borers, but each comes with its own limitations.
- For reasons of costs and availability of pest control methods, farmers often use no control measures at all
- HPR, the resistance is embedded in the seed, and is, therefore, the easiest control method for subsistence farmers
- However, HPR, needs investment in germplasm development, establishing insect mass rearing and seed multiplication

Fall armyworm: a new maize pest in Africa

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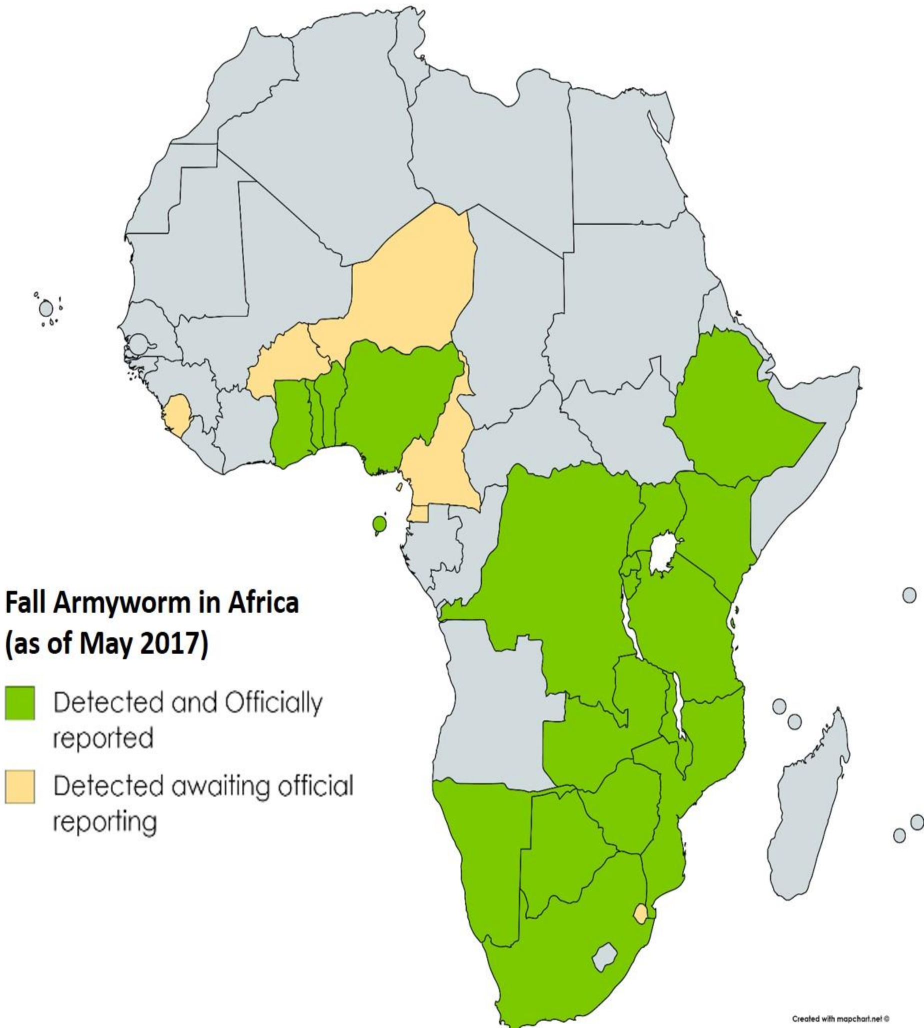
Insect Pests of Maize in the field

April 2017

Fall Armyworm in Africa: Status and Strategy for Effective Management

- Contingency Planning and Awareness Creation on FAW among Farming Communities in Africa
- FAW Monitoring and Early Warning Systems
- Socio-economic Impact Assessments and Modelling of Potential Losses
- Development and Dissemination of FAW Management Option
- Coordination of Institutional Interventions for FAW Management in Africa

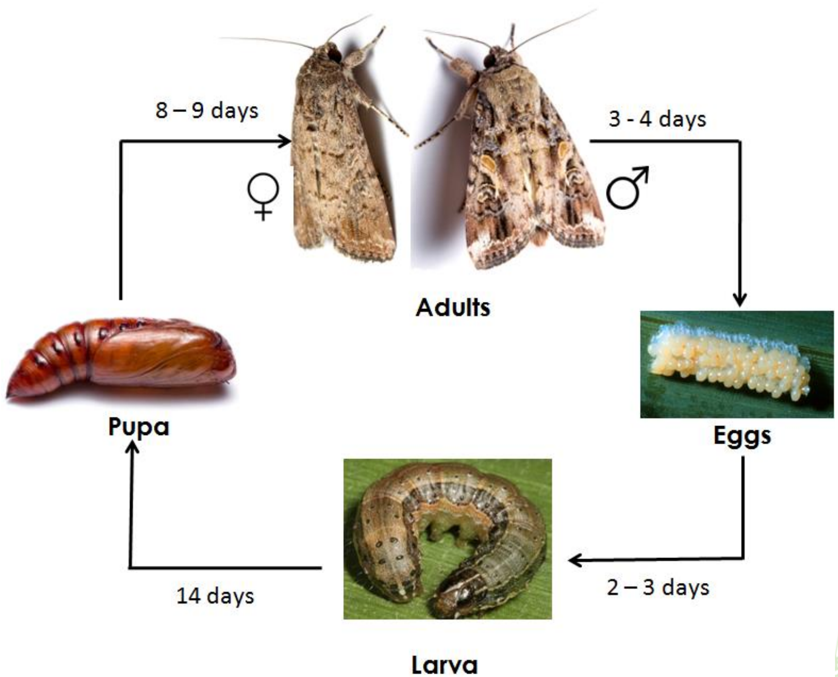


Insect Pests of Maize in the field: FALL ARMYWORM (*Spodoptera frugiperda*)

(a) Male fall armyworm moth

(b) Female fall armyworm moth

(c) Fall armyworm larva



Life cycle of the fall armyworm Capinera 2014

Description and life cycle:
When full-grown (4 to 5 cm long), the black or dark-green larvae turn into reddish dark-brown pupae below the soil surface. The adult is a grayish dark-brown moth.
This moth lays its eggs on maize leaves in nearly spherical, yellowish white, fuzz-covered clusters that become dark as the time for hatching approaches.

FALL ARMYWORM (*Spodoptera frugiperda*)

Nature of damage:

- As newly emerged larvae begin feeding on the leaves,
- Create a "windowpane" effect.
- Later, larvae may eat entire leaves, leaving only the midribs.
- Under severe infestation, the entire young plant may be consumed
- Fall armyworms cause heavy damage in maize by feeding on leaves and ears.
- Damage maize plants in nearly all stages of development, they prefer concentrate on later or younger crops

FALL ARMYWORM (*Spodoptera frugiperda*)

Behavioral ecology

Photophobic –

- ✓ Adults are nocturnal, and are most active in the evenings while
- ✓ larvae also shun light and tend to conceal themselves during the brightest time of the day and, mostly found eating in the whorl of the maize plant during day

Cannibalism - The rate of cannibalism depends on the type and quality of the host plant on which the larvae are. Cannibalism is high when the larvae are on a less preferred host or on a preferred host plant but its quality is poor

Dispersal - Fall armyworm moths are strong fliers such that they easily spread to other areas

Host range - Fall armyworms are very polyphagous and some of their alternative host crops are cowpea, barley, Bermuda grass, buckwheat, cotton, clover, oat, millet, peanut, rice, ryegrass, sorghum, sugarbeet, sudangrass, soybean, sugarcane, tobacco, and wheat.

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Management of FAW

The decision on pest control should depend on the level of infestation, control cost and production monetary value

CIMMYT recommend IPM:

- **Chemical control**

✓ Lambda-cyhalothrin
✓ Thiamethoxam
✓ Deltamethrin
✓ chlorpyrifos methyl
✓ chlorpyrifos ethyl
✓ Trichlorfon

But chemical control is socially and environmentally unsustainable

- **Biological control**

Potentially efficient egg and larval parasitoid species need to be identified and tested before deployment in the African context.

✓ Nuclear polyhedrosis Virus (NPV)) are reported to be the most prevalent and potent in natural populations.

✓ Fungal pathogen *Beauveria globulifera and Beauveria bassiana* that cause a common disease in larvae.

✓ Parasitoids from Sceliniodae, Ichneumonidae, Braconidae and Eulophidae Families like: *Cotesia magniventris Chelonus insularis, Chelonus cautus, Chelonus sonorensi, Campoletis sonorensis, Pristomerus* sp. and *Euplectrus plathyphenae, Archytas marmoratus*

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Management of FAW

Habitat management

- early planting and/or early maturing varieties
- The mixed cropping systems are likely to support more predators, disrupt egg laying by fall armyworm female moths and also hinders the plant to plant migration of fall armyworm larvae after hatching
- diversification of the plot and landscape with trees and hedgerows
- stress-tolerant germplasm
- Good agronomic practices

Host plant resistance

Conventional breeding:

- The resistance mechanism could be antixenosis, antibiosis or tolerance
- 65 CML's have been identified to be resistance to FAW in Mexico
- Host plant resistance is an important component of IPM

Conventional breeding:

- MON84006 event singly and pyramided with MON810 had superior control of whorl-stage damage by *S. frugiperda*
- MON8946 has a better control

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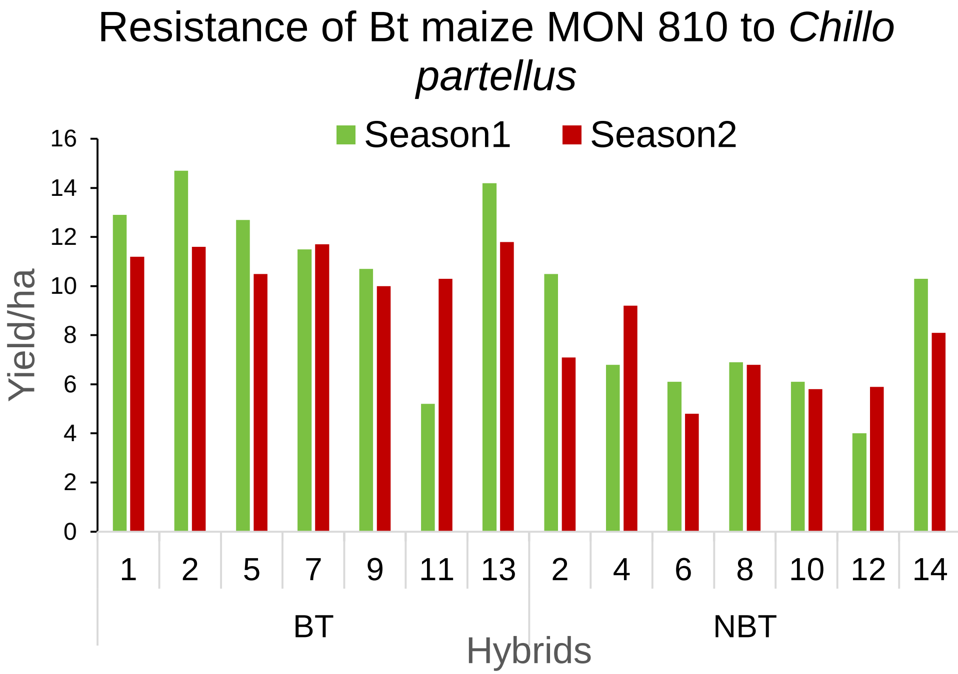
Use of Bt maize for stemborer and FAW Control

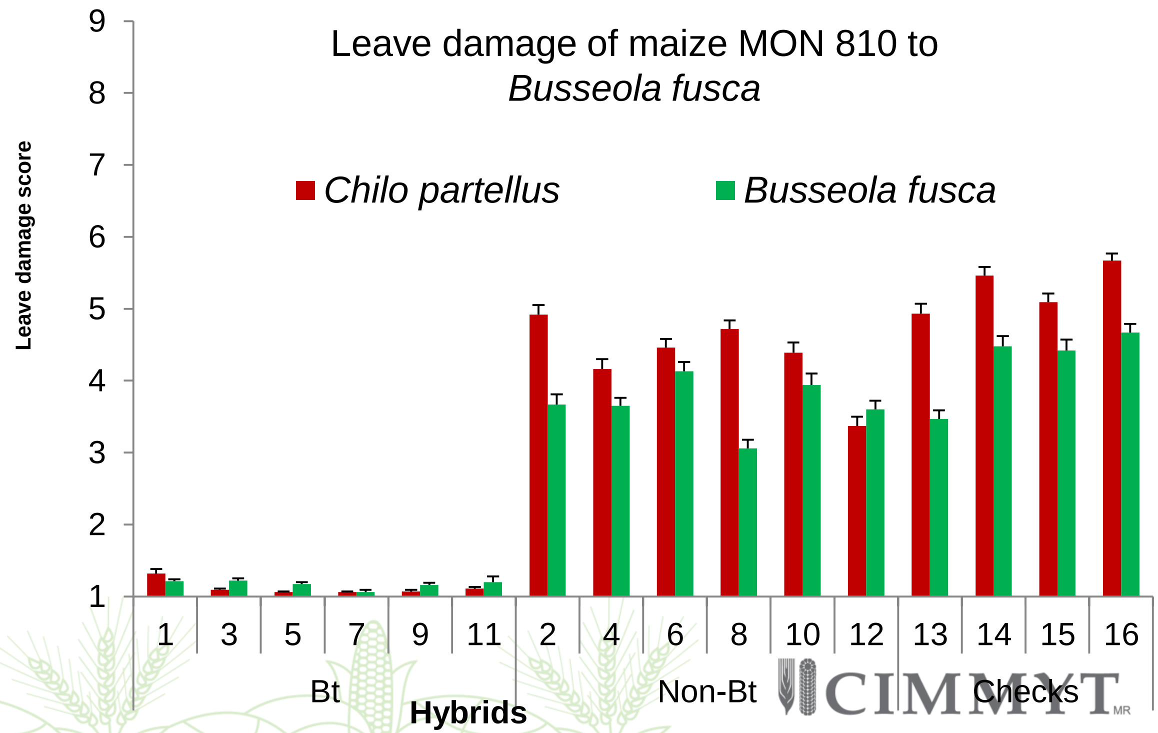
Transgenic method: MON 810

•Most larvae die (2-3 days) after taking only a few bites

•Bt corn provides high levels of yield protection even during heavy infestations

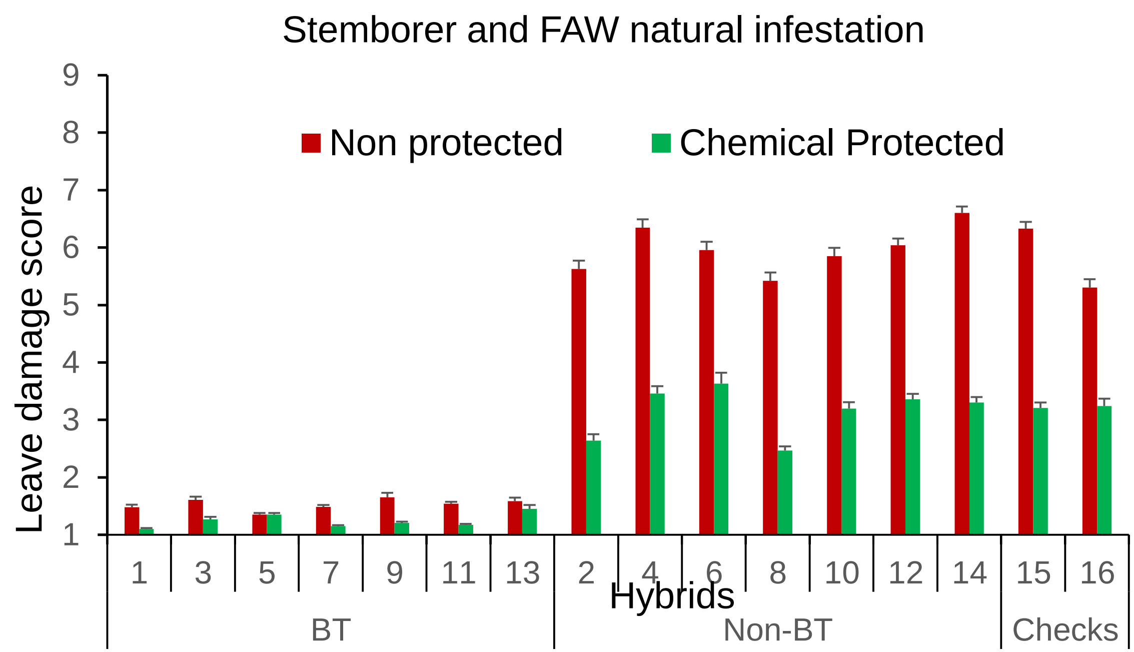
•Bt corn (MON810) provides 96% average control of European corn borer larvae the same trend is found for *Chilo partellus* at the Kiboko CFT


Resistance of Bt maize MON 810 to *Chillo partellus*
Season1
Season2
Yield/ha
0
2
4
6
8
10
12
14
16
1
2
5
7
9
11
13
2
4
6
8
10
12
14
BT
NBT
Hybrids


Leave damage of maize MON 810 to *Busseola fusca*
Chilo partellus
Busseola fusca
Leave damage score
1
2
3
4
5
6
7
8
9
1
3
5
7
9
11
2
4
6
8
10
12
13
14
15
16
Bt
Non-Bt
Checks
Hybrids

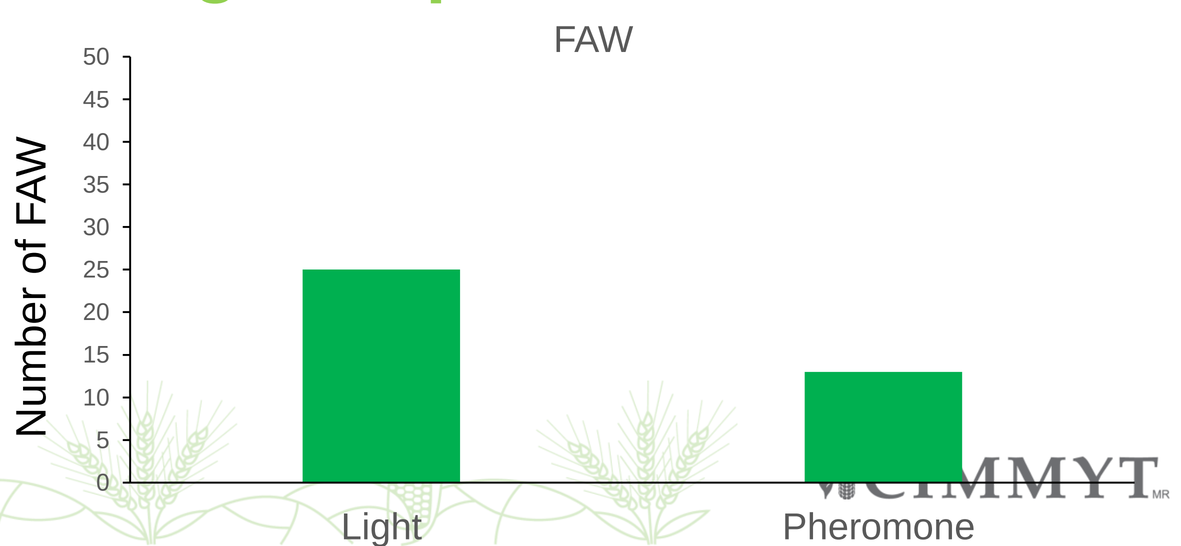
Preliminary result from CFT Mozambique

One plot was pesticide free where stemborer and FAW pests were allowed to lay their eggs. Almost all plants in the plot were attack by FAW and few stemborers.
The chemical protected plot were sprayed with granule pesticide 4 times in weekly interval



Pheromones and light traps in Kiboko

The traps were placed in the experimental plot at Kiboko for 20 days and FAW were recorded on daily basic.
5 traps per treatment were used.



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Management of postharvest pests in maize

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Important post harvest pests

Sitophilus zeamais

Prostephanus truncatus

Sitotroga cerealela

Mussidia nigrivenella

Grain infected with *Aspergillus* spp

Weevil damage

LGB damage on maize

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Traditional storage method

Types of losses

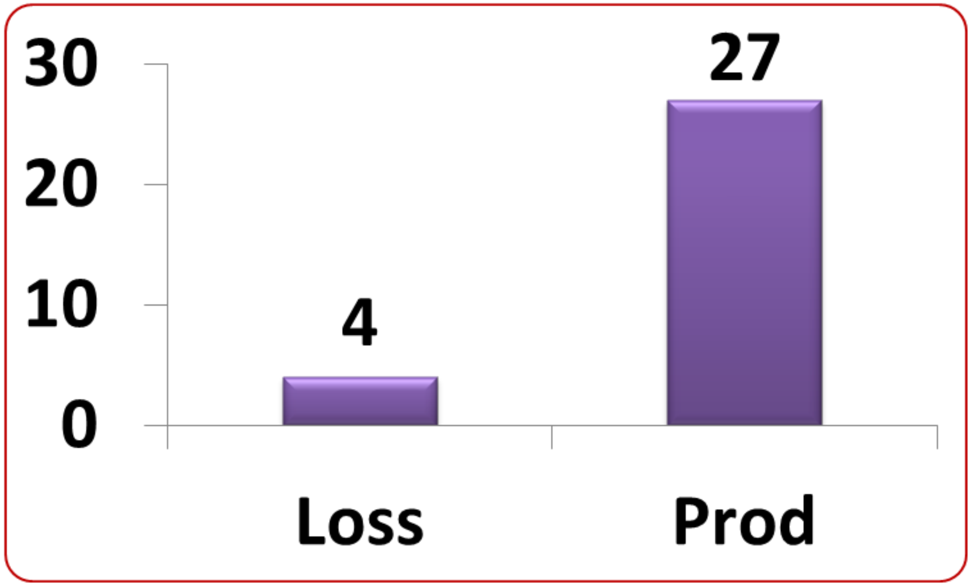
Physical losses

Monetary losses

Quality losses

- Weight loss
- Opportunity loss
- Nutritive loss

Postharvest losses: How big is the problem?



Estimated value of produced and lost grains annually in SSA

Loss equivalent to:

- **Annual caloric value of at least 48M people**
- **Food aid received for a decade**
- **1% reduction PHL, $40M gains**

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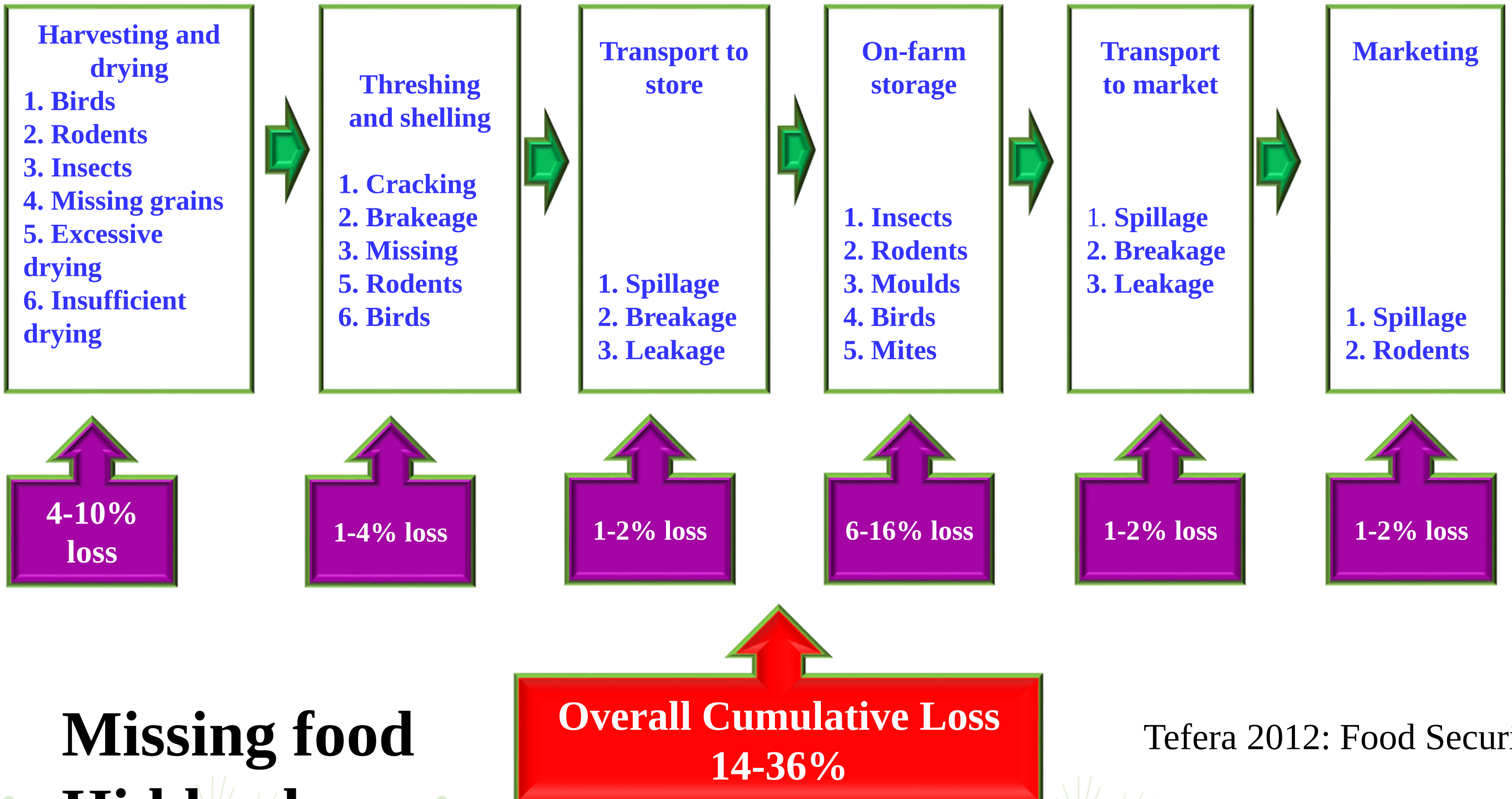
Maize post-harvest system & losses



- **Missing food**
- **Hidden hunger**

Tefera 2012: Food Security

CIMMYT

Post Harvest Maize Pests

- Insects are a major cause of maize storage losses in the tropics. They infest and damage grain, resulting in direct and indirect losses of both quality and quantity of the food stored.
- Losses vary according to region, environmental conditions, main storage pest(s), and method of storage.
- Under certain conditions, weight losses of over 30% have been observed after only a few months of maize storage in some African countries.

Control method

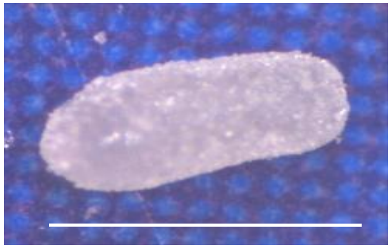
- Effective controls of maize storage insect pests rely mainly on pesticide use
- **However,**
- Some pesticides (e.g. Actellic) are becoming inefficient. Insect resistance? Or fake products?
- Application of effective synthetic pesticides pose serious and increasing risks (Health & environmental problems)
- While improved practice may limit pesticide misuse, safe alternative measures appropriate to the needs of poorer households are needed.

Biological control

- A predator, *Teretrius nigrescens,* of the LGB was released in Africa with some successes in hot-humid areas of West Africa (Borgemeister et al. 1997).

- Only two populations of *T. nigrescens* from limited geographical and temporal isolation efforts were released separately in Africa (Schneider *et* al. 2004)

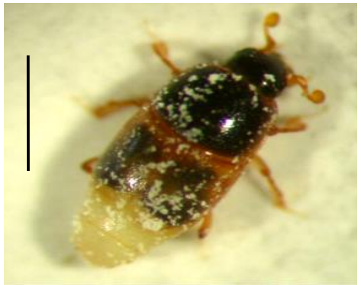
- Additional research needs to be done on the adaptation of the predator to different climatic zones



Egg

larvae

Pupa



Freshly eclosed adult *T. nigrescens*

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Hermetic storage technologies

- The most promising option is the hermetic storage which is promoted by CIMMYT and its partners.
- From the pilot study, metal silo and hermetic bags maintained a low grain damage and loss (< 5%) over 6 months period.
- On station trails were conducted between 2012 and 2013 in the four countries and the resulted confirmed the effectiveness of hermetic storage
- Based on this result there is a need to up scale the technology in maize surplus areas

Metal silos

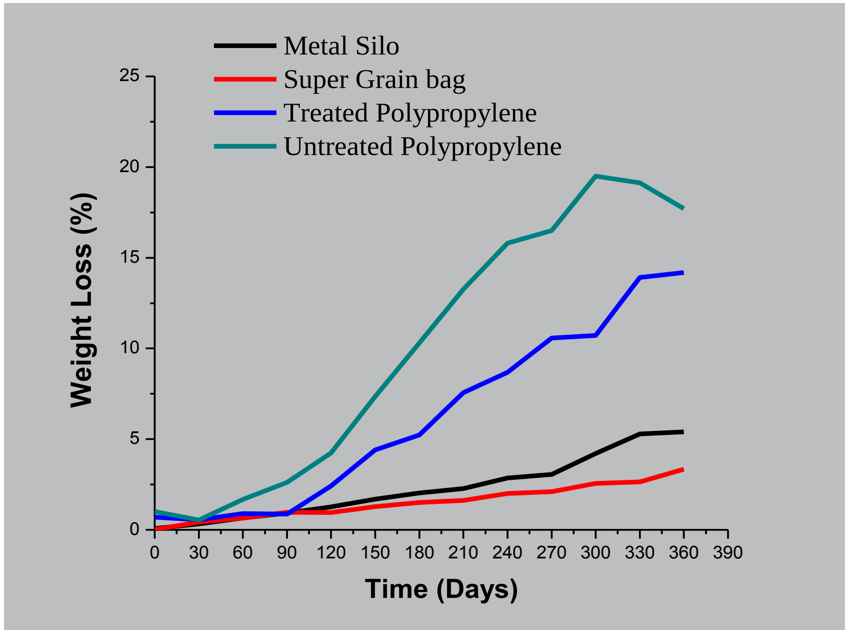
- A metal silo is of one standard design, cylindrical structure, fabricated by trained local tinsmith from galvanized iron sheet with a top loading inlet and a lateral unloading spout at the bottom and hermetically sealed with rubber band.

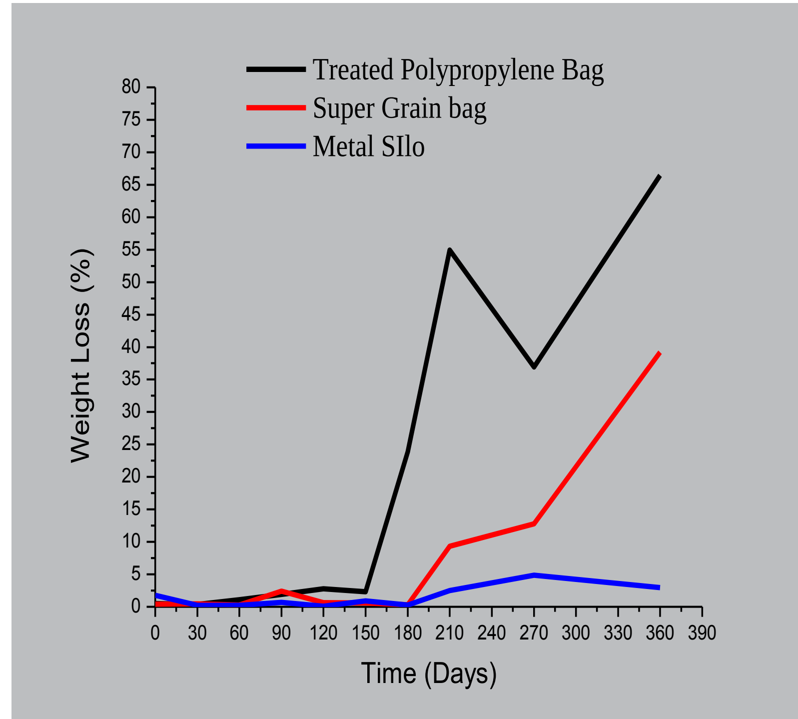

GrainPro, Inc.
STORING THE FUTURE
CONTROL
ACTELLIC

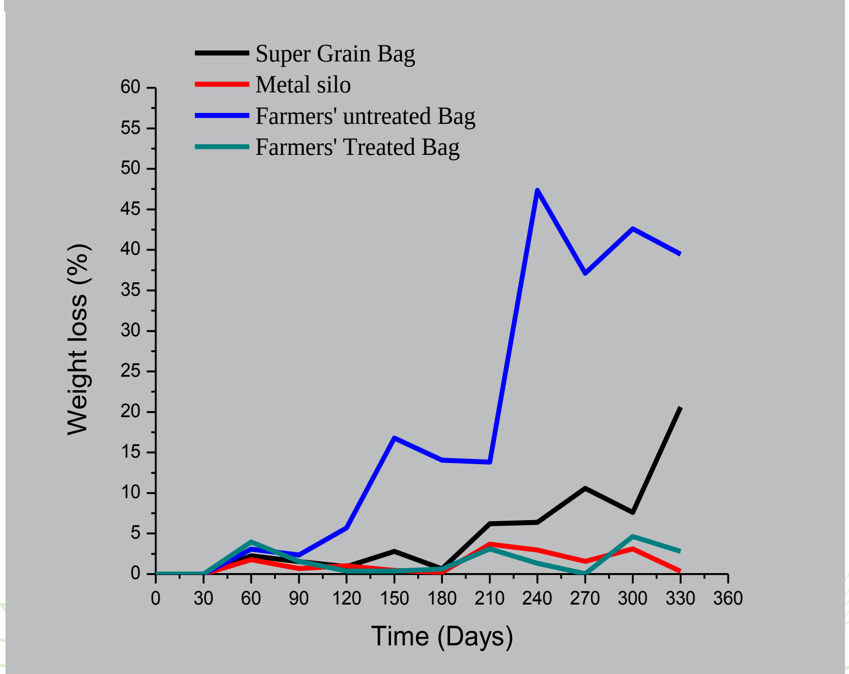
Trial Set-up

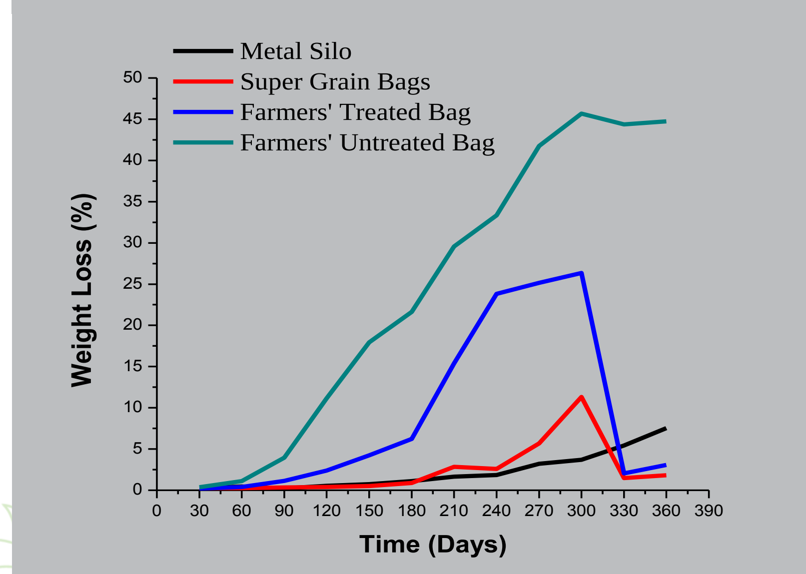

Hard Rock

Results


Metal Silo
Super Grain bag
Treated Polypropylene
Untreated Polypropylene
Weight Loss (%)
0 5 10 15 20 25
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Time (Days)


Treated Polypropylene Bag
Super Grain bag
Metal SIlo
Weight Loss (%)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Time (Days)


Super Grain Bag
Metal silo
Farmers' untreated Bag
Farmers' Treated Bag
Weight loss (%)
0 5 10 15 20 25 30 35 40 45 50 55 60
0 30 60 90 120 150 180 210 240 270 300 330 360
Time (Days)


Metal Silo
Super Grain Bags
Farmers' Treated Bag
Farmers' Untreated Bag
Weight Loss (%)
0 5 10 15 20 25 30 35 40 45 50
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Time (Days)

Untreated Polypropylene bag

Super grain bag

Metal silo

Treated Polypropylene bag

Conclusion

- Improved hermetic technologies tested (metal silo and super grain bags) can significantly reduce weight loss and grain damage caused by storage pests.

- From the farmers' side, the technologies are well accepted, however they consider them expensive.

- Need for concerted efforts to ensure that access to these improved hermetic storage technologies is achieved for the farmers

Development of Post Harvest Pests Resistant Maize

- Developing LGB resistant maize varieties
  - Testing new sources of resistance
  - Developing new sources through crossing germplasm
  - Evaluation of OPVs and hybrids as finished products

- Resistance is based on a genebank accession found to have resistance to LGB.
  - Crosses made to adapted germplasm
  - Inbred lines developed
  - TWCs formed and tested for agronomic performance
  - Screening grain for LGB resistance done at every stage

SPR Variety Testing Protocol

- Alpha lattice designs used
- Standard field agronomic assessments and measurements done
- To evaluate for resistance to storage pests, two different approaches are used; a) choice; b) No choice

SPR Variety Testing Protocol: Choice Method

- At harvest, 3 well filled and representative ears are selected and kept separately for each plot
- All the selected ears are dried to a uniform moisture content (±12.5%) in an artificial drier
- The ears are then packed in 2-5kg mesh bags and hung down from a plank at plate level in a well ventilated shed containing other untreated maize samples.

CIMMYT MR

Free-choice Cob Evaluation for Resistance to the Maize Weevil and to the Larger Grain Borer

SPR Variety Testing Protocol: Choice Method

90 Days from initial storage date the samples are examined for weevil and LGB damage and scored from 1 (10% damage) to 10 (100% damage).

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SPR Variety Testing Protocol: No choice Method

- At harvest, after selecting 3 well filled and representative ears, the remaining clean ears for each plot are shelled in bulk to produce at least 300g of grain for each plot
- 300g of grain are scooped from each plot and dried to a relatively uniform moisture content
- After drying the moisture content for grain from each plot is determined

SPR Variety Testing Protocol: No choice Method

The jars are incubated in a room with climatic control at 28^{0}C and relative humidity of at least 70% for 90 days

SPR Variety Testing Protocol: No choice Method

After 90 days the grain, insects and flour are separated using appropriate sieves

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SPR Variety Testing Protocol: No choice Method

- Samples are separated into components
- Each of the components is weighed and grain weight loss of original sample is also calculated

- Collected data included:
  - Initial and final grain weights
  - Flour weight
  - Grain weight loss
  - Insects weight
  - % Grain damage (derived trait), and
  - Standard agronomic trial data

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2012 SPR Results

Entry	Pedigree	BLUE Yield (t/ha)	Yield Rank	AD (days)	% Grain Damage	Dust Weight g	Weight loss %	% Grain Damage	Dust Weight g	Weight Loss %
					Larger Grain Borer			Maize weevil		
1	CKPH12001	5.3	1	69.8	16.5	39.2	11.7	53.6	3.3	18.5
15	CKPH12017	5.2	2	67.8	15.2	43.8	14.2	52.4	3.1	15.3
31	CKPH12034	5.2	2	70.8	16.8	41.8	16.6	57.1	3.4	17.3
28	CKPH12031	5.2	2	70.5	14.6	45.9	25.0	59.1	3.1	16.1
22	CKPH12024	5.2	2	68.1	18.4	35.2	19.6	43.7	2.0	1.5
14	CKPH12016	5.2	2	69.4	13.7	43.4	17.3	51.6	3.6	22.9
33	CKPH12036	5.2	2	67.1	16.7	39.5	22.9	54.4	3.7	18.7
37	CKPH12040	5.1	8	68.6	17.8	33.5	17.9	46.2	2.6	10.6
20	CKPH12022	5.1	8	65.8	18.9	41.6	14.4	55.9	4.1	23.7
4	CKPH12004	5.1	8	69.0	17.6	37.5	20.8	53.4	3.0	20.1
46	WH505	4.8	15	71.0	16.7	40.2	17.4	58.0	3.7	23.3
47	H513	4.7	24	68.0	13.2	47.8	17.5	54.9	4.6	18.1
49	Local check 1	4.5	36	68.6	17.2	42.2	23.2	61.1	5.8	21.6
50	Local check 2	4.4	41	68.8	18.1	39.6	10.0	47.9	4.2	14.3
48	Pioneer 3253	4.3	45	67.2	10.5	51.7	6.8	60.4	6.1	16.1
	nlocs	28		32	4	4	3	4	4	3
	Grand_Mean	4.7		68.2	16.8	39.9	16.4	51.6	3.1	16.5
	LSD	0.40		1.23	5.0	6.3	11.7	1.4	8.1	12.4
	CV	4		1						
	Heritability	0.80		0.90	0.3	0.7	0.3	0.7	0.7	0.1

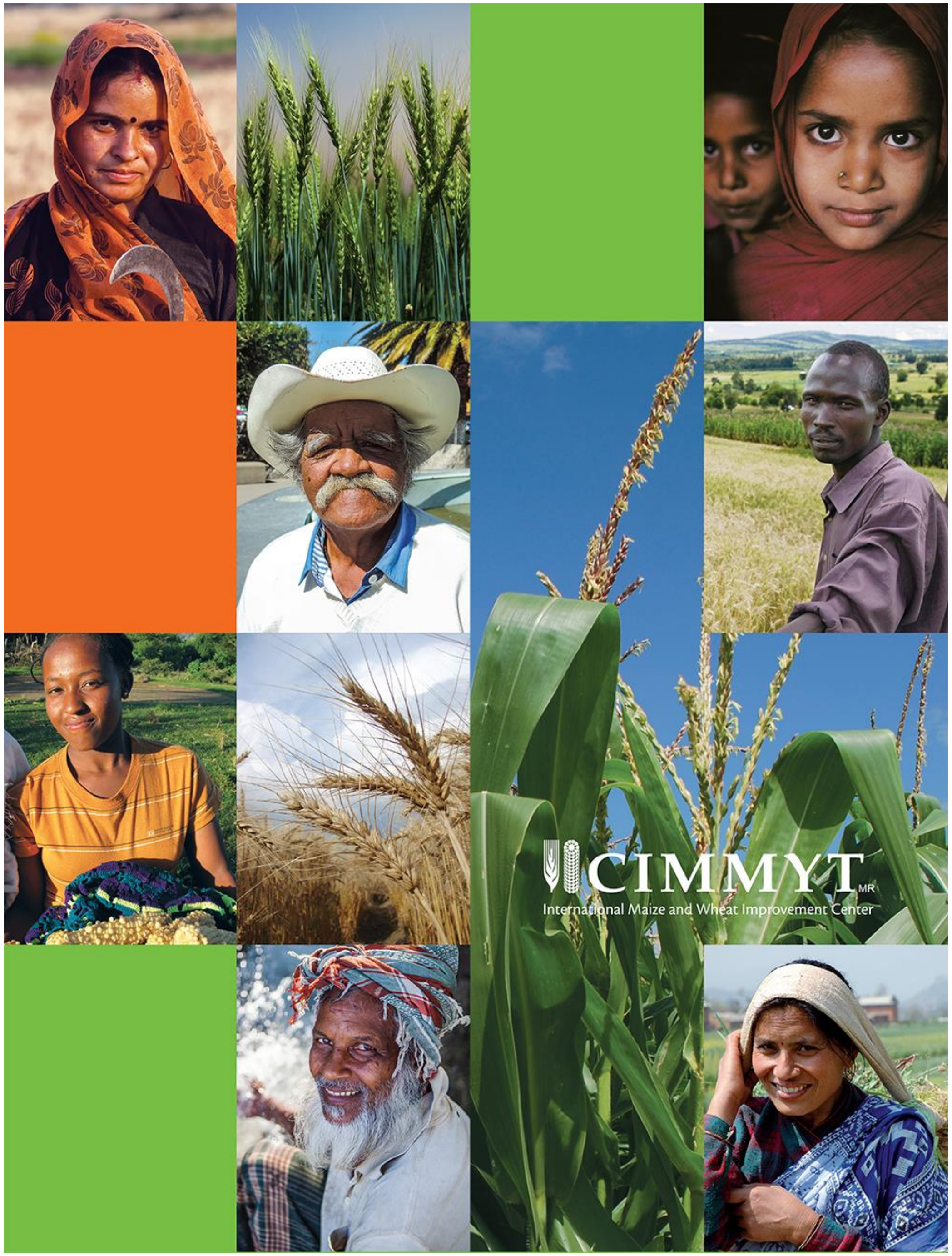
Why you need to work with an entomologist

- Development and evaluation of infestation techniques.
- Mass rearing of stem borers and culture of postharvest pests.
- Formation of insect pests resistant synthetics for use as OPV's or sources of resistance for line recycling activities
- Obtain information on the genetics of inheritance for resistance in elite germplasm

Entomology activities are only a component of the overall germplasm improvement process, and by itself is not an effective tool for providing the products needed by farmers

Conclusions

1. CIMMYT and IITA have used these methods to develop a good number of inbred lines, open-pollinated varieties, hybrids, and source populations with resistance to stem borers and post harvest pests
2. This germplasm is available to NARs and seed companies for use:
   - Directly as variety per se
   - As sources of alleles to breed maize for resistance to the major stem borers and to maize weevil and LGB.
3. New populations of stem borer and post harvest resistant germplasm are being developed for major ecologies in ESA



Thank you for your interest!