Global Forum on Biological Control and Training Workshop on Biological Control

Nairobi, Kenya 26-30 June 2023

Invasion biology of Fall armyworm, impacts and sustainable management options in developing countries

Subramanian Sevgan on behalf of the FAW IPM team

Co-organized by

Food and Agriculture Organization of the United Nations

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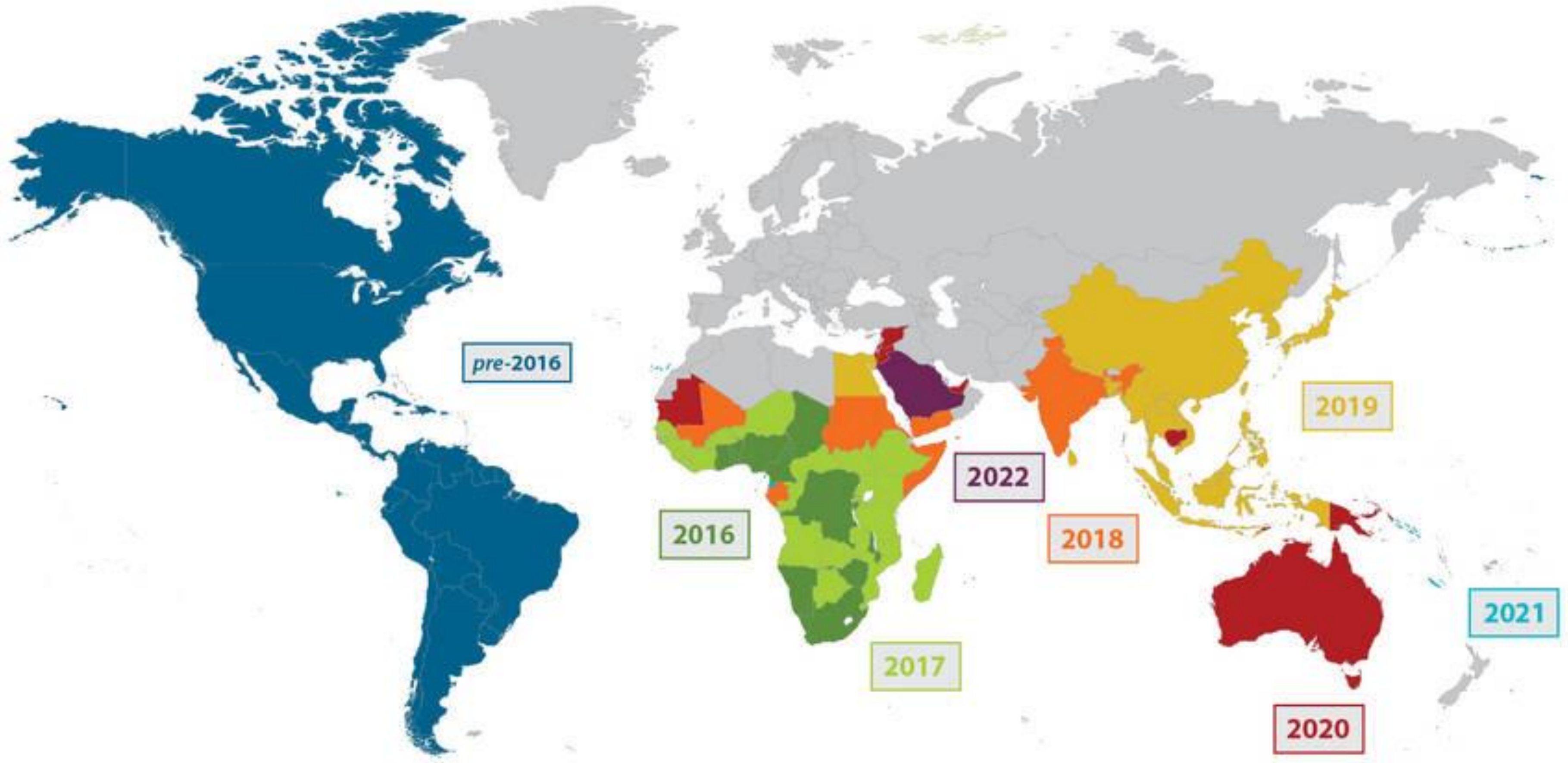
Global invasion of FAW



Source: FAO

Average yield loss to maize: 10.4 – 45%

Economic Impact : US$ 1,088 and US$ 4,661 (CABI, 2018)

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Host range and economic importance

- **Host Range,** over 100 plant spp.
- Montezano et al. (2018) – 353 host plants
- **Cereals:** maize, sorghum, wheat
- **Fodder grasses**: Napier grass
- **Vegetables:** Kales, Cabbages, pulses


FAW is a threat to:

- Food security
- Maize seed sector
- Export trade
- Livestock feed industry

Fall Armyworm

Adult
- Sexual dimorphism
- 7 to 21 days
- Up to 3 weeks oviposition period
- Prefers undamaged plants
- Ability to migrate

Egg
- 100–200 eggs/ mass
- ≈ 1500 eggs/female
- gray scales above
- 2 – 3 days egg period

Total life cycle
31 – 81 days

Larva
- Six instars
- 14 – 30 days
- Conceals during the day
- Economically damaging stage
- Resistant to pesticides

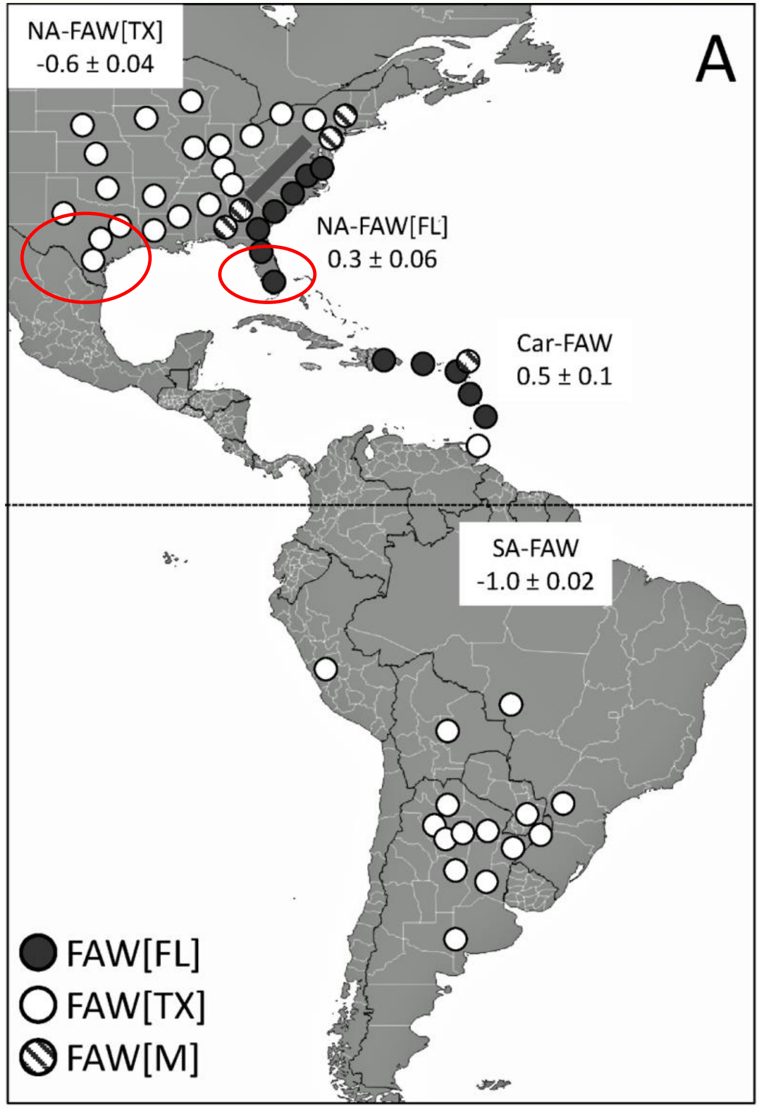
Pupa
- Soil pupation, rarely in dry leaf cocoon
- 2 to 8 cm depth
- 8 – 30 days duration
- Susceptible to cold

Strains/haplotypes of Fall Armyworm

Features	Corn Strain (C)	Rice Strain (R)
Host preference	Maize, Cotton and Sorghum	Rice, Bermuda grass and turfgrass
Morphology	Similar	
Molecular	Variations at the mitochondrial cytochrome oxidase I gene	
Pesticide efficacy	More susceptible to Carbofuran	More susceptible to Carbaryl and Diazinon
Multiplication rate	Greater compared to R strain	Lesser compared to C strain
Mating compatibility	C-Female x R-Male	R-Female x C-Male
Pheromone	More responsive	Less responsive
Situation in Africa	Both strains widely distributed	

Nagoshi et al., 2007, 2018; Hardke et al., 2015; Srinivasan et al., 2018

Migratory pattern in the Neotropics



- ❑ Overwintering populations in Texas and Florida
- ❑ Annual migration northwards
- ❑ Texas population widespread in South America
- ❑ Migratory behavior in South America not widely studied, expected to be endemic
- ❑ Adults can migrate over 2000km
- ❑ Migration facilitated by wind

- ❑ Similarly can FAW migrate from North Africa to Europe

Nagoshi et al., 2017

Potential pathways for spread of FAW

High as eggs on commodities exported

Very low to medium

Very low

High as migrating moths

FAW interception in EU

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Year	Country	Commodity
2017	-	Two consignments
2018	Kenya	Rosa, Eryngium, Coriandrum
	Senegal	Maize, *Solanum aethiopicum*
	Togo	*Solanum aethiopicum*
	Mali	*Solanum aethiopicum*
	Zimbabwe	Rosa, *Pisum* sp
	Tanzania	*Eustoma grandiflorum*
	Uganda	*Capsicum*
2019	Senegal	Maize
	Zimbabwe	Solidago, Eryngium
	Mozambique	Capsicum

- In August 1999, *Spodoptera frugiperda* (EPPO A1 quarantine pest) was found in Baden-Württemberg on sweet maize plants grown in a nursery (3 ha).

- Regularly intercepted from consignments from Peru (Asparagus), Suriname (Capsicum, Solanum sp) and Mexico (*Rubus ulmifolius, Momordica* sp), Gautemela (*Imperata cylindrica)*

Yield loss due to FAW

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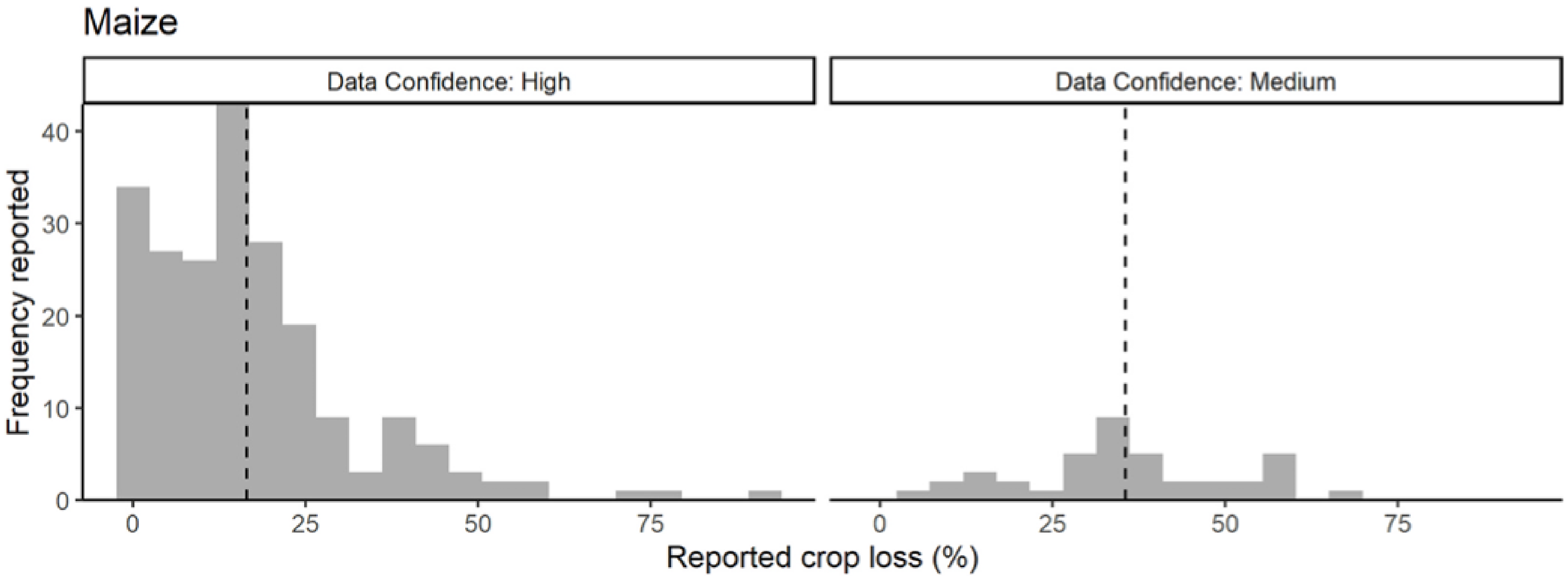
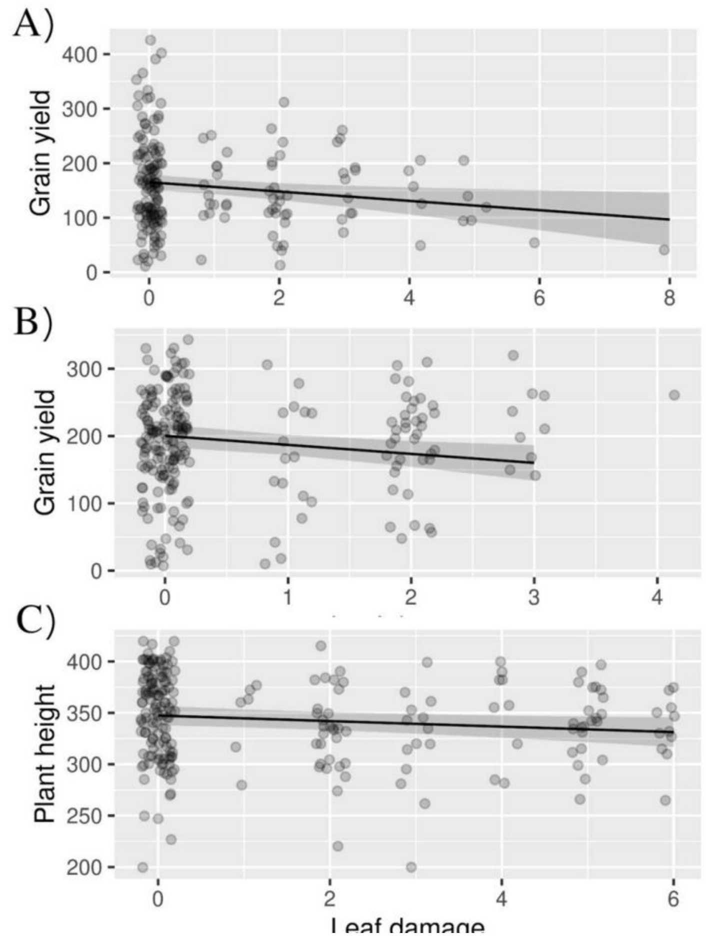


Fig. 4. The frequency (number of entries) of cases reporting of crop losses in maize due to fall armyworm infestations derived through high confidence methodologies (i.e. experimentally derived yield losses), and medium confidence methodologies (i.e. reported estimates of yield losses by farmers conducted through surveys).

Source: Overton et al., 2021

Yield loss in relation to leaf damage



3 WAE – Early maturing variety

5 WAE – medium maturing variety

7 WAE – Late maturing variety

PLOS ONE

RESEARCH ARTICLE

Understanding the impact of fall armyworm (*Spodoptera frugiperda* J. E. Smith) leaf damage on maize yields

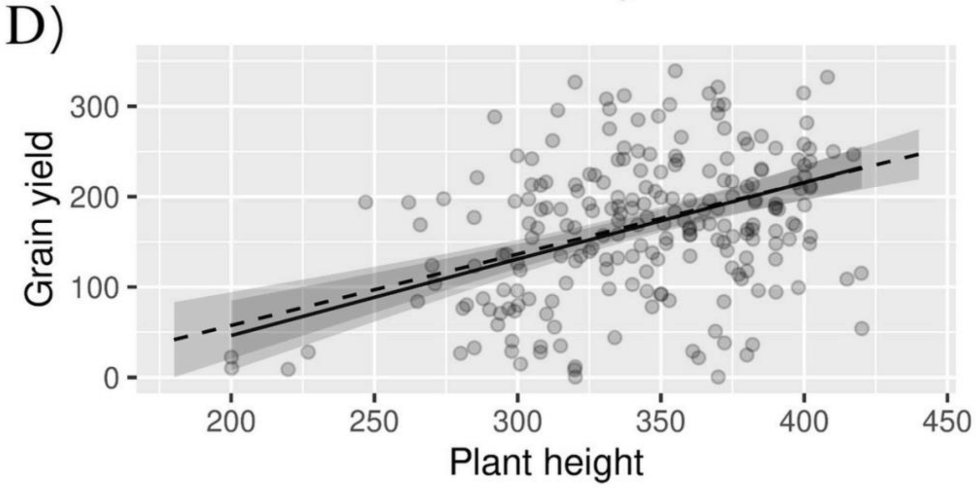
Chipo Chisonga[1,2], Gilson Chipabika[2], Philemon H. Sohati[2], Rhett D. Harrison[1]*

1 CIFOR-ICRAF, Zambia Office, St Eugene Office Park, Lusaka, Zambia, 2 Department of Plant Science, School of Agriculture Sciences, University of Zambia, Lusaka, Zambia

* r.harrison@cifor-icraf.org

Check for updates

Abstract



Correlation between plant height and maize yield

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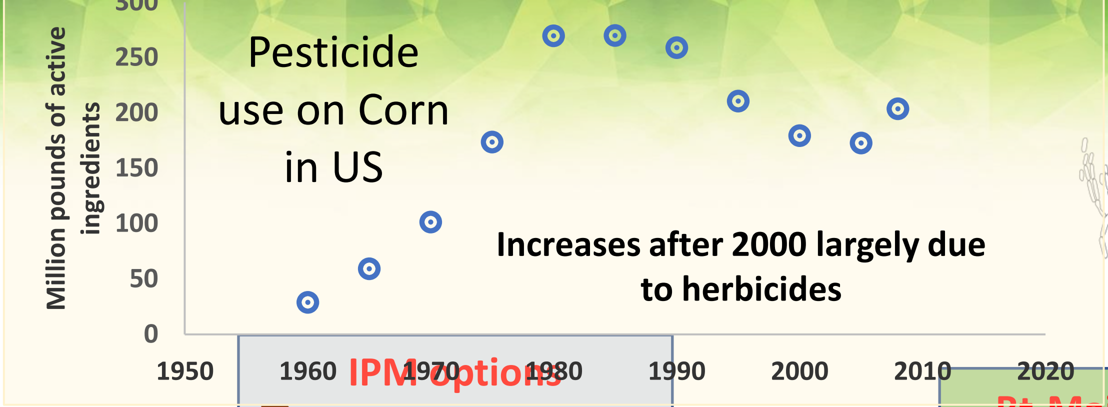
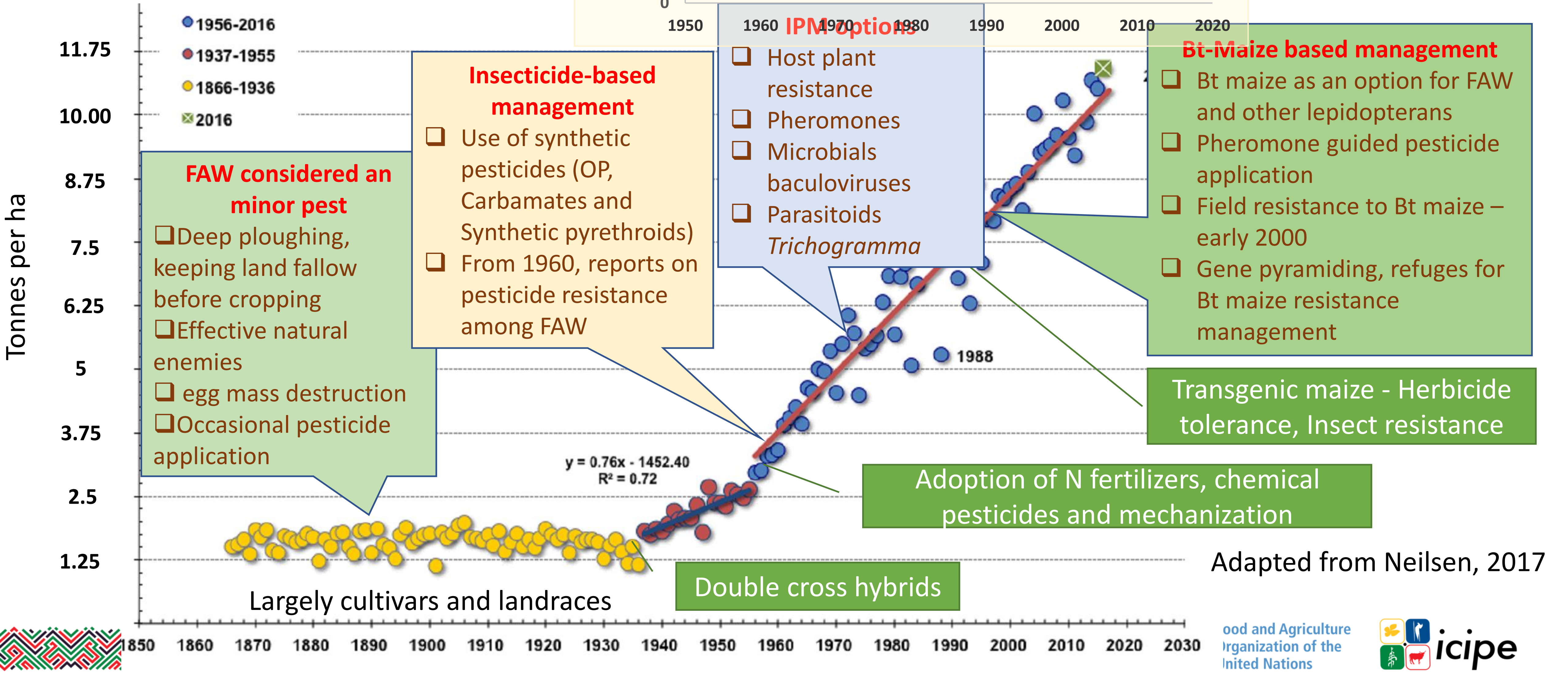
History of maize pest management in US





Adapted from Neilsen, 2017

Some critical factors to consider in development of FAW management in Africa

Factors	Africa	North and South America	Relevance for FAW management in Africa
Cropping system	Smallholder production	Large-scale	- Diversified maize production can offer resilience
Crop productivity	Nearly 2.0 t/ha	10.5 t/ha	- Nature-based and low cost management is critical
FAW prevalence	Year-round	Migratory-seasonal/ year-round	- Year round survival of natural enemies
Pesticide use statistics	0 – 0.25 kg per ha	2.5 – 5 kg per ha	- Low pesticide use, offers potential for effective conservation of natural enemies

Sustainable Fall armyworm IPM strategy for Africa

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FAW-IPM Africa-specific, science-led, sustainable and integrated management of the fall armyworm

KALRO LZARDI RAB Ethiopian Institute of Agricultural Research NARO

german cooperation DEUTSCHE ZUSAMMENARBEIT

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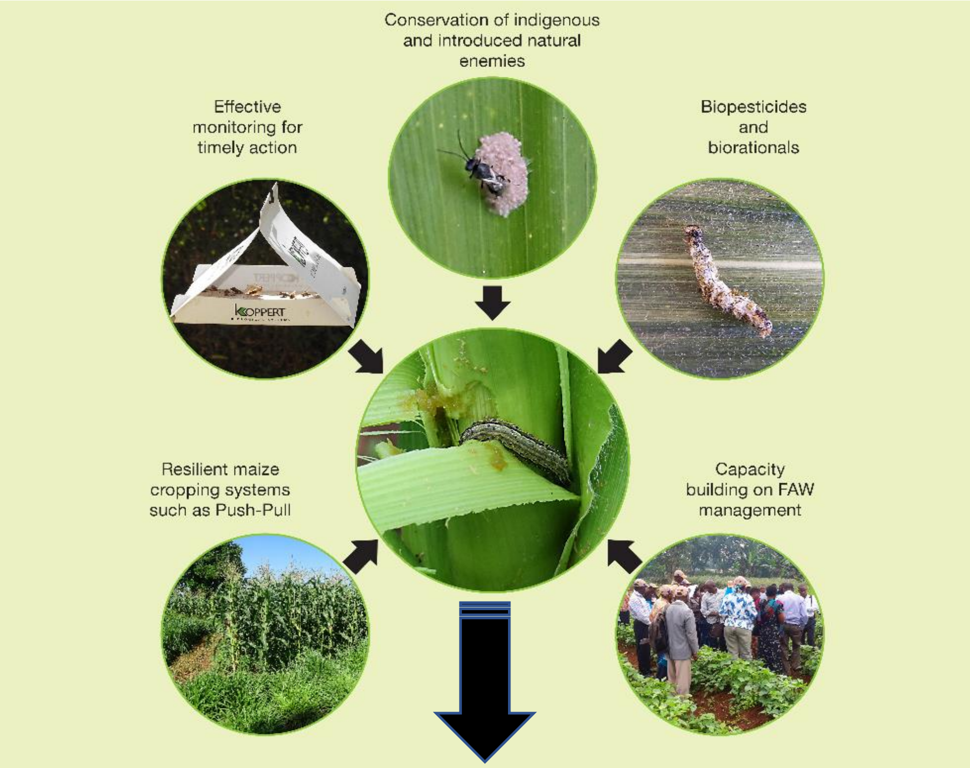
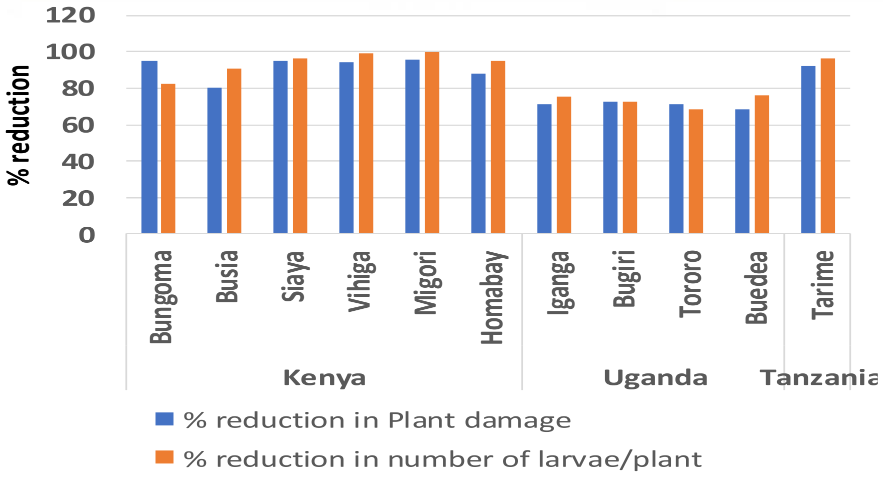
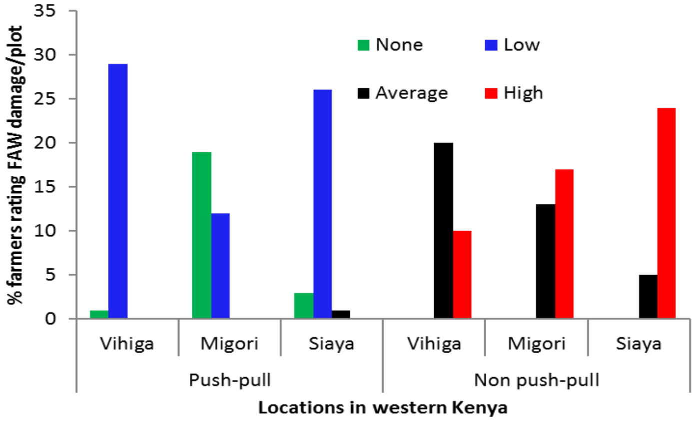


- Enhanced productivity and food security ensured
- Safer environments and products
- Better livelihoods

Push-pull controls FAW

Conventional Push-pull






Crop Protection 105 (2018) 10-15

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

A climate-adapted push-pull system effectively controls fall armyworm, *Spodoptera frugiperda* (J E Smith), in maize in East Africa

Charles A.O. Midega[a,*], Jimmy O. Pittchar[a], John A. Pickett[b], Girma W. Hailu[a], Zeyaur R. Khan[a]

[a] International Centre of Insect Physiology and Ecology (icipe), Nairobi, Kenya

[b] Department of Biological Chemistry and Crop Protection, Rothamsted Research, Harpenden, UK

Push-pull farm

Monocrop maize

Midega et al., 2018. Crop Protection 105, 10-15

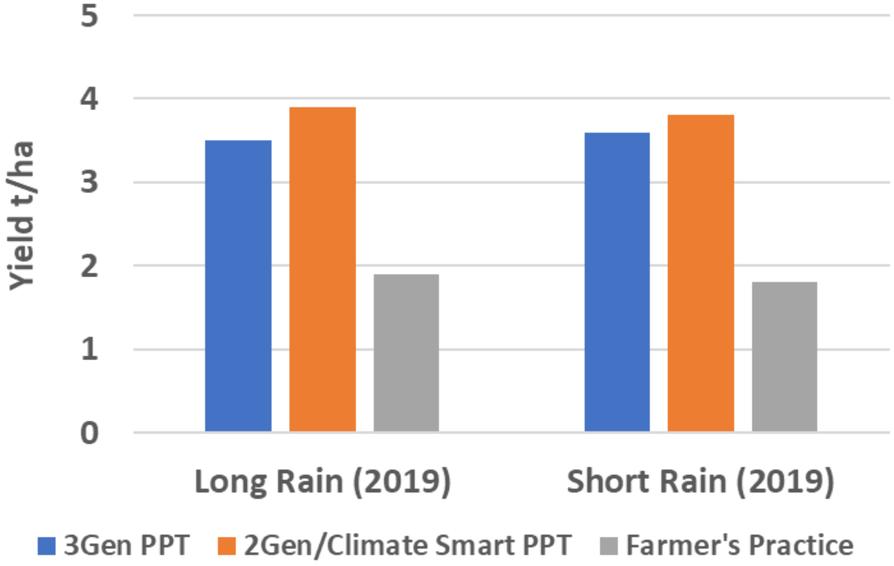
Development of a third generation PPT

A: *Desmodium incanum*
- Excellent seed yield
- Tolerant to drought
- Effectively controls *Striga*

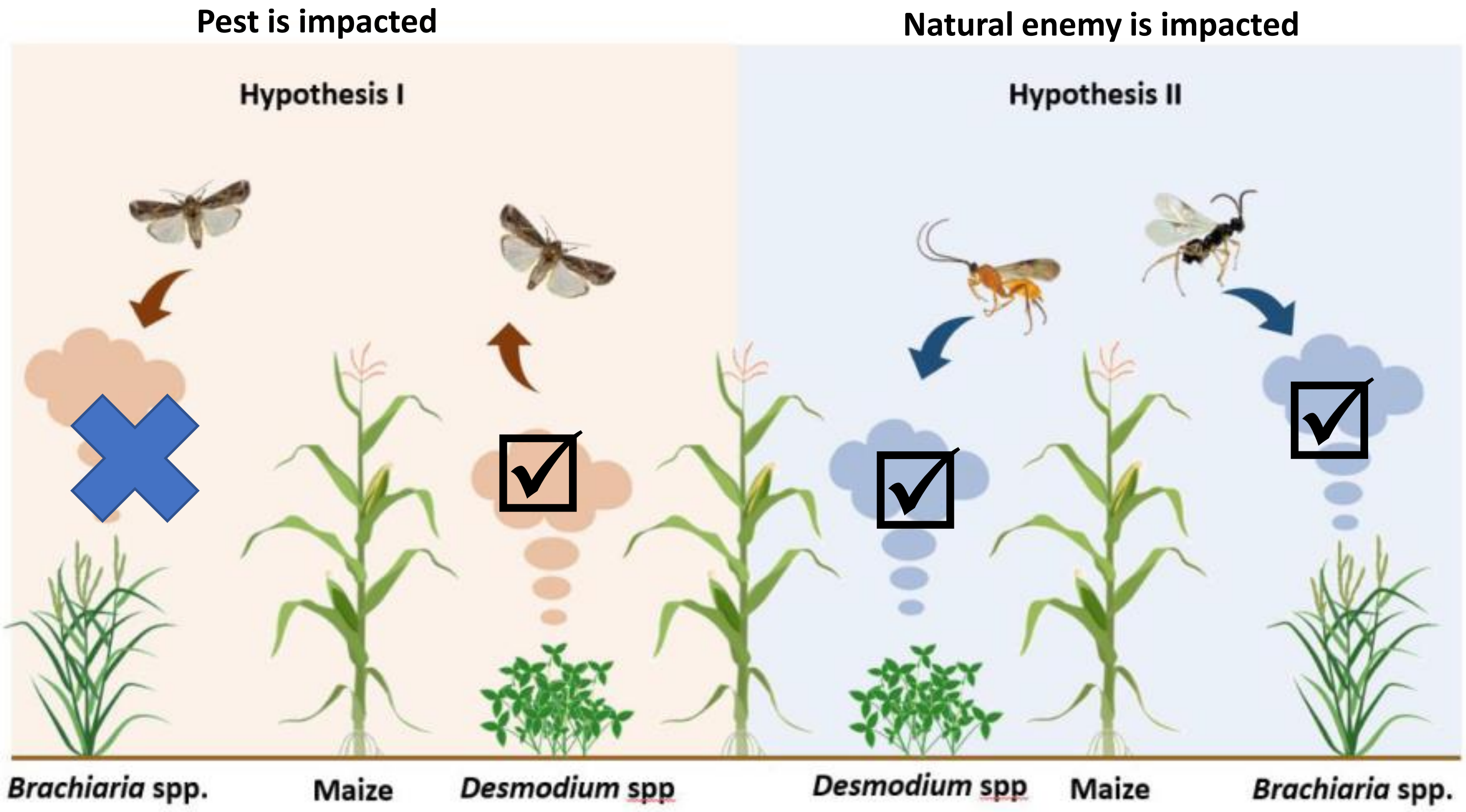
B: *D. intortum* (greenleaf)
- Used in Climate smart PPT
- Do not produce seeds in some regions

C. *Brachiaria brizantha* cv. Xaraes
- Drought tolerant
- Resistant (moderately) to spider mites
- High biomass yield
- Supports oviposition by stemborers

D. *B. brizantha* cv. Mulato II
- Drought tolerant
- Highly susceptible to Spider mites
- Supports oviposition by stemborers



Push-pull technology: mechanism for control of fall armyworm



BR – Brachiaria
GL – Green leaf desmodium
SL - Silver leaf desmodium

Islam S. Sobhy et al. 2022 Frontiers in Ecology and Evolution

Larval dispersal - Balooning

Photo Credit: Diedrich **Visser**, Agricultural Research Council - Vegetable and Ornamental Plants (**ARC-VOP**), Roodeplaat, Pretoria.

Sokame et al., 2020, Entomologia Experimentalis et Applicata, *168*(4), 322-331

FAW interaction with other stemborers

Larval migratory behaviour

Entomologia Experimentalis et Applicata

FOUNDED 1958

Spatial spread of larvae of the invasive Fall Armyworm, Spodoptera frugiperda (Lepidoptera: Noctuidae) and the African lepidopteran cereal stemborers

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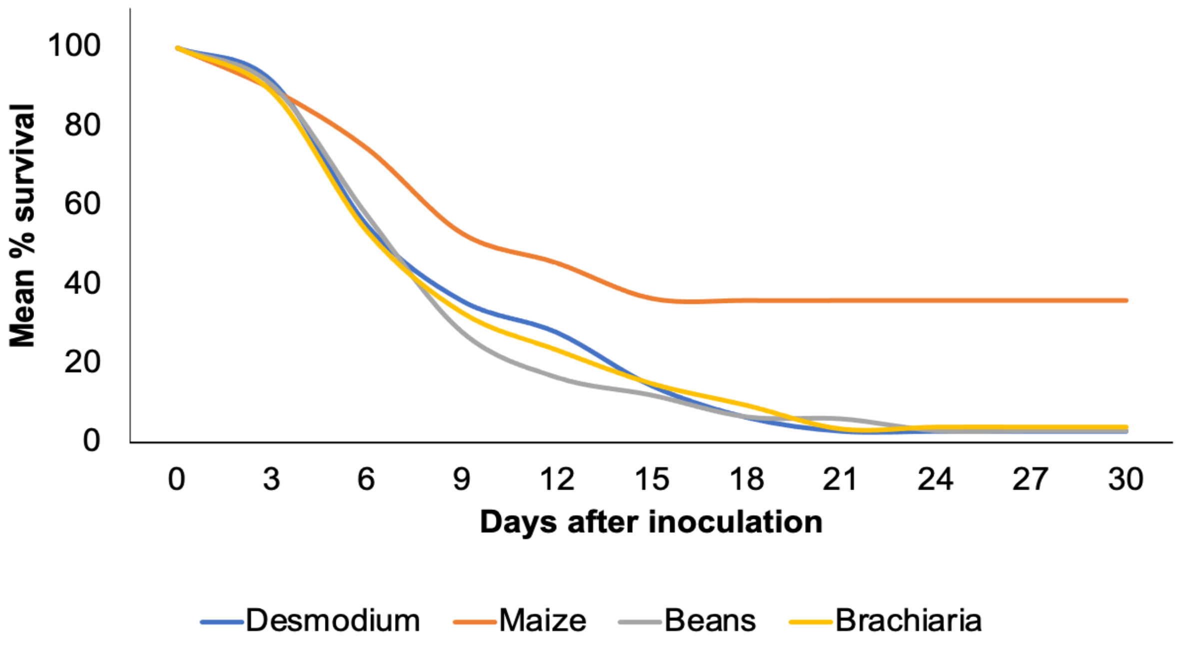
FAW survival on maize and some of the intercrops



Research Article SCI

Received: 18 September 2020 Revised: 13 December 2020 Accepted article published: 9 January 2021 Published online in Wiley Online Library:

(wileyonlinelibrary.com) DOI 10.1002/ps.6261

The role of *Desmodium intortum*, *Brachiaria* sp. and *Phaseolus vulgaris* in the management of fall armyworm *Spodoptera frugiperda* (J. E. Smith) in maize cropping systems in Africa

Laetitia Scheidegger,[a] Saliou Niassy,[b*] Charles Midega,[b] Xavier Chiriboga,[b] Nicolas Delabays,[a] François Lefort,[a] Roger Zürcher,[a] Girma Hailu,[b] Zeyaur Khan[b] and Sevgan Subramanian[b]

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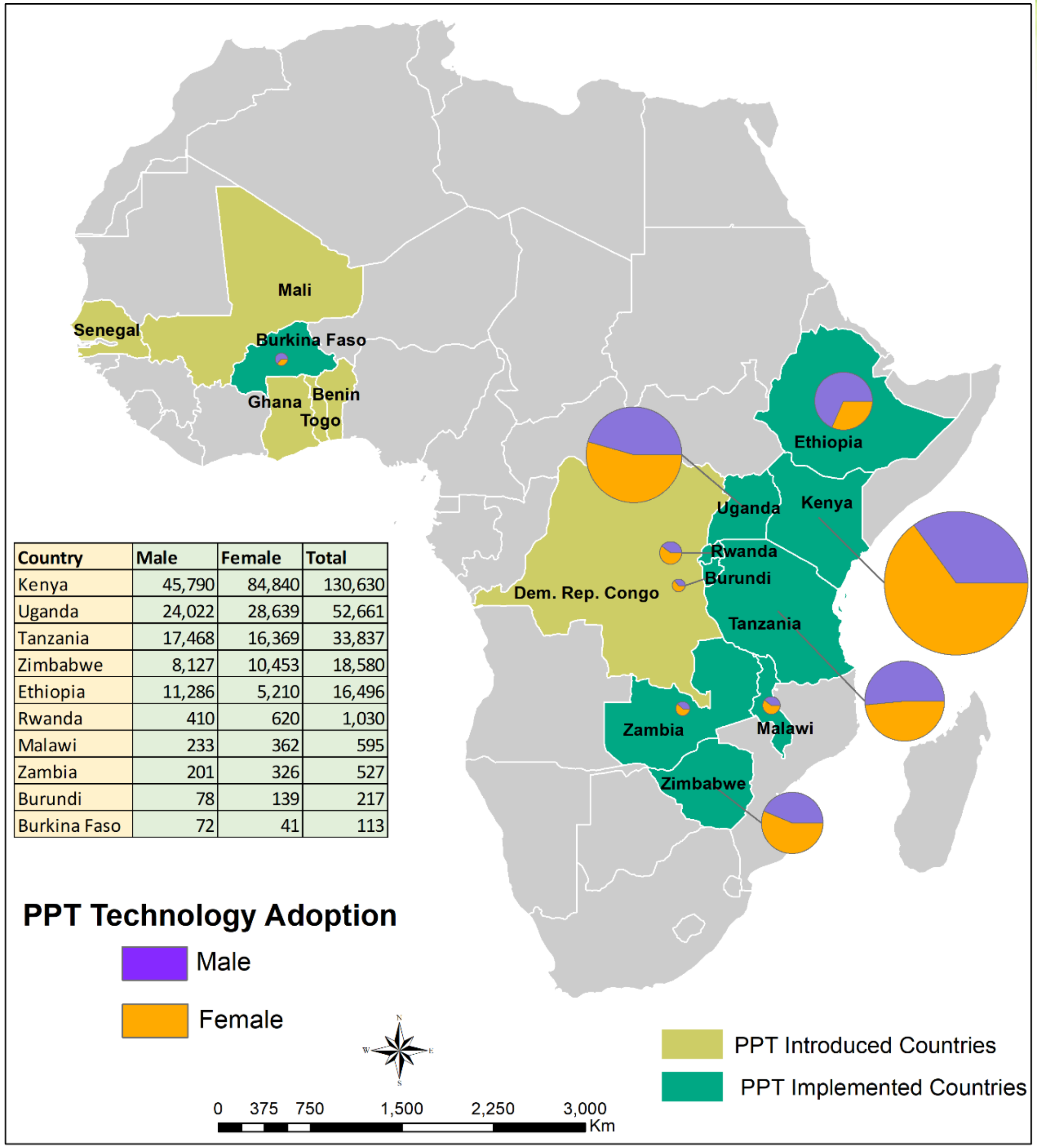
Scaling Push-Pull technology for Fall armyworm management

Global Forum on Biological Control and Training Workshop on Biological Control



Country	Male	Female	Total
Kenya	45,790	84,840	130,630
Uganda	24,022	28,639	52,661
Tanzania	17,468	16,369	33,837
Zimbabwe	8,127	10,453	18,580
Ethiopia	11,286	5,210	16,496
Rwanda	410	620	1,030
Malawi	233	362	595
Zambia	201	326	527
Burundi	78	139	217
Burkina Faso	72	41	113

Scaling efforts

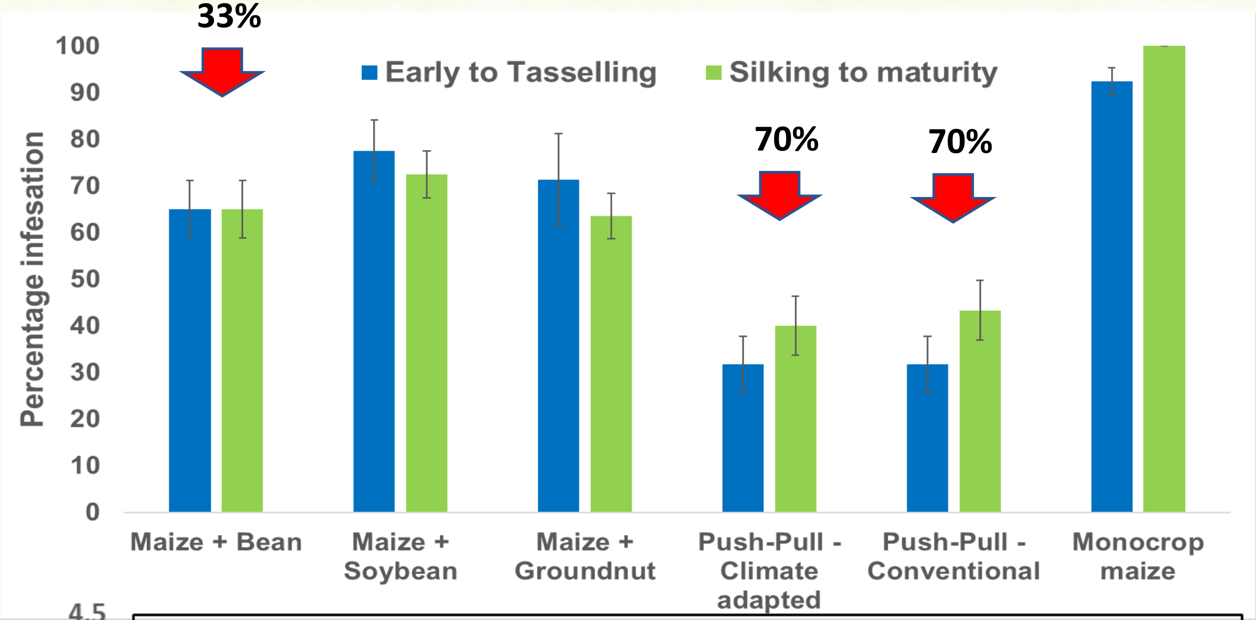
- ❖Adoption: ~254,971 farmers
- ❖Reach: 1,225,582 beneficiaries
- ❖Partners: > 20
- ❖Seed producers: <5
- ❖Successful collaborations with NARS

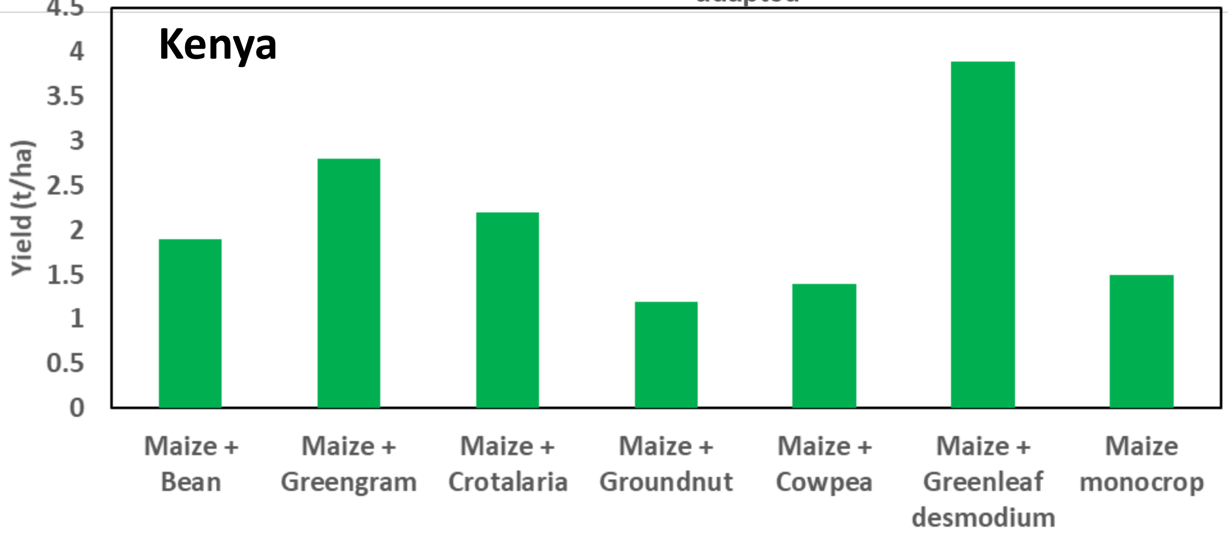
Needs for further scaling

- ❖Promotion of local production of companion crop seeds and distribution system
- ❖Enhance awareness on the benefits of Push-Pull and intercropping
- ❖Integration of Push-Pull and intercropping in national level agricultural development program and policy support

https://www.push-pull.net/

Impact of maize-legume intercropping on FAW





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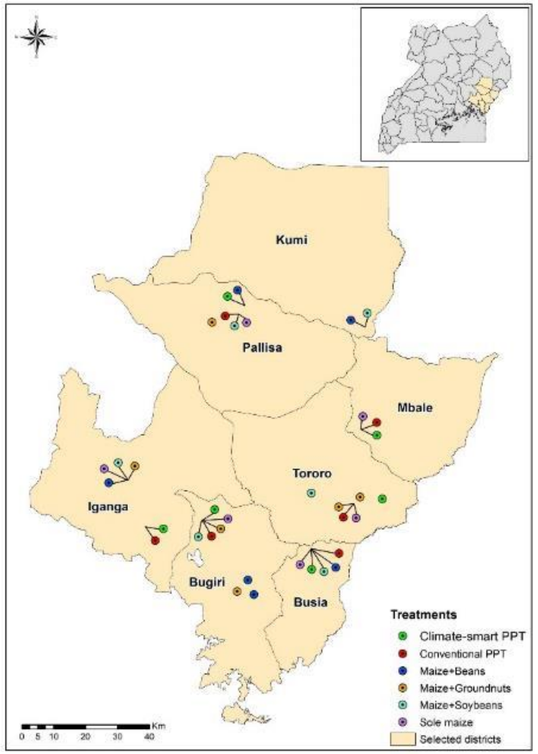

Published online September 27, 2018
PEST INTERACTIONS IN AGRONOMIC SYSTEMS

Maize–Legume Intercropping and Push–Pull for Management of Fall Armyworm, Stemborers, and Striga in Uganda

Girma Hailu,* Saliou Niassy, Khan R. Zeyaur, Nathan Ochatum, and Sevgan Subramanian

Food and Agriculture Organization of the United Nations

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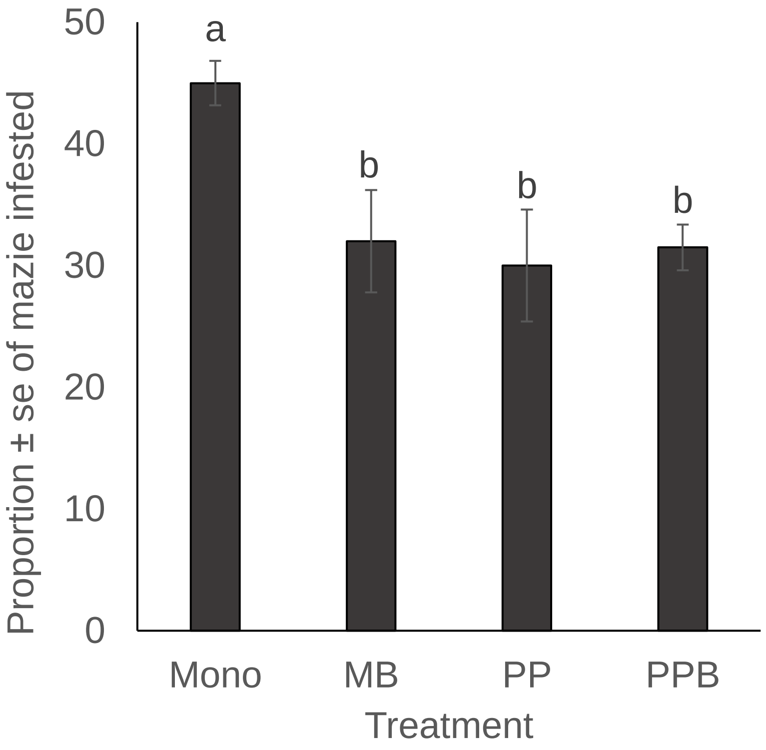
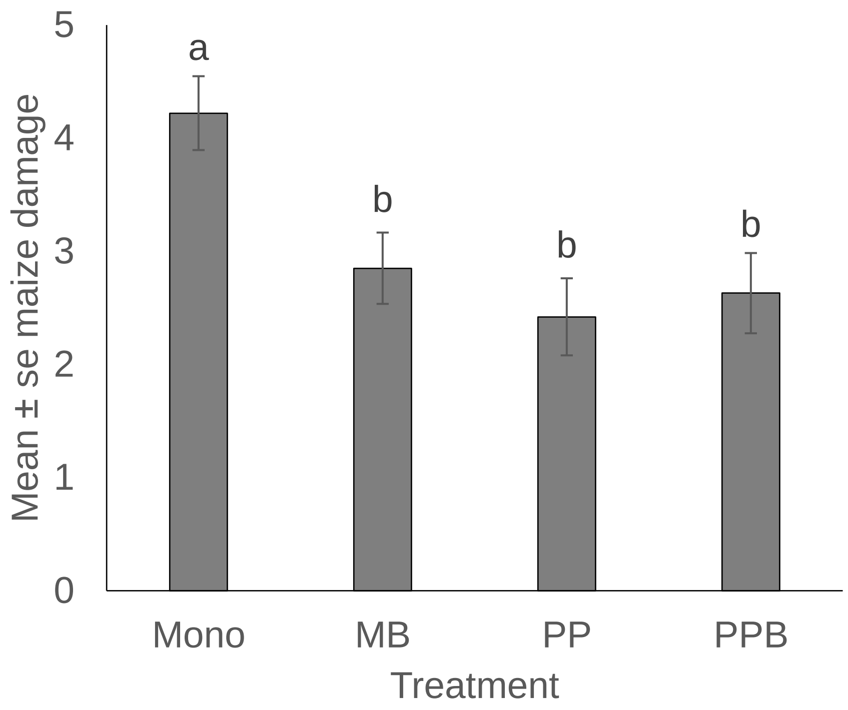
Integration of edible legumes (beans) into push-pull for FAW control in maize-based cropping systems

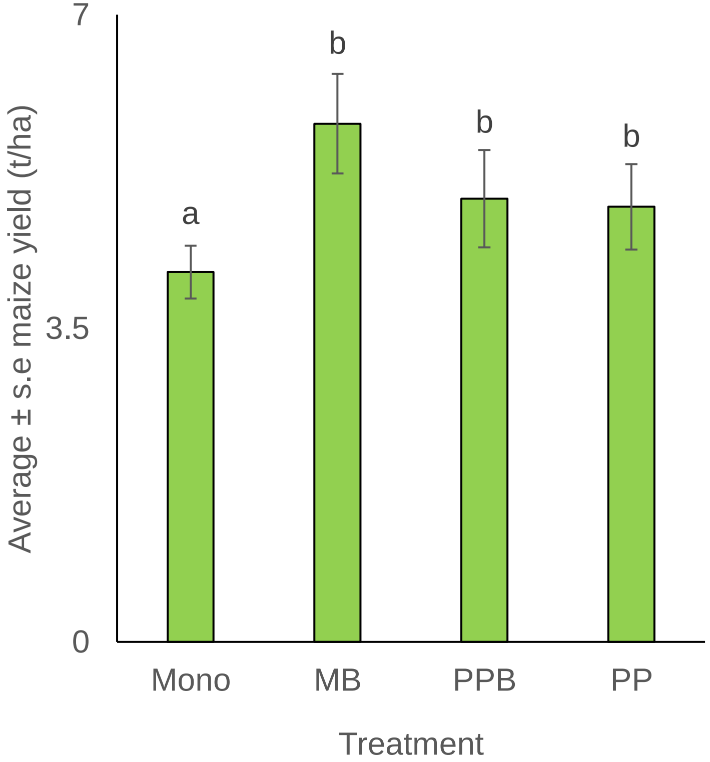
FAW infestation in short rain season 2022



FAW damage in short rain season 2022



Yield short rain season 2022

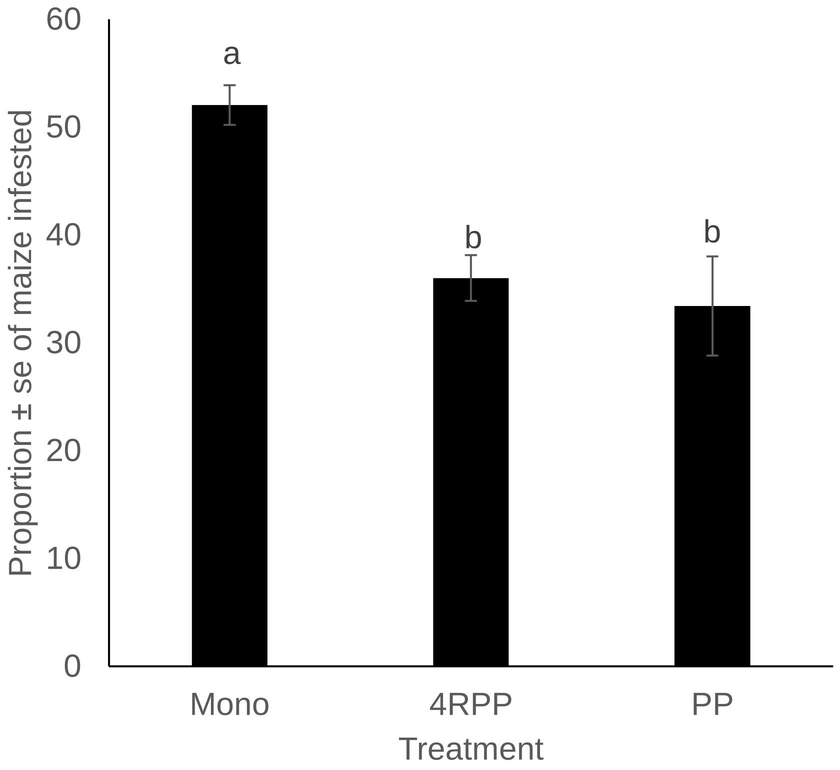


Mono – Monoculture
MB – Maize-Beans
PP – Push-pull
PPB – Push-pull - Beans

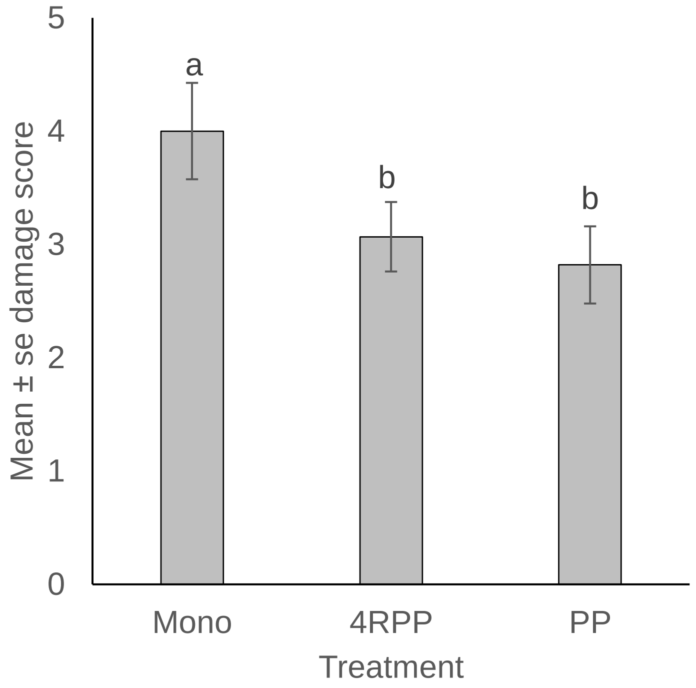
- Low FAW maize infestations and damage in MB, PP, and PPB observed
- Lower yields in Mono compared to MB, PP, and PPB

Spatial arrangement of push plant (Desmodium) for FAW control in maize-based cropping systems

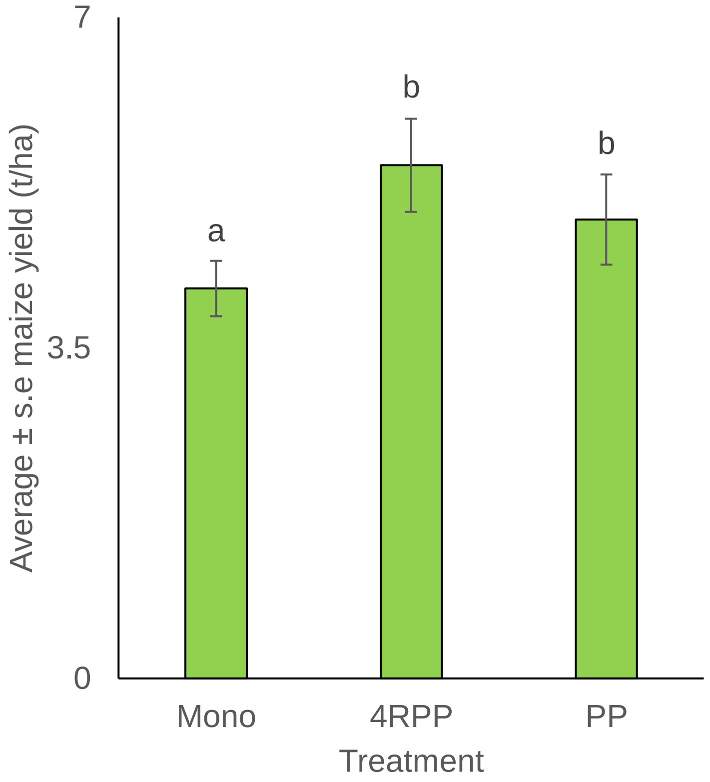
FAW infestation in long rain season 2021



FAW damage in short rain season 2022



Yield short rain season 2022



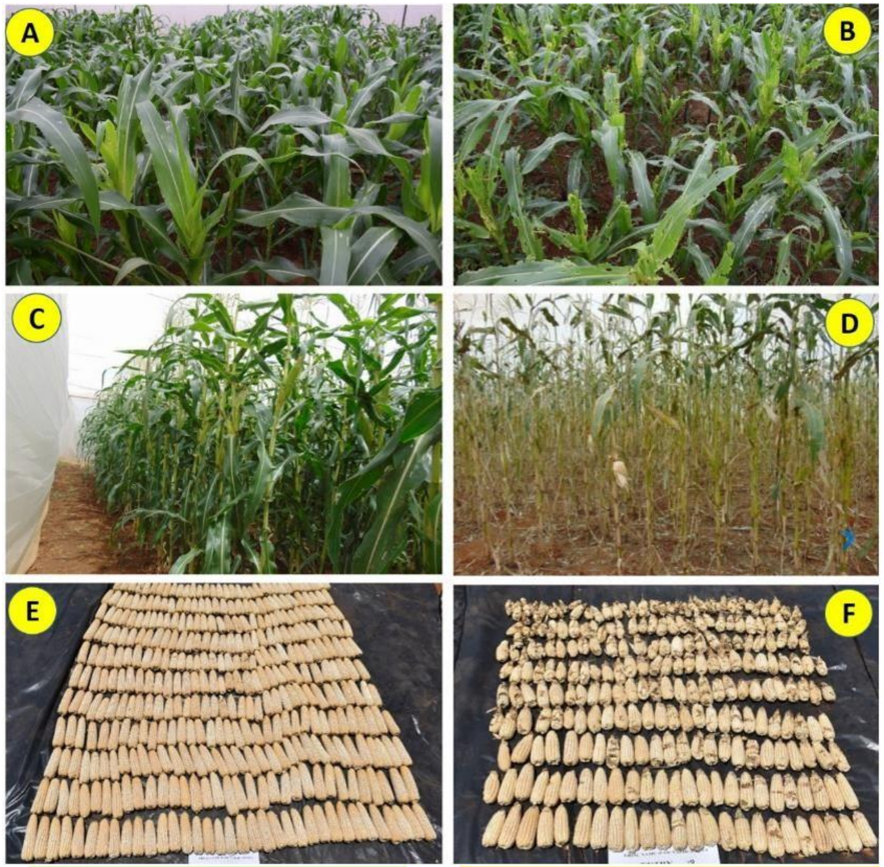
- Low maize infestations and damage in PP and 4RPP compared to Mono
- Higher yields in 4RPP and PP compared to Mono

Mono – Monoculture
4RPP – Desmodium after 4 rows of maize
PP – Push-pull

Native Genetic Resistance to FAW

FAW-tolerant Maize Hybrids from CIMMYT

- More than **6000** CIMMYT maize germplasm entries screened so far against FAW under artificial infestation at Kiboko, Kenya, during 2017-2020.
- CIMMYT Maize Lines (CMLs) with native genetic resistance to FAW disseminated to partners across Africa and Asia.



FAW-tolerant Hybrids

FAW-susceptible Checks

Three FAW-tolerant hybrids announced by CIMMYT for partners in Africa in Dec 2020; presently undergoing National Performance Trials (NPTs) in several countries.

Source: B.M. Prasanna (CIMMYT)

CGIAR

CIMMYT[MR]
International Maize and Wheat Improvement Center

Evidence-Based Decision Making through FAW Monitoring, Forecasting and Early Warning

Global Forum on Biological Control and Training Workshop on Biological Control

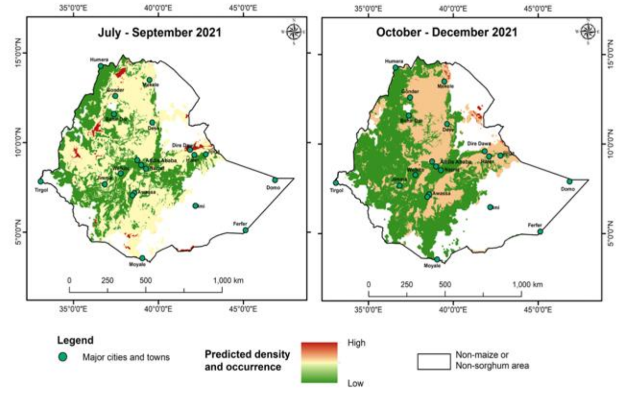
Informed decision
- Plan
- Prioritize
- Prepare

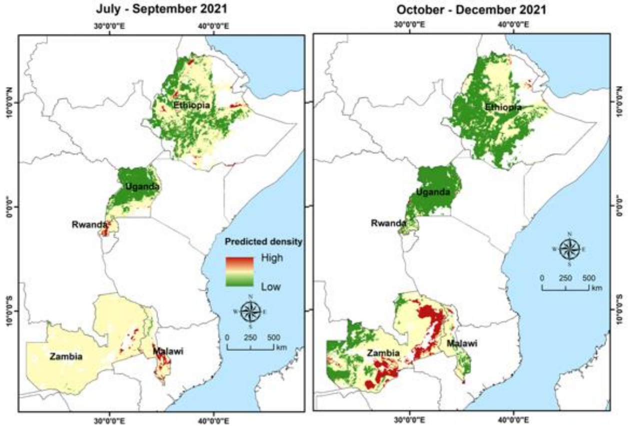
Pheromone Trapping

Effective Field Scouting

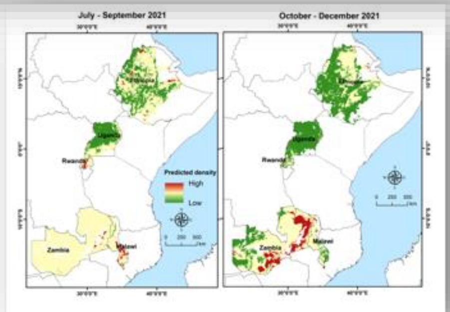
Adult and larvae scouting

GAP and cultural	Push-Pull	Legume intercropping	Biopesticides and Biorationals	Natural enemies



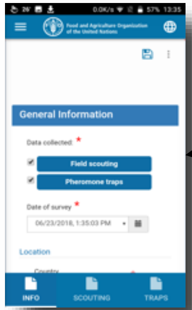


Informed stakeholders
- Citizens
- Farmers
- Extension
- Policy
- Researcher



Newsletter
Modelling and dissemination

Data Transmission using FAMEWS



Community–based Fall Armyworm Monitoring, Forecasting, Early Warning and Management System in Eastern Africa

Farmer field schools established in Chirundu and Chilanga districts and inputs for the schools were made available.

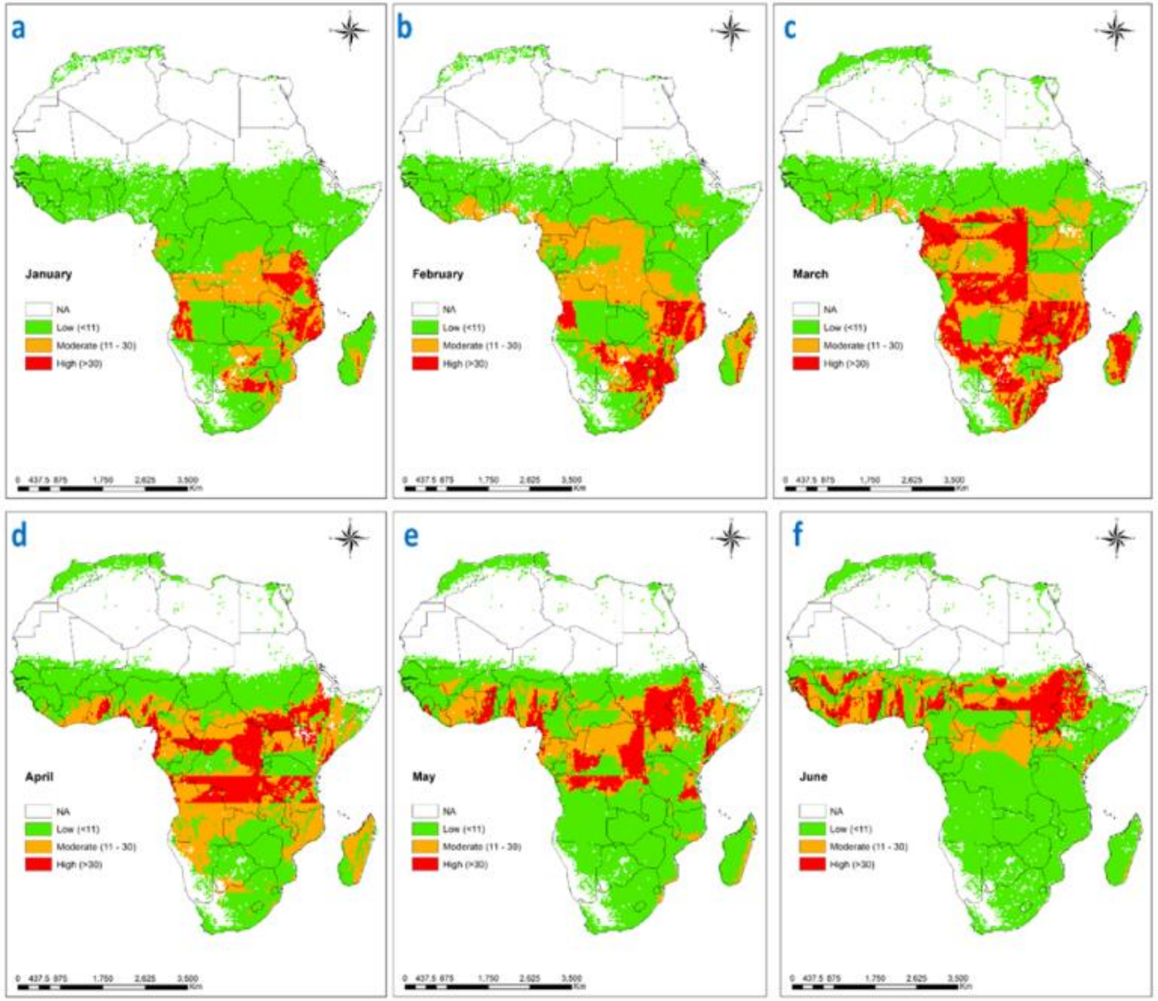
Harnessing data for fall armyworm infestation prediction in Africa

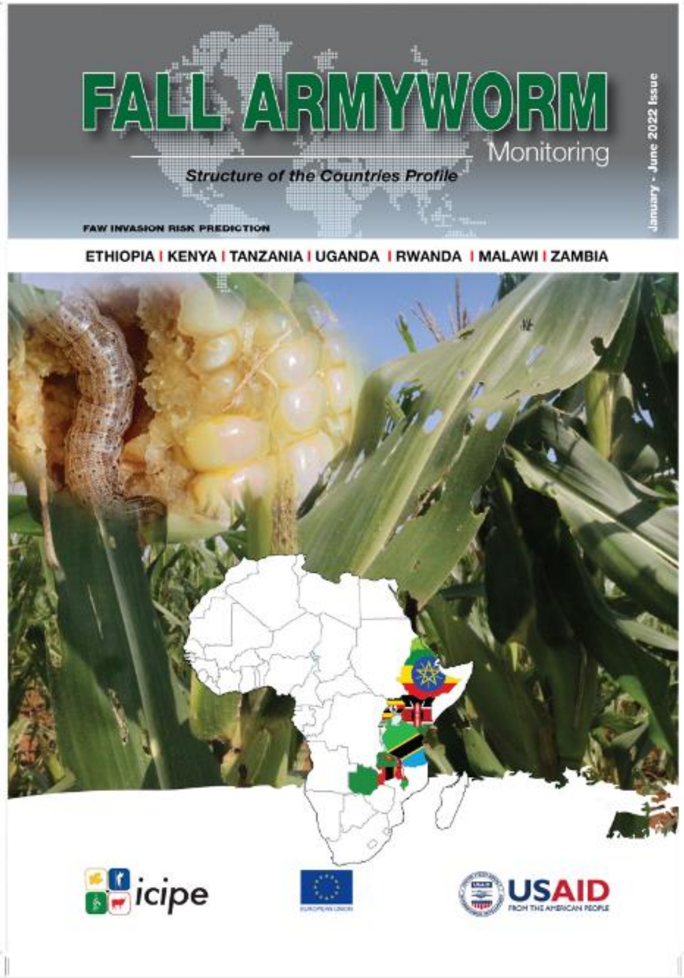
Variable
Fixed Effect
Wind speed
Solar Radiation
Mean monthly temperature
Rainfall
Elevation
Farm area
Cropping system
Crop stage
Main crop
Month of the year
Irrigation status

Contents lists available at ScienceDirect
Global Ecology and Conservation
journal homepage: www.elsevier.com/locate/gecco

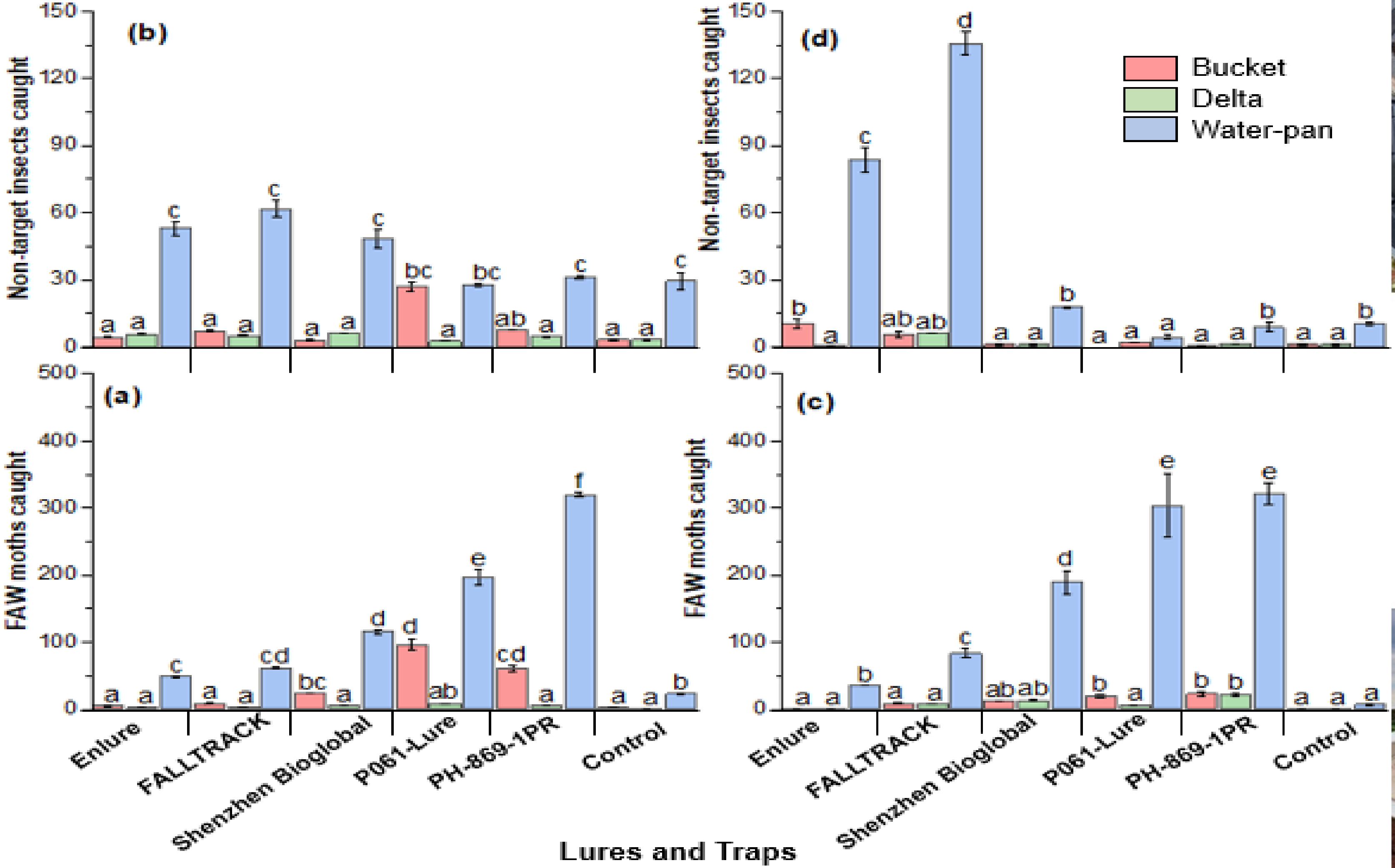
Harnessing data science to improve integrated management of invasive pest species across Africa: An application to Fall armyworm (*Spodoptera frugiperda*) (J.E. Smith) (Lepidoptera: Noctuidae)

Ritter A. Guimapi [a,b,1], Saliou Niassy [a,2], Bester Tawona Mudereri [a,c,3], Elfatih M. Abdel-Rahman [a,4], Ghislain T. Tepa-Yotto [d,e,5], Sevgan Subramanian [a,6], Samira A. Mohamed [a], Karl H. Thunes [a,b,7], Emily Kimathi [a,8], Komi Mensah Agboka [a,9], Manuele Tamò [d,10], Jean Claude Rwaburindi [f], Buyung Hadi [f], Maged Elkahky [f], May-Guri Sæthre [g], Yeneneh Belayneh [h], Sunday Ekesi [a], Segenet Kelemu [a], Henri E.Z. Tonnang [a,*,11]





Evaluation of pheromone lures & traps



New association of natural enemies of FAW in Africa

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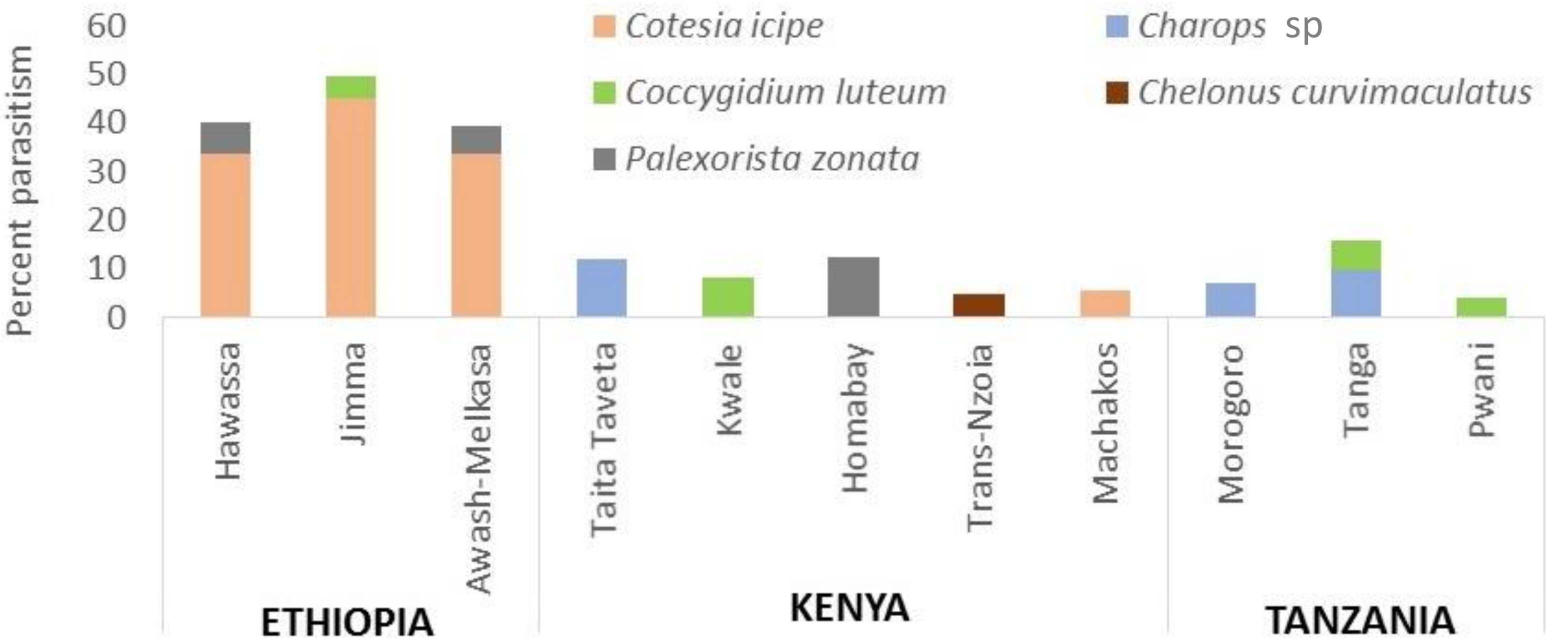

Received: 17 April 2018 | Accepted: 17 May 2018
DOI: 10.1111/jen.12534

SHORT COMMUNICATION

WILEY

First report of the fall armyworm, *Spodoptera frugiperd*
(Lepidoptera: Noctuidae), natural enemies from Africa

Birhanu Sisay[1,2,3] | Josephine Simiyu[4] | Peter Malusi[4] | Paddy Likhayo[4] |
Esayas Mendesil[1] | Nsami Elibariki[5] | Mulatu Wakgari[2] | Gashawbeza Ayalev
Tadele Tefera[1]

Cotesia icipe

Chelonus curvimaculatus

Charops sp

Palexorista zonata

Coccygidium luteum

Up to 45% parasitism of larvae in the field

Food and Agriculture Organization of the United Nations

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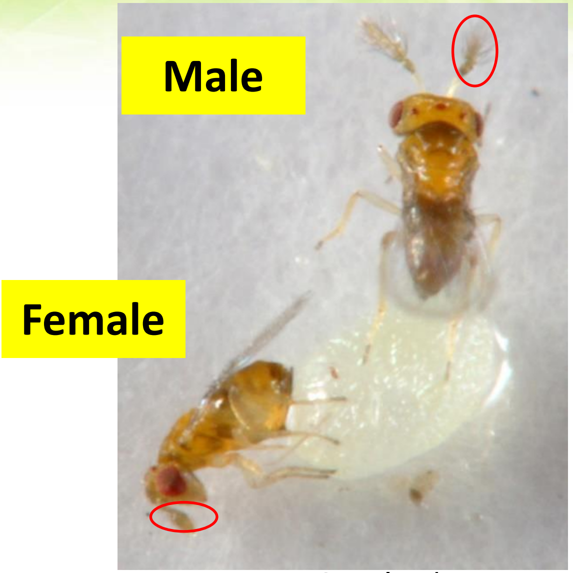
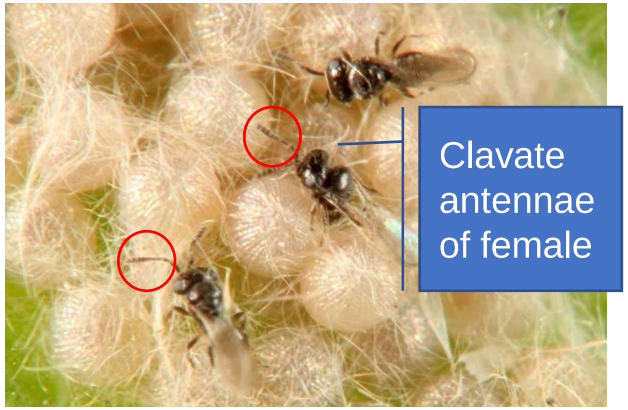
Potent egg parasitoids of FAW identified

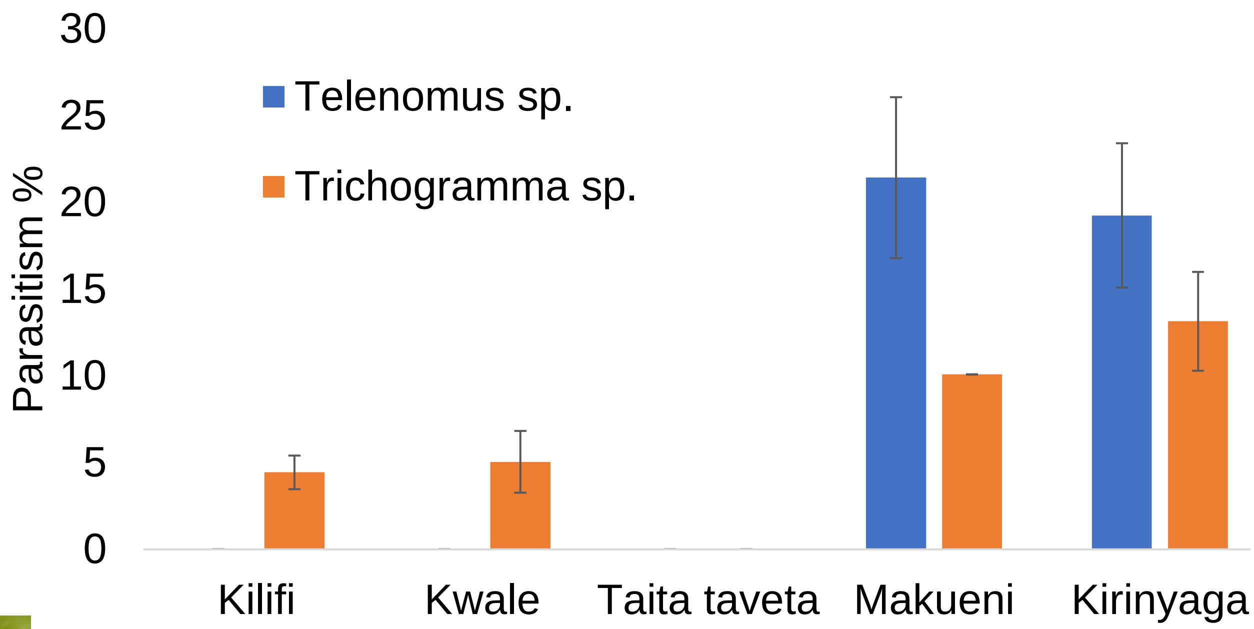


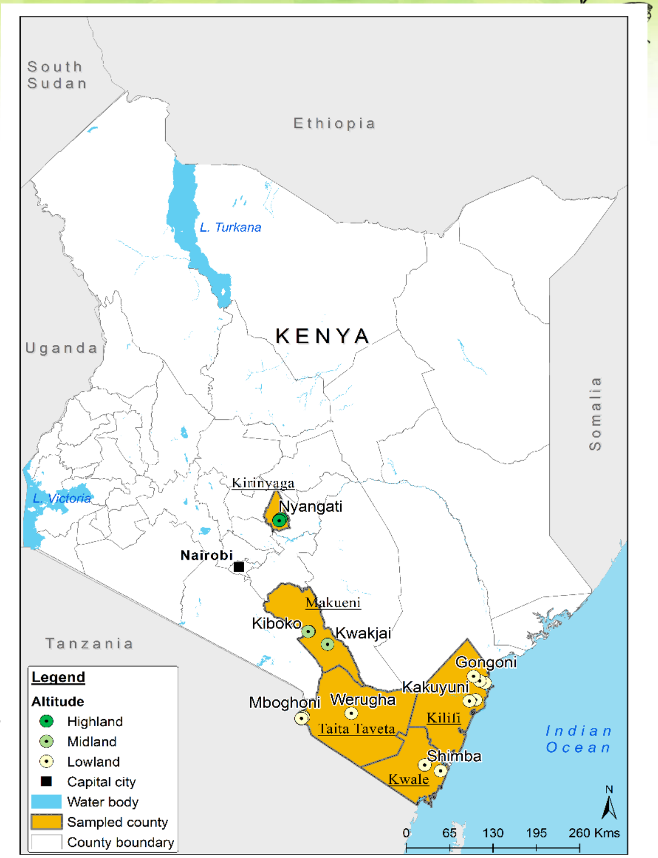
By Dr. Copeland;
(Biosystematics *Icipe*)

Trichogramma chilonis on factitious egg



Telenomus remus on FAW eggs





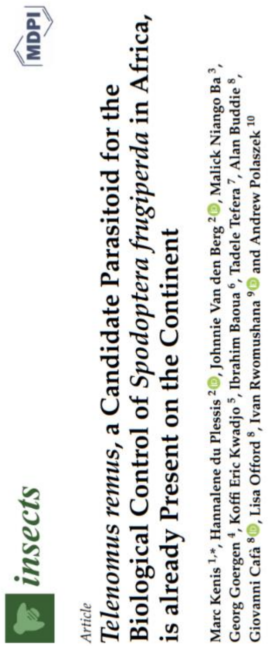
Distribution of *Telenomus remus*

South Africa, Cote d'Ivoire, Niger, Benin, Kenya, Uganda

Kenis et al., 2019; Otim et al., 2021

Potent natural enemies of FAW in Africa

Global Forum on Biological Control and Training Workshop on Biological Control


insects

MDPI

Article

Telenomus remus, a Candidate Parasitoid for the Biological Control of *Spodoptera frugiperda* in Africa, is already Present on the Continent

Marc Kenis [1,*], Hannalene du Plessis [2], Johnnie Van den Berg [2], Malick Niango Ba [3], Georg Goergen [4], Koffi Eric Kwadjo [5], Ibrahim Baoua [6], Tadele Tefera [7], Alan Buddie [8], Giovanni Cafà [8], Lisa Offord [8], Ivan Rwomushana [9] and Andrew Polaszek [10]

Telenomus remus

Chelonus curvimaculatus

Trichogramma sp.

Charops sp

Coccygidium luteum

Cotesia icipe

Palexorista zonata

Up to 30% parasitism of eggs in the field

Up to 45% parasitism of larvae in the field

Food and Agriculture Organization of the United Nations

icipe

Mass releases of FAW parasitoids in the field and establishment

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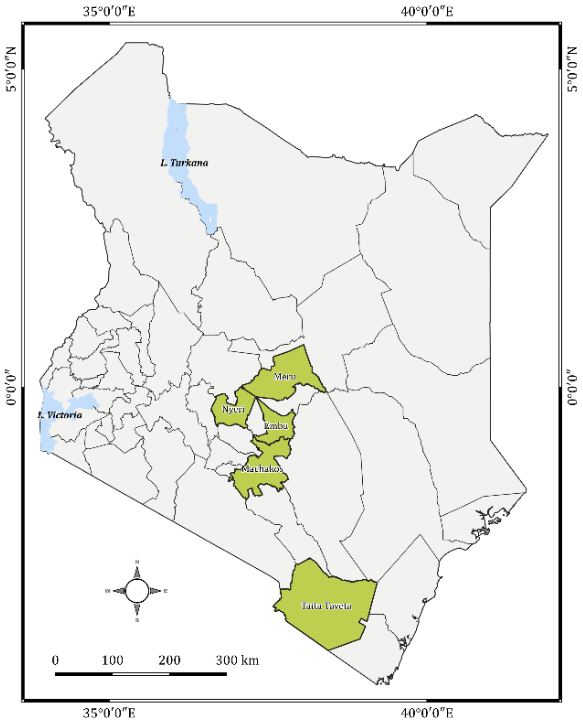
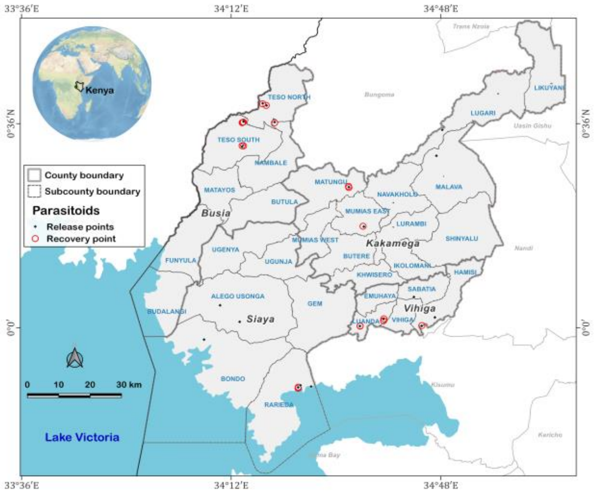
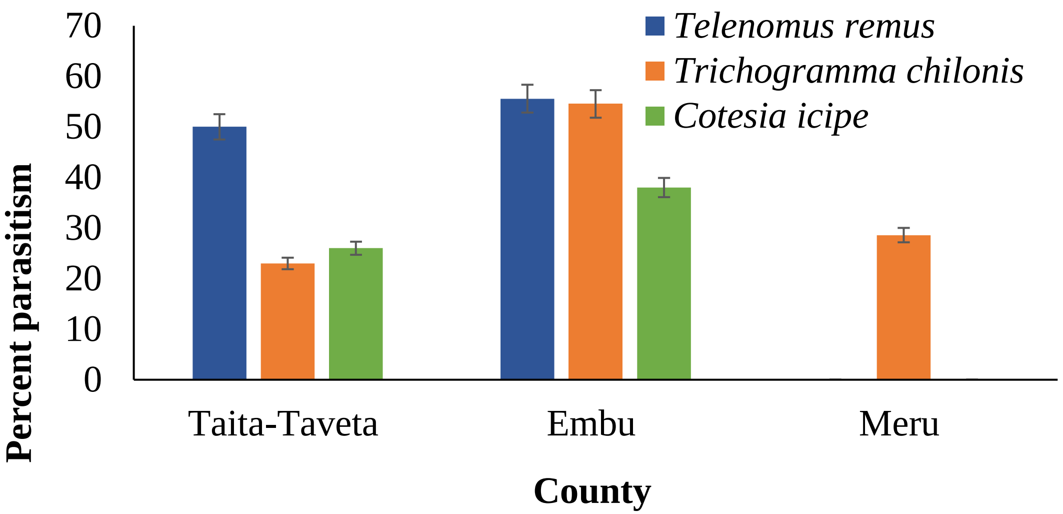
Release of **Egg parasitoids** in four counties

Release of larval parasitoid, *Cotesia icipe* in 5 counties





Post-release establishment of FAW parasitoids



Pre-release percent parasitism ranged from 0 – 7% in the three counties

Released @ 50,000-100,000 wasps (or pupae)/Ha

The parasitoids were recovered/dispersed within a radius of ~1km from the release points.

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Training of farmers on use of parasitoids in biocontrol of FAW

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Efficacy of Entomopathogenic fungi against FAW

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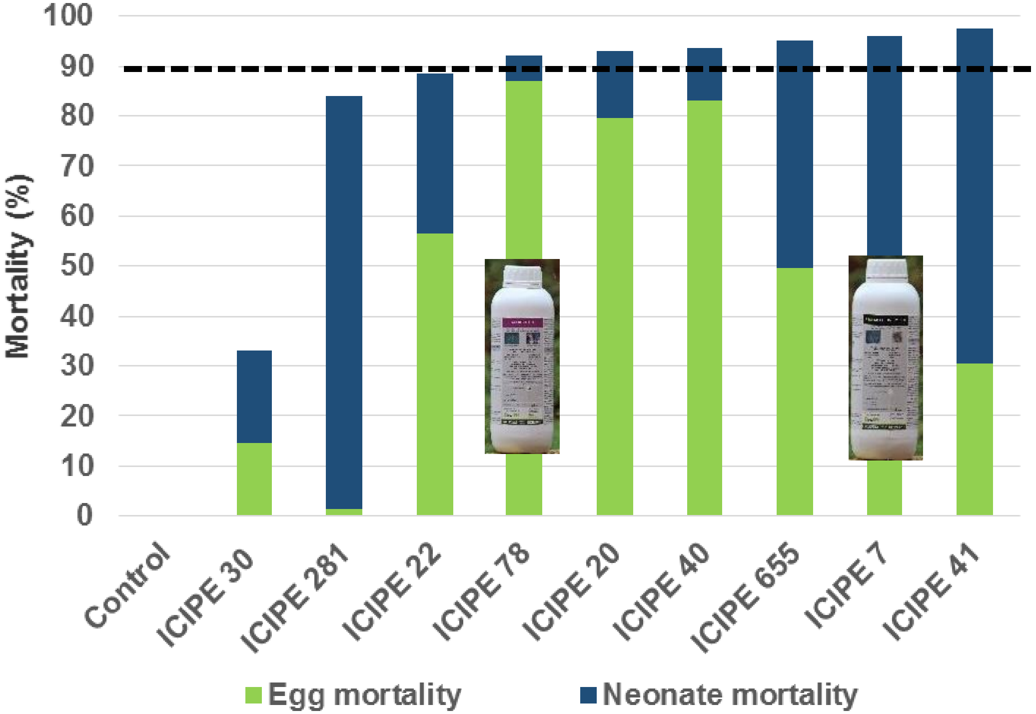

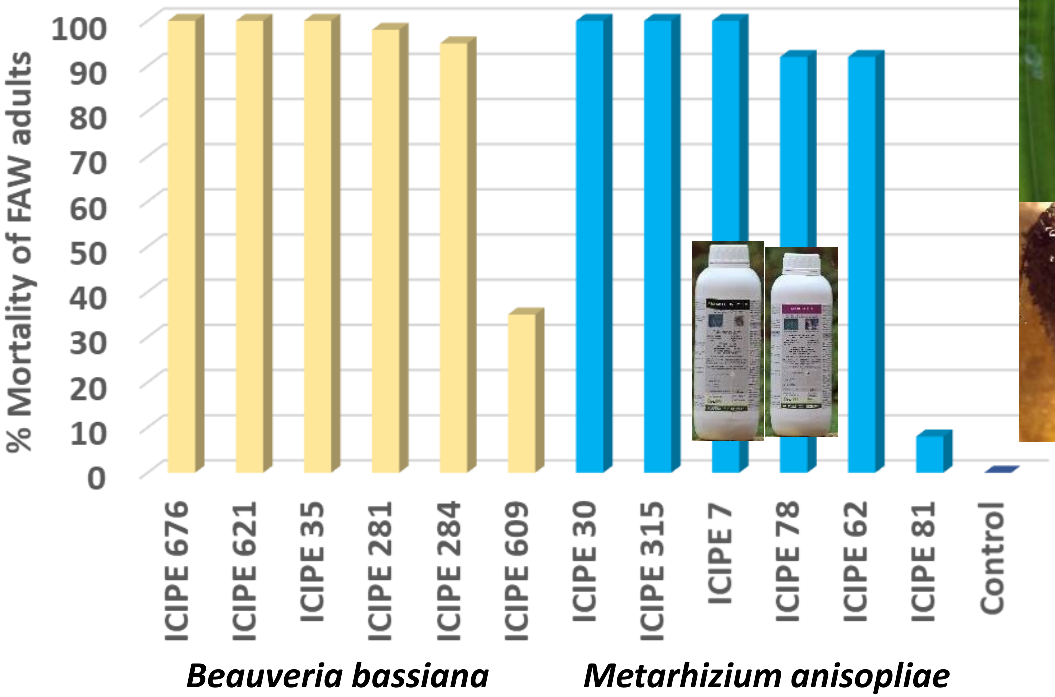

ORIGINAL CONTRIBUTION

WILEY JOURNAL OF APPLIED ENTOMOLOGY

Ovicidal effects of entomopathogenic fungal isolates on the invasive Fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

Komivi Senyo Akutse | Jane Wanjiru Kimemia | Sunday Ekesi |
Fathiya Mbarak Khamis | Odhiambo Levi Ombura | Sevgan Subramanian

Contents lists available at ScienceDirect

Journal of Invertebrate Pathology

journal homepage: www.elsevier.com/locate/jip

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Combining insect pathogenic fungi and a pheromone trap for sustainable management of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

Komivi S. Akutse[a,*], Fathiya M. Khamis[a], Felicitas C. Ambele[a,b], Jane W. Kimemia[a], Sunday Ekesi[a], Sevgan Subramanian[a]

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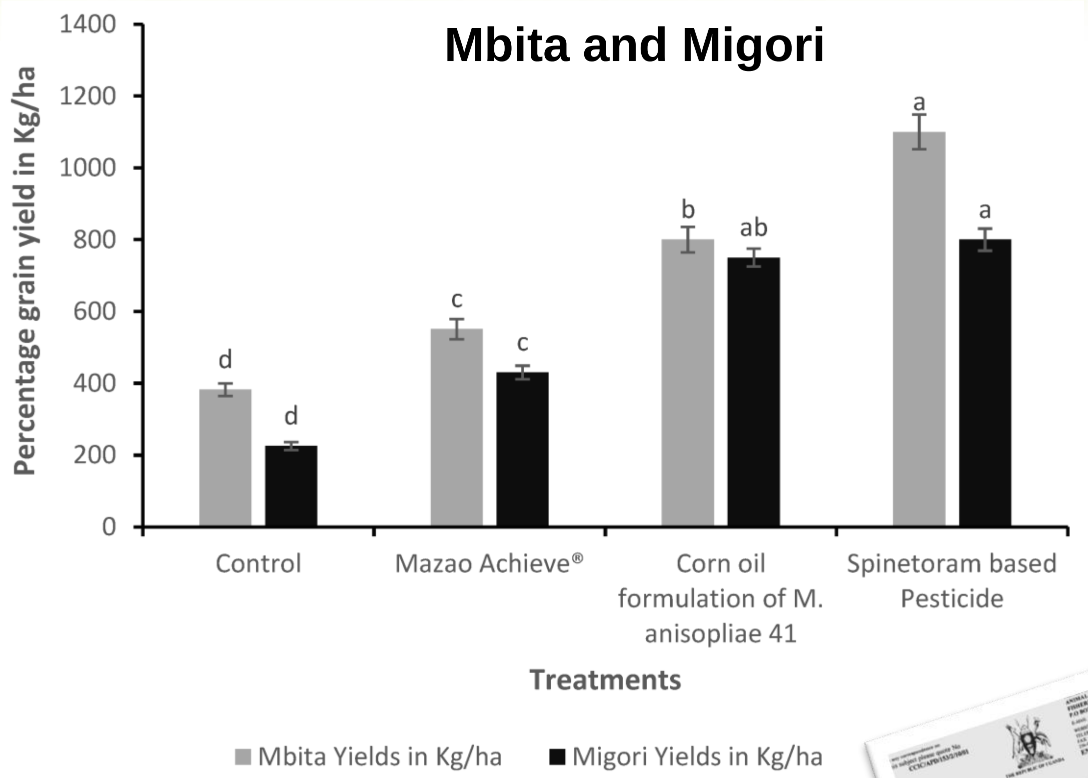
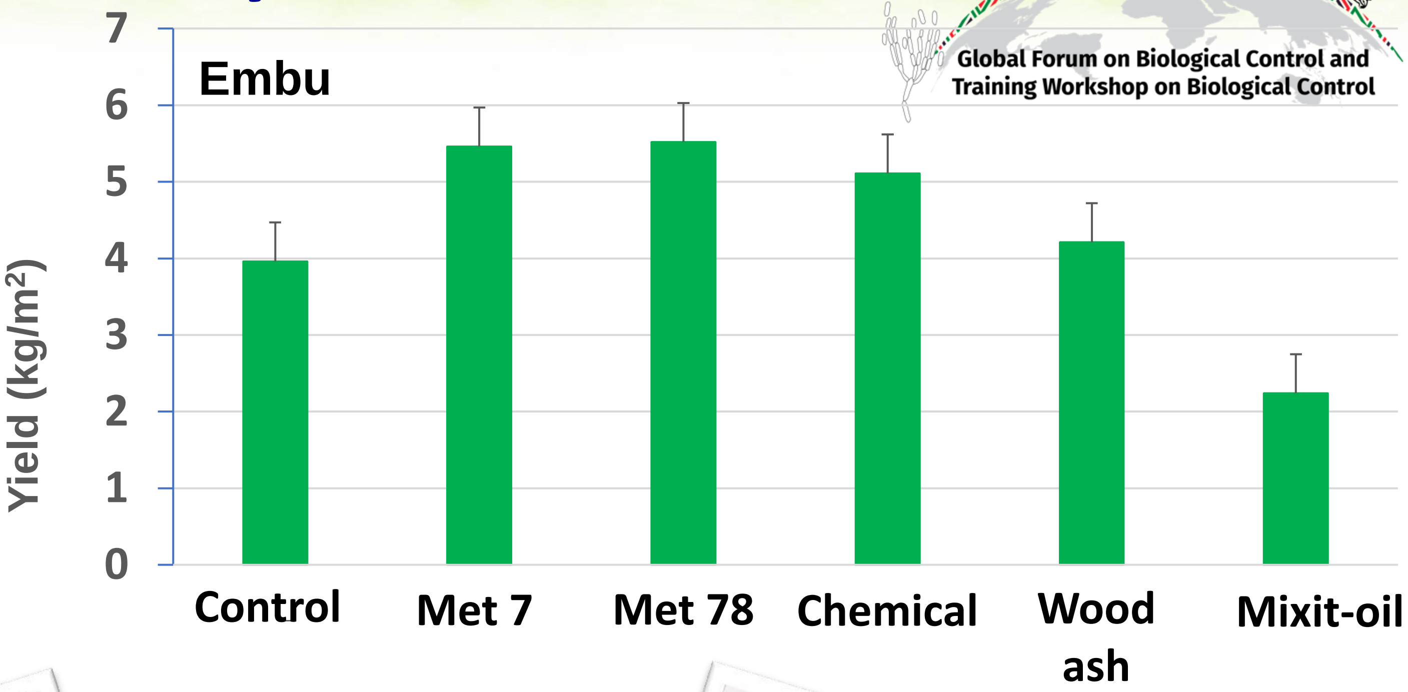
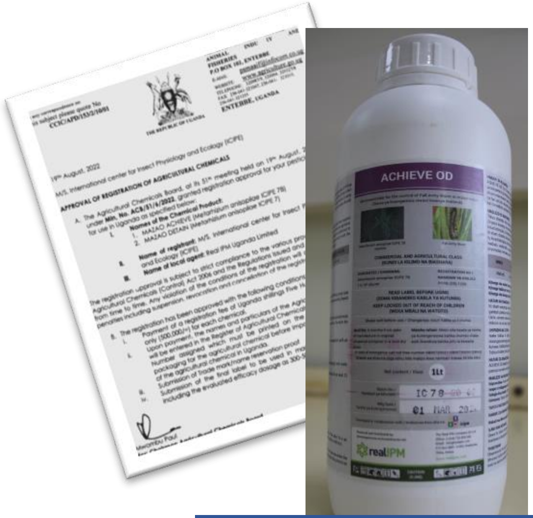
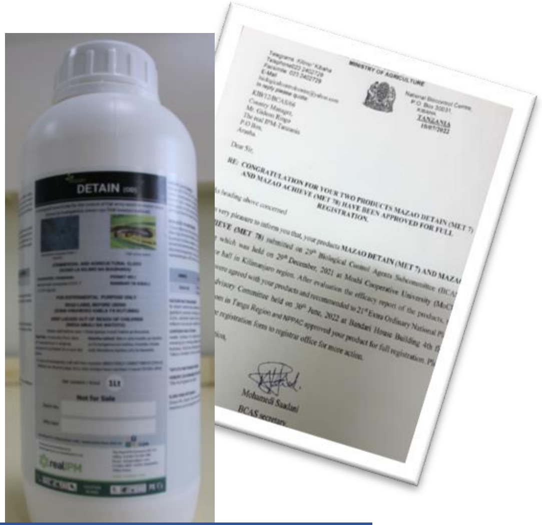
Impact of biopesticide application on yield of maize







Mazao Achieve
(ICIPE 78)



Mazao Detain
(ICIPE 7)

Evaluation of FAW Infestation (%) of maize using locally available material in Bulambuli and Tororo districts of eastern Uganda

Treatment	Level of infestation (%)		
	Bulambuli	Tororo	Average
Neem extract	29.8 (0.022)a	36.4 (0.023)ab	33.1 (0.016)ac
Lantana camara	37.1 (0.023)ac	39.8 (0.023)bc	38.4 (0.016)bc
Soil	37.8 (0.023)ab	44.7 (0.023)bc	41.2 (0.016)bd
Detergent	39.6 (0.023)bc	43.6 (0.023)bc	41.6 (0.016)bd
Insecticide	29.3 (0.021)a	28.2 (0.021)a	28.8 (0.015)a
Water	46.4 (0.024)b	47.8 (0.024)c	47.1 (0.017)d

Baculoviruses for FAW management in Africa

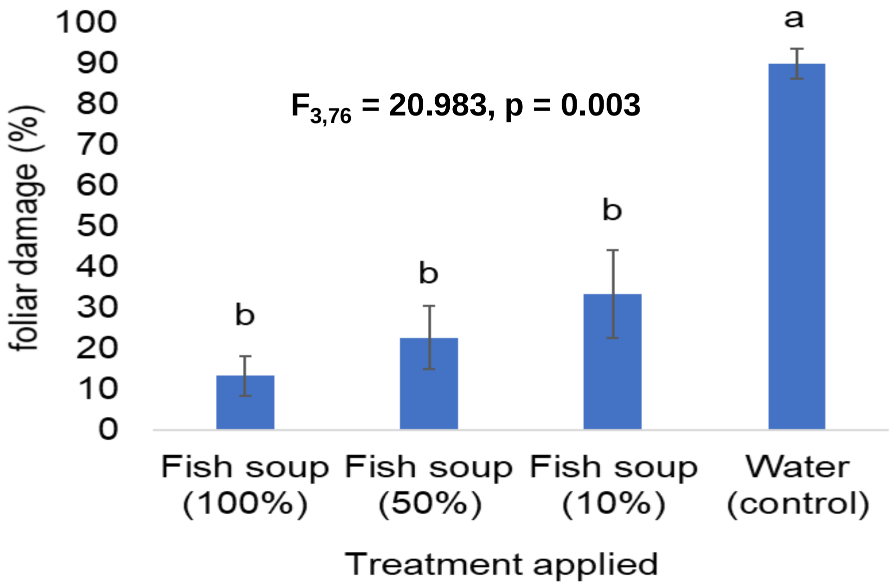
- ❑ Novel baculovirus “Fawligen” tested in Kenya
- ❑ Maize yield advantage of 1.5 t/ha over untreated control
- ❑ Fawligen officially registered in Kenya (Feb 2021)
- ❑ Community small-holder production being tested
- ❑ 95% of farmers willing to pay for biopesticide if available at an agro-dealer near to them, at a price comparable to a synthetic insecticide

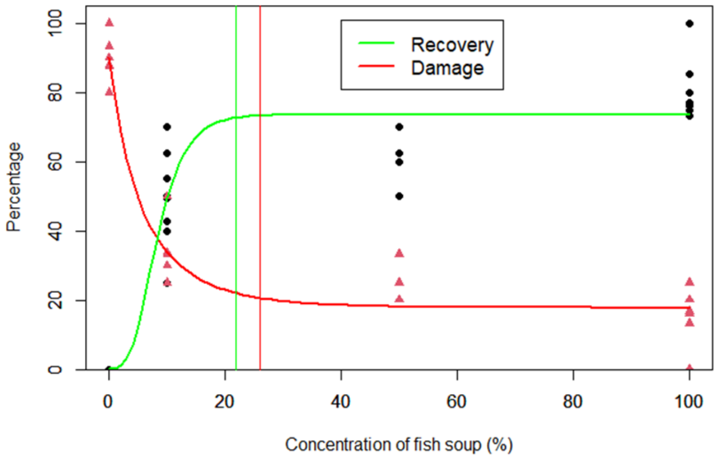
Source: Ivan Rwomushana. Senior Scientist, Invasive Species Management. **CABI**

CABI

AgBiTech

Impact of Fish-soup treatment on fall armyworm damage and recovery





Laboratory

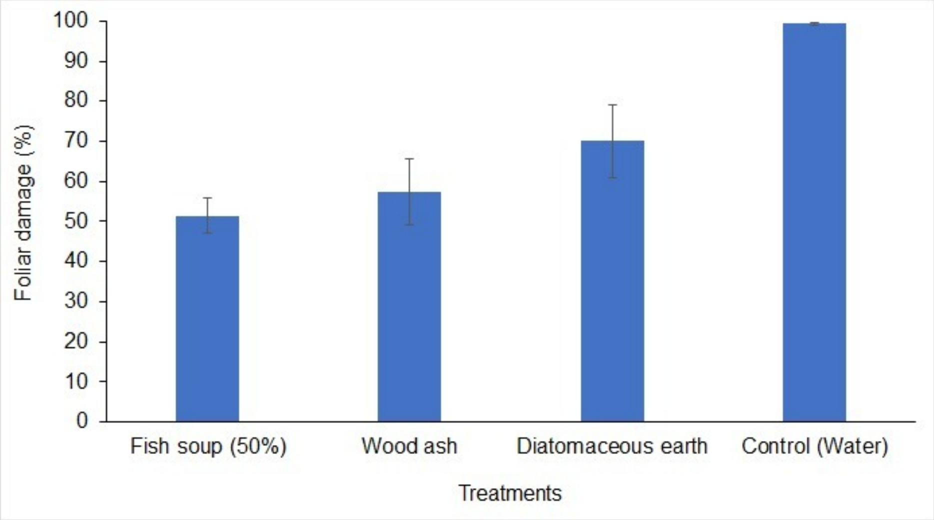
- Grinded 2kg of omena fish
- Cooked in 5L of water (45min)
- Added 450g sugar and stirred
- Decanted the concoction to have residues and soup solution separately
- Conducted a series of dilutions of 50% and 10% while leaving some of 100%
- Moulded the fish residues into pellets to use for bioassay

Field

- Grew maize in pots (SC Duma)
- Filled with soil up to 15cm from the top edge at a ratio of 2:1:1 top soil, compost and sand soil respectively

Divided pots into blocks and kept them far apart from each other

- Kept watering and hand weeding consistent across all the pots
- Placed them under sufficient natural light and ambient temperatures.



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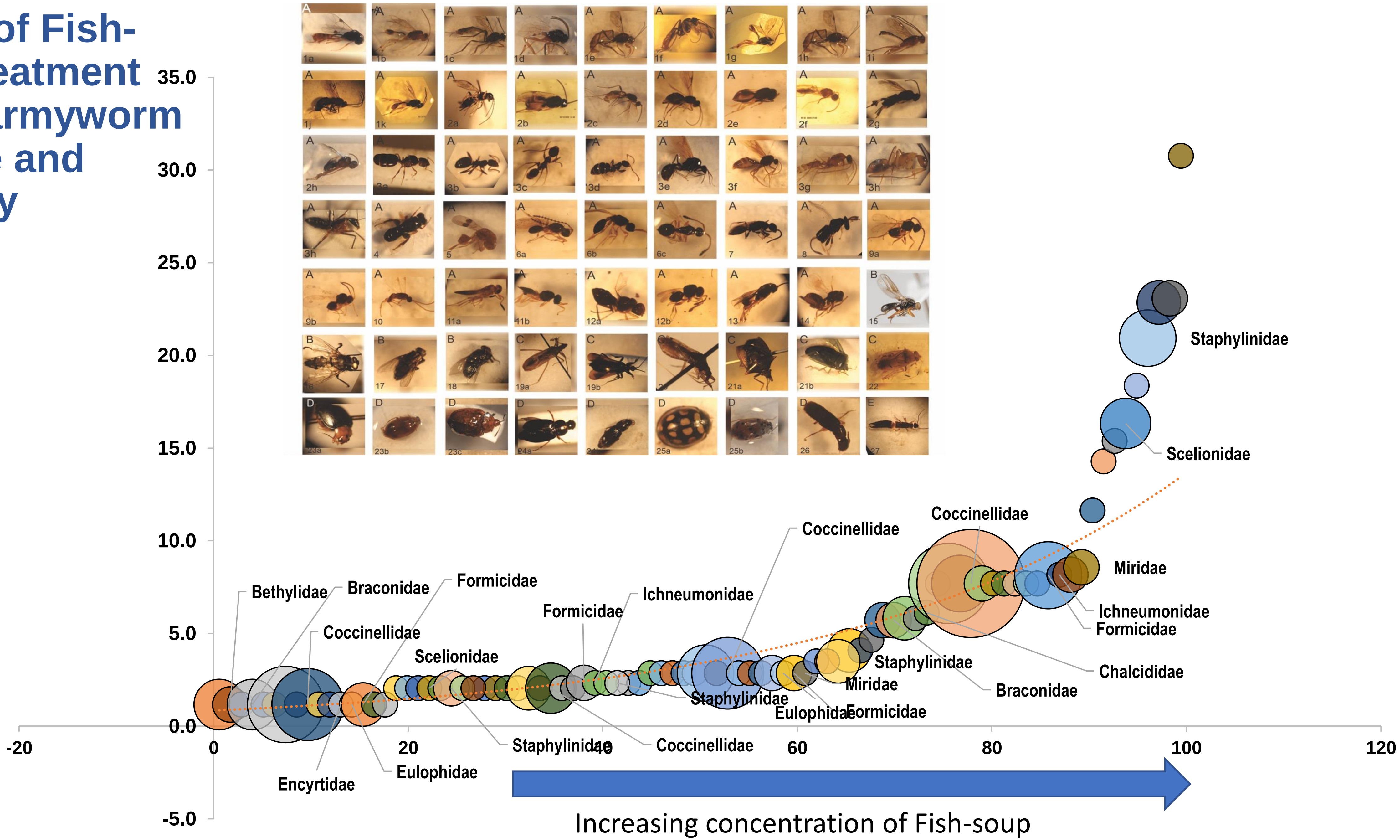
Impact of Fish-soup treatment on fall armyworm damage and recovery



System-level integration and way forward

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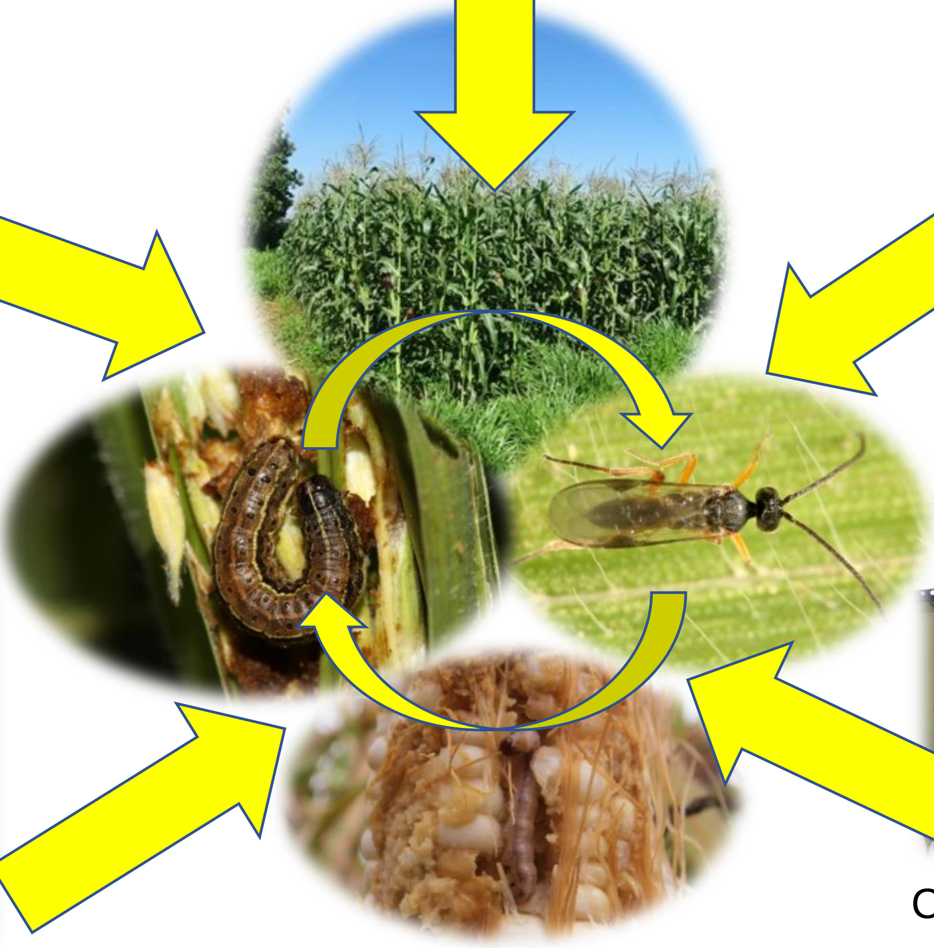
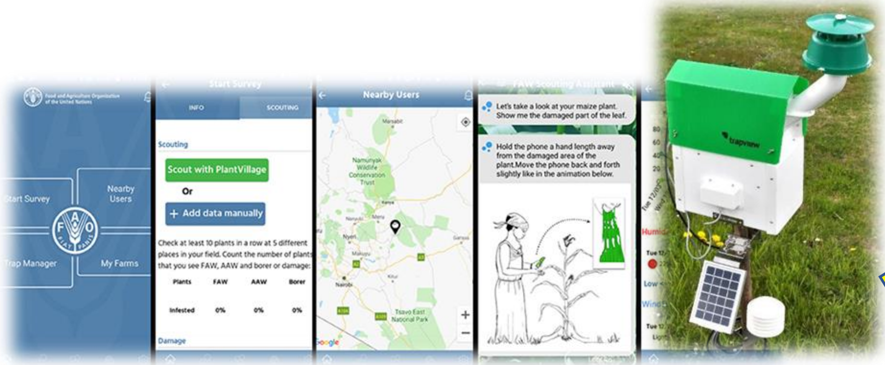
Resistant cultivars/hybrids



Safe biopesticides/judicious use of less toxic molecules

Building capacity and PPP partnerships for biological control



Robust surveillance and monitoring mechanism

Creation of enabling policies at regional/continental level

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