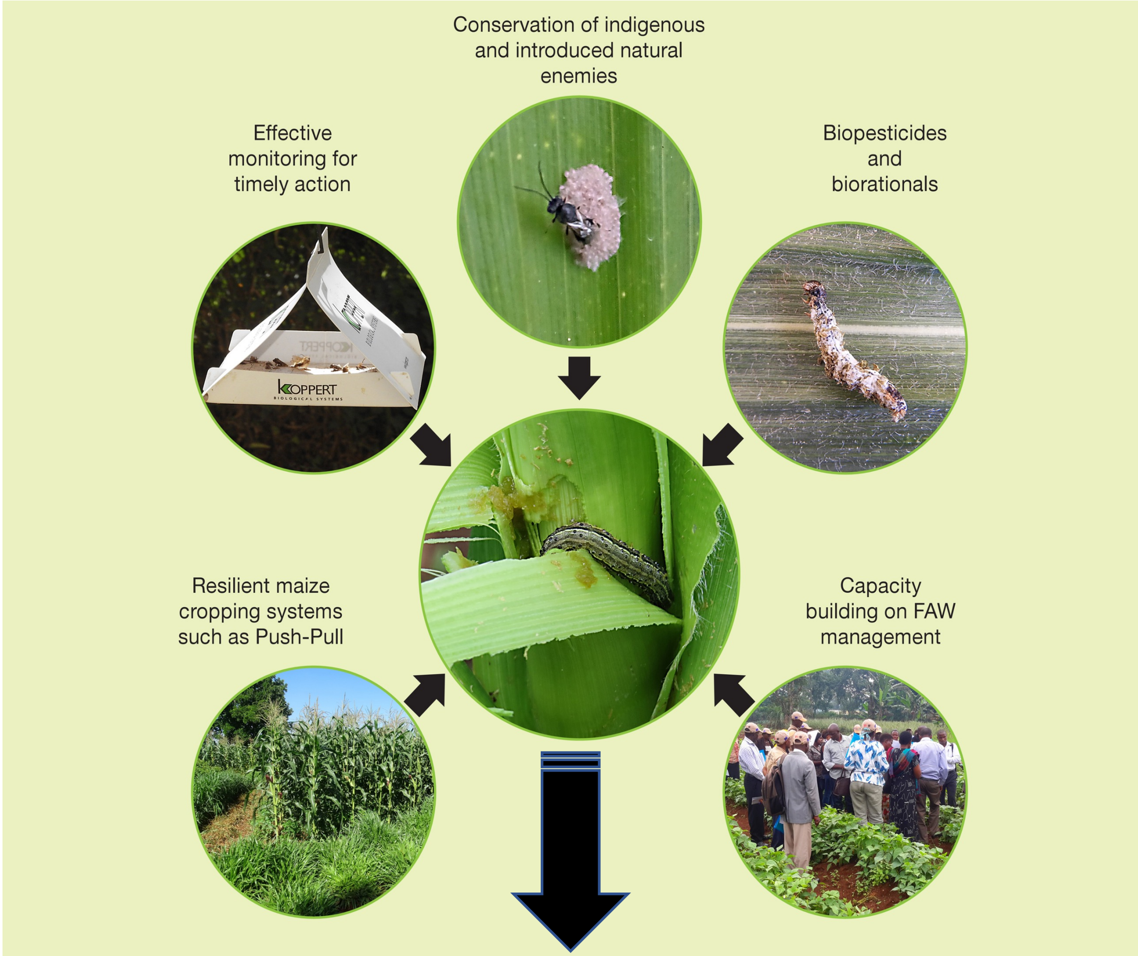
Agroecological Approaches for Fall Armyworm Management

Saliou Niassy, PhD

Scientist, Head of Technology Transfer Unit

(***on behalf of FAW team***)

icipe



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

Review of Cultural Practices against FAW

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Review

Agro-ecological options for fall armyworm (*Spodoptera frugiperda* JE Smith) management: Providing low-cost, smallholder friendly solutions to an invasive pest

Rhett D. Harrison[a,*], Christian Thierfelder[b], Frédéric Baudron[c], Peter Chinwada[d], Charles Midega[e], Urs Schaffner[f], Johnnie van den Berg[g]

- Soil fertility management, which improves crop health and pest resistance promoting,
- Increased biodiversity providing living space for natural enemies,
- Control outbreaks and reduce their impact

Introduction cont’

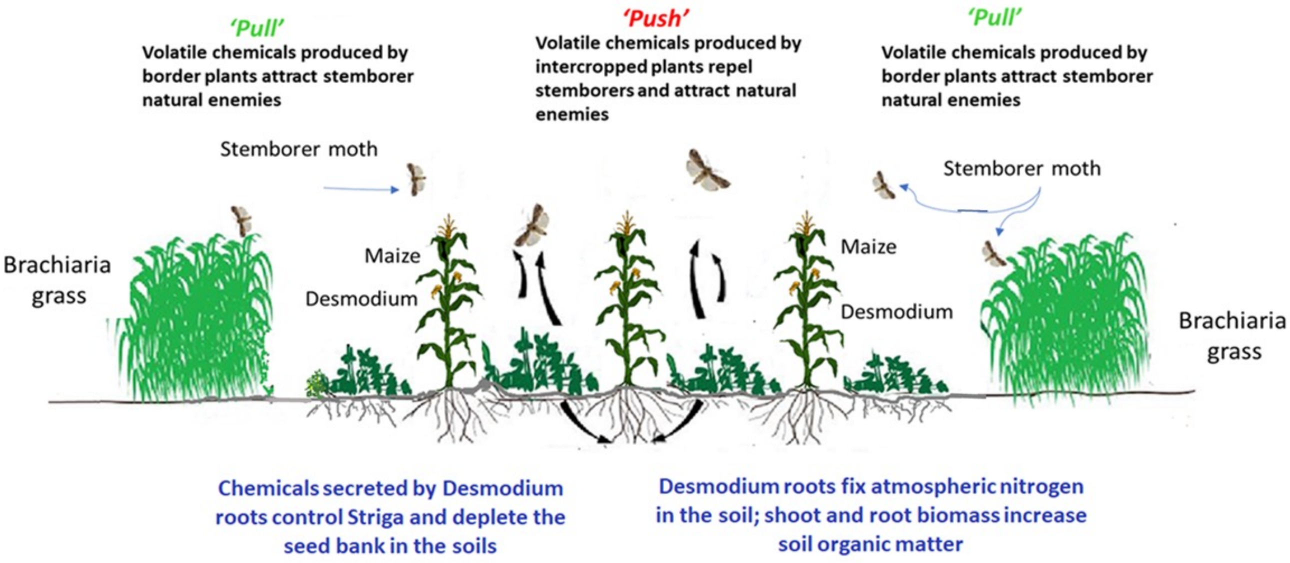




- Indigenous/locally available knowledge for management of lepidopteran pests (stem borers) have been adopted for armyworms:
  - ✓ Fish soup
  - ✓ handpicking and crushing of larvae/eggs
  - ✓ adding soil to plant whorls
  - ✓ placing sand or ash in the whorls
  - ✓ use of detergents
  - ✓ biorationals (tobacco/neem extracts)
  - ✓ rotation of maize with non-host crops.
- They are accepted and validated by society over time and has become part of people’s social and cultural lives.

Push-pull technology

1 cereal + 2 perennial companion crops



Push-pull encompasses intercropping maize with the legume Desmodium and a border row of Napier grass around the plot; both Desmodium and Napier grass are perennial fodder plants

What is Push-Pull System?

The 'Push-Pull' system is a novel approach in pest management, developed by understanding the complex mechanisms that govern the ecology of plants and insects, which uses carefully-selected repellent intercrops and attractive trap plants. Insect pests are repelled from the food crop and are attracted to a trap crop. The repellent intercrop also effectively controls parasitic striga weed.

Push-pull encompasses intercropping maize with the legume Desmodium and a border row of Napier grass around the plot; both Desmodium and Napier grass are perennial fodder plants

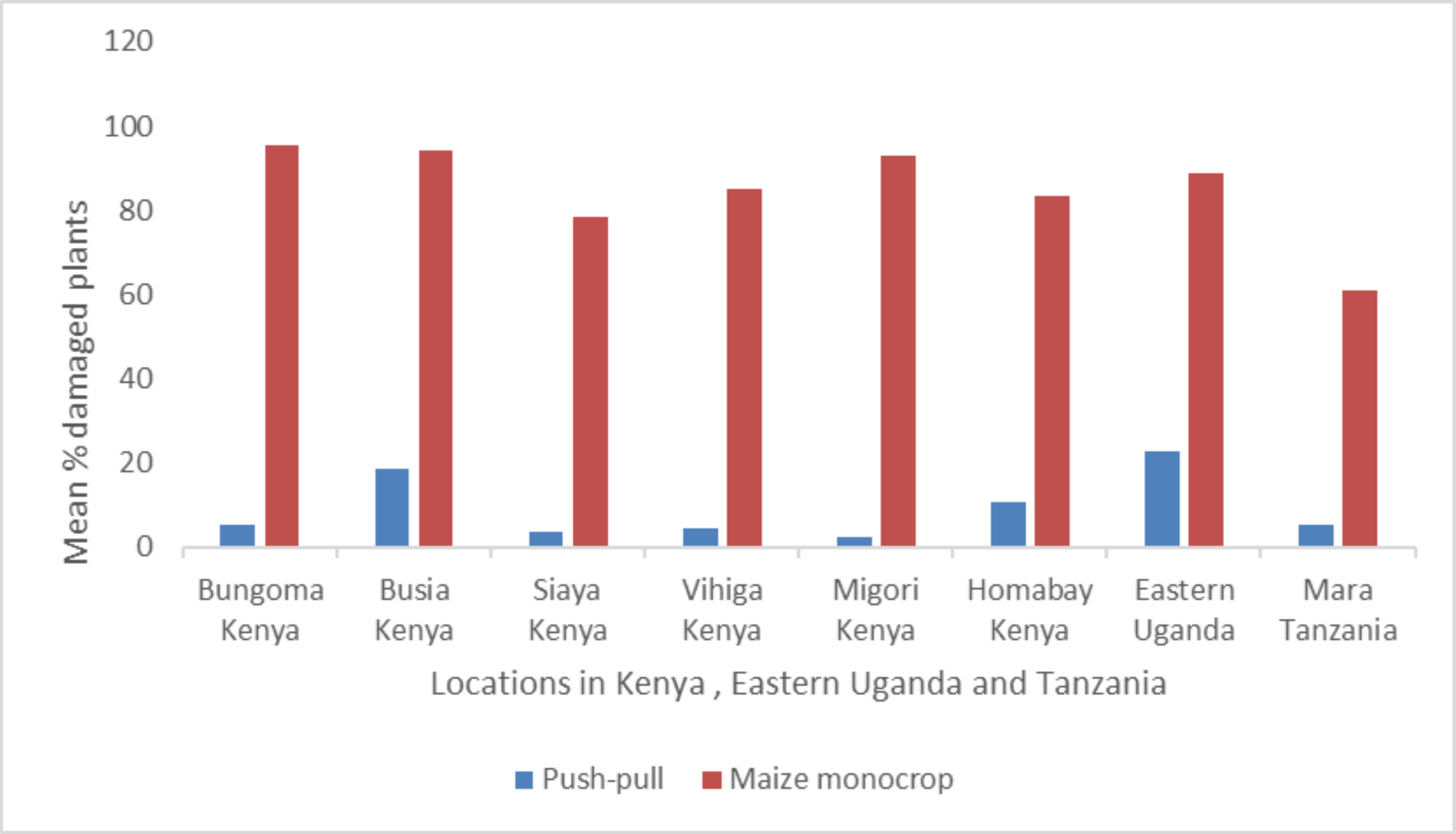
Push-Pull protects maize from FAW

Lilian and John Wagombe 1997

Lilian and John Wagombe 2017

icipe

FAW Damage on Maize under Push-pull and Control Plots

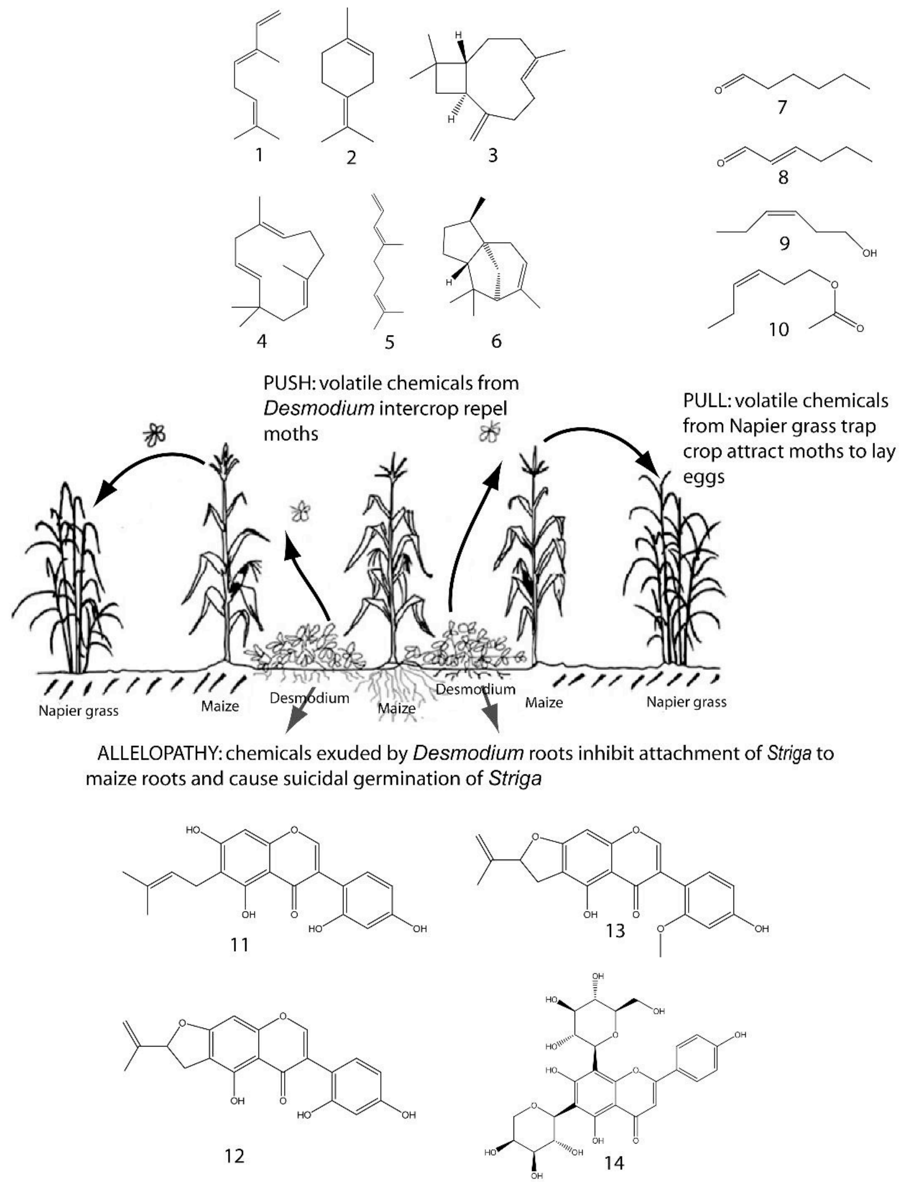


What is Push-Pull System?

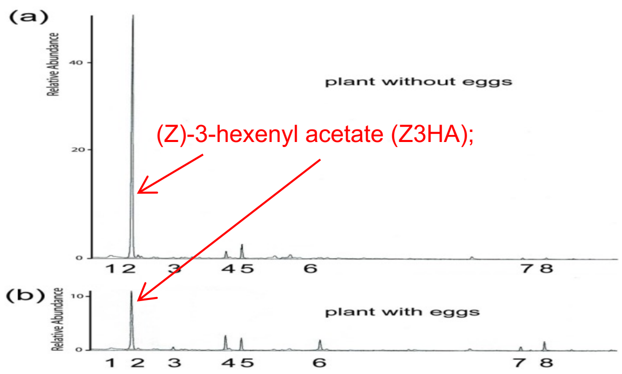
1= (*E*)-ß-ocimene;
2= α-terpinolene;
3= β-caryophyllene;
4= humulene;
5= (*E*)-4,8-dimethyl-1,3,7-nonatriene;
6= α-cedrene;

7= hexanal;
8= (E)-2-hexenal;
9= (Z)-3-hexen-1-ol;
10= (Z)-3-hexen-1-yl acetate ;

11= 5,7,2′,4′-tetrahydroxy-6-(3-methylbut-2-enyl)isoflavanone (uncinanone A);
12= 4″,5″-dihydro-5,2′,4′-trihydroxy-5″-isopropenylfurano-(2″,3″;7,6)-isoflavanone (uncinanone B);
13= 4″,5″-dihydro-2′-methoxy-5,4′-dihydroxy-5″-isopropenylfurano-(2″,3″;7,6)-isoflavanone (uncinanone C);
14= di-*C*-glycosylflavone 6-*C*-α-L-arabinopyranosyl-8-*C*-β-Dglucopyranosylapigenin



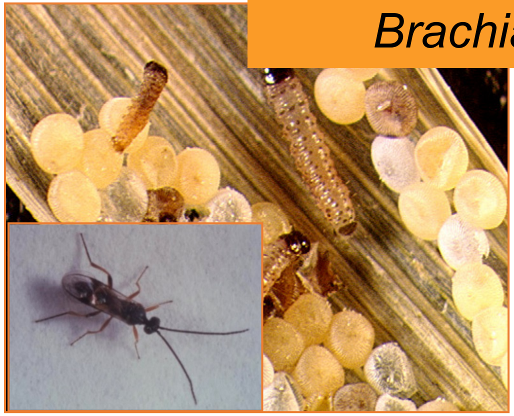
Early Herbivory Alert



Brachiaria brizantha has an early herbivore signaling strategy. It starts its defense right after oviposition by stemborers, through massive reduction in production of main attractive volatile (*Z*)-3-hexenyl acetate (Z3HA). These plants became **less** attractive for further oviposition by stemborers but **more** attractive for the larval parasitoid *Cotesia sesamiae* by producing plant volatiles that attract natural enemies.

Bruce et al. 2010. Biol. Let. 6: 314–317

Brachiaria brizantha

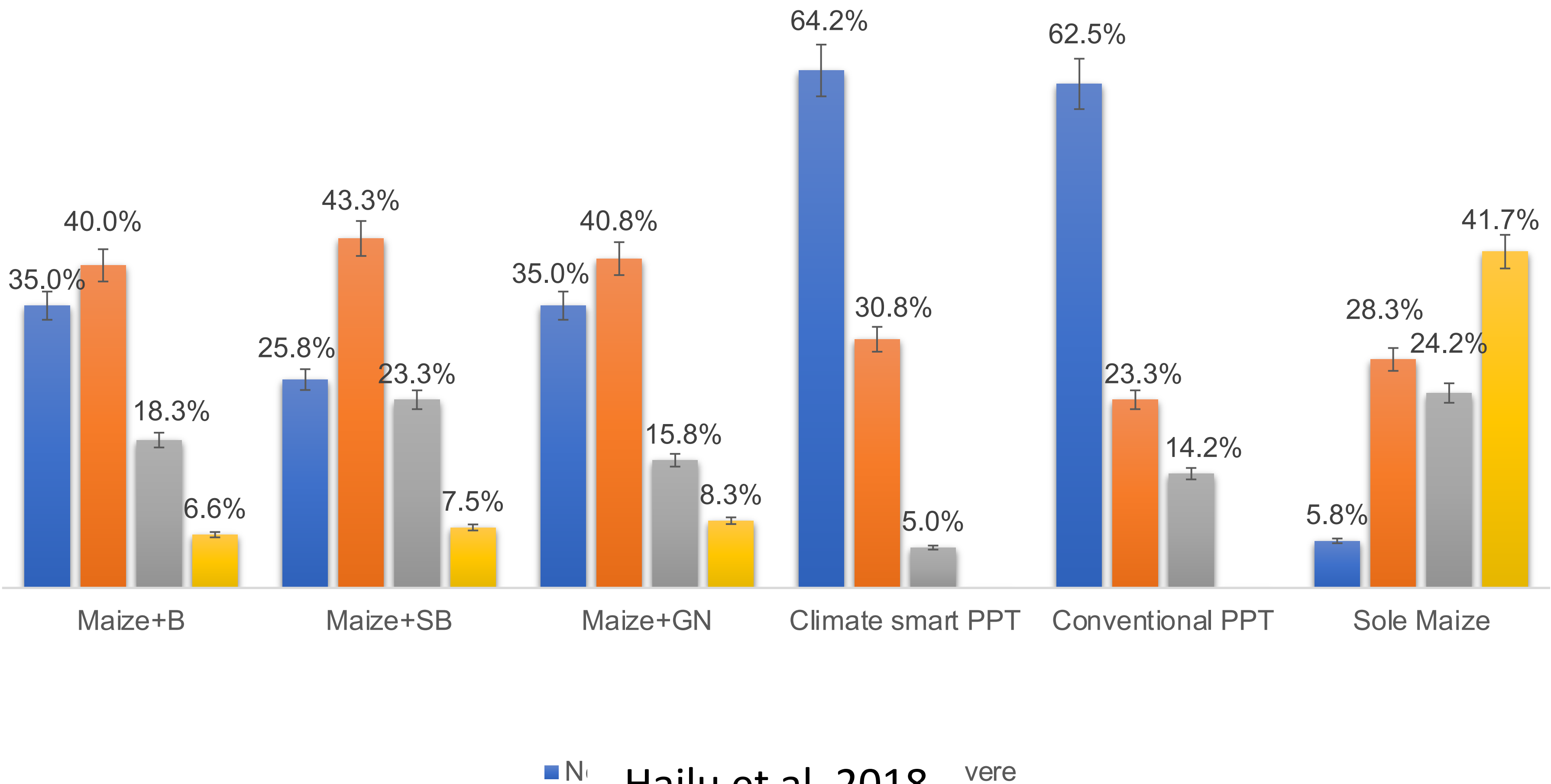


Conventional Push-Pull

Climate Smart Push-Pull

Third generation Push-Pull

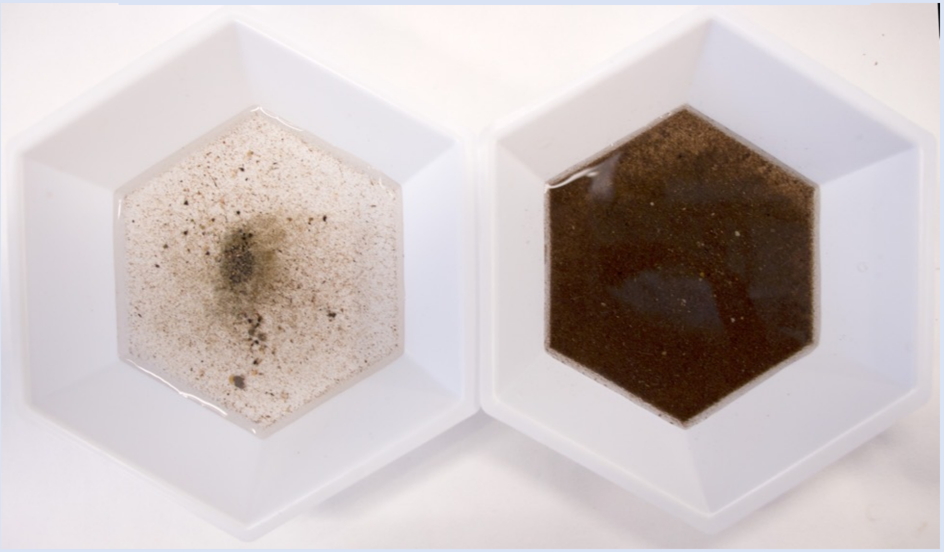
FAW damage under Push-pull and various intercrops



Hailu et al. 2018

Organic matter in Push-Pull and control fields

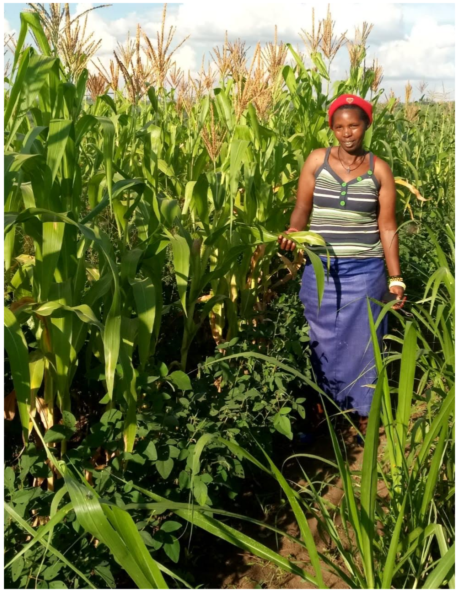
Drinkwater et al. 2021



Control Field

Push-Pull Field

POM plays an important role in giving the soil "crumb structure", so it impacts water infiltration/water holding capacity and is also an important nutrient reservoir that we believe can supply N (and probably P) to crops



Push-Pull Rwanda

International Scholars Journals

International Journal of Agricultural Extension and Rural Development ISSN 3254-5428 Vol. 8 (3), pp. 001-015, March, 2020. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Adoption and willingness to pay for the push-pull technology among smallholder maize farmers in Rwanda

Saliou Niassy[1]*, Michael Kidoido[1], Nyang'au Isaac Mbeche[1], Jimmy Pittchar[1], Girma Hailu[1], Rachel Owino[1], David Amudavi[2] and Zeyaur Khan[1]

[1]International Centre of Insect Physiology and Ecology (ICIPE), P.O. Box 30772- 00100, Nairobi, Kenya.
[2]Biovision Africa Trust C/O International Centre of Insect Physiology and Ecology (ICIPE) Carroll Wilson Building, Ground Floor, P.O. Box 30772, 00100, Duduville, Kasarani, Nairobi, Kenya.

icipe

Push-Pull West & Southern Africa

Crop Protection 145 (2021) 105612

Contents lists available at ScienceDirect

Crop Protection

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

Effect of spatial arrangement of push-pull companion plants on fall armyworm control and agronomic performance of two maize varieties in Ghana

Stephen Yeboah [a,*], Stella A. Ennin [a], Adama Ibrahim [a], Patricia Oteng-Darko [a], Daniel Mutyambai [b], Zeyaur R. Khan [b], Moses B. Mochiah [a], Sunday Ekesi [b], Saliou Niassy [b]

[a] CSIR-Crops Research Institute, Kumasi, Ghana
[b] International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya

sustainability

MDPI

Article

Performance of Push–Pull Technology in Low-Fertility Soils under Conventional and Conservation Agriculture Farming Systems in Malawi

Saliou Niassy [1,*], Mawufe Komi Agbodzavu [1,2], Bester Tawona Mudereri [1], Donwell Kamalongo [3], Ivy Ligowe [3], Girma Hailu [1], Emily Kimathi [1], Zwide Jere [4], Nathan Ochatum [1], Jimmy Pittchar [1], Menale Kassie [1] and Zeyaur Khan [1]

KURDO **Alexis Ltd** **Mukushi Seed Company**

- **Mukushi contracted farmers in the Murehwa district**
- **Mukushi has contracted KURDO producer groups as part of their out-grower scheme**
- **Seed is produced and sold at $10/kg instead of $50/kg when imported**

Intercropping

- Evaluating the effect of maize edible legume intercropping to control FAW infestation

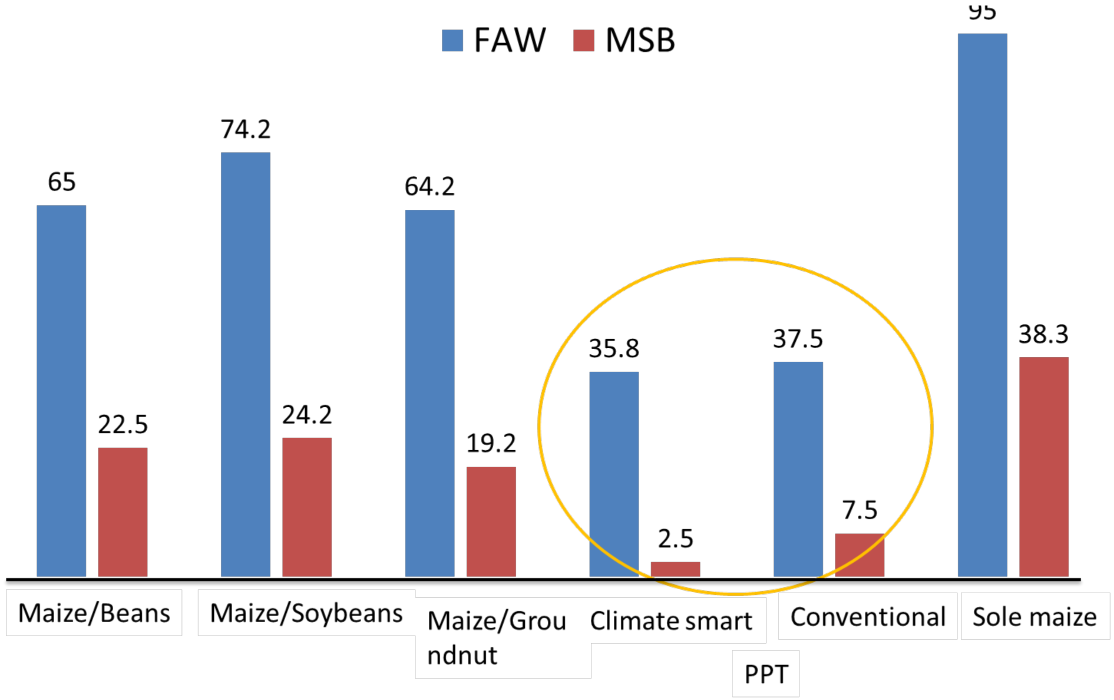
Agronomy Journal

Pest Interactions in Agronomic System | Open Access

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

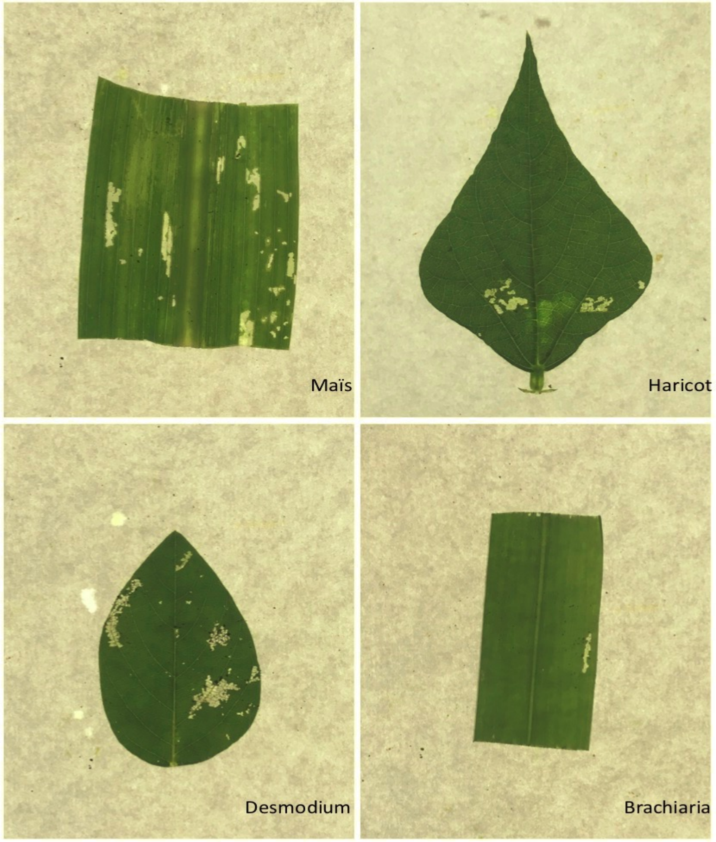
Girma Hailu, Saliou Niassy, Khan R. Zeyaur, Nathan Ochatum, Sevgan Subramanian

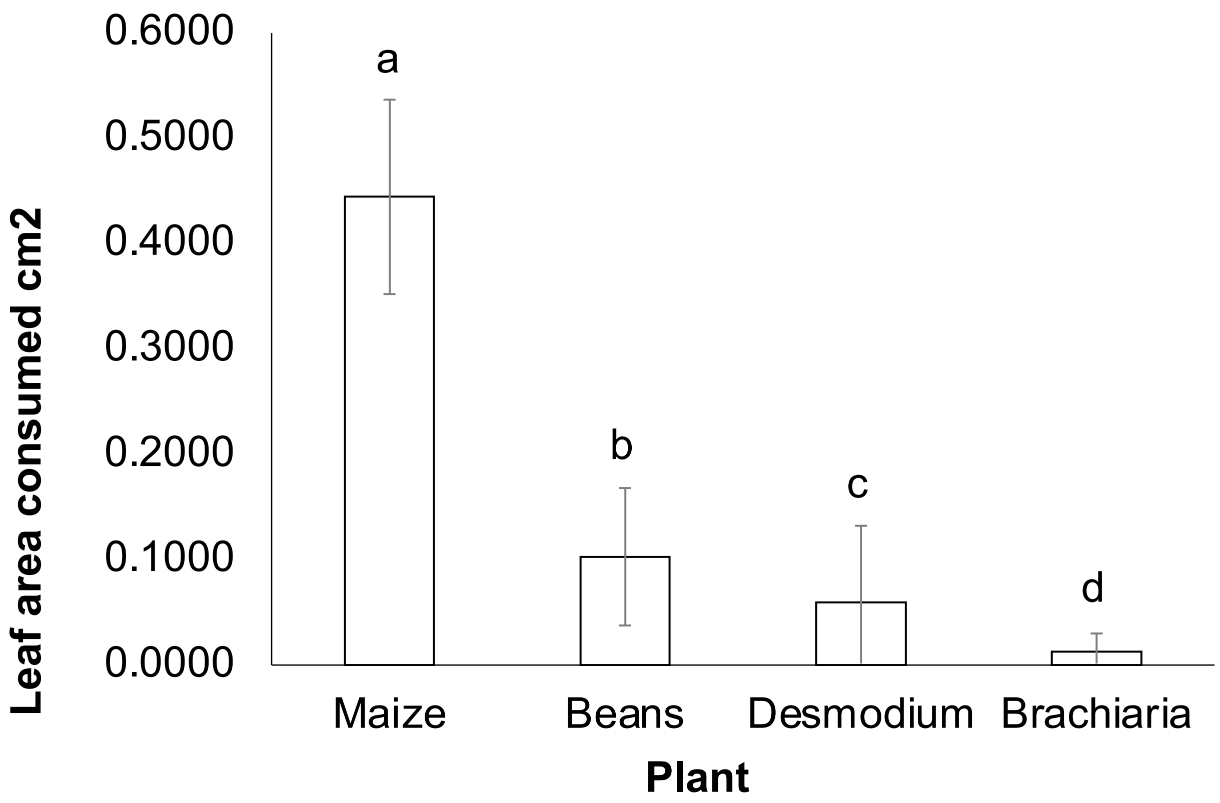
Infestation (%) of maize due to FAW and cereal stemborer in different intercropping systems



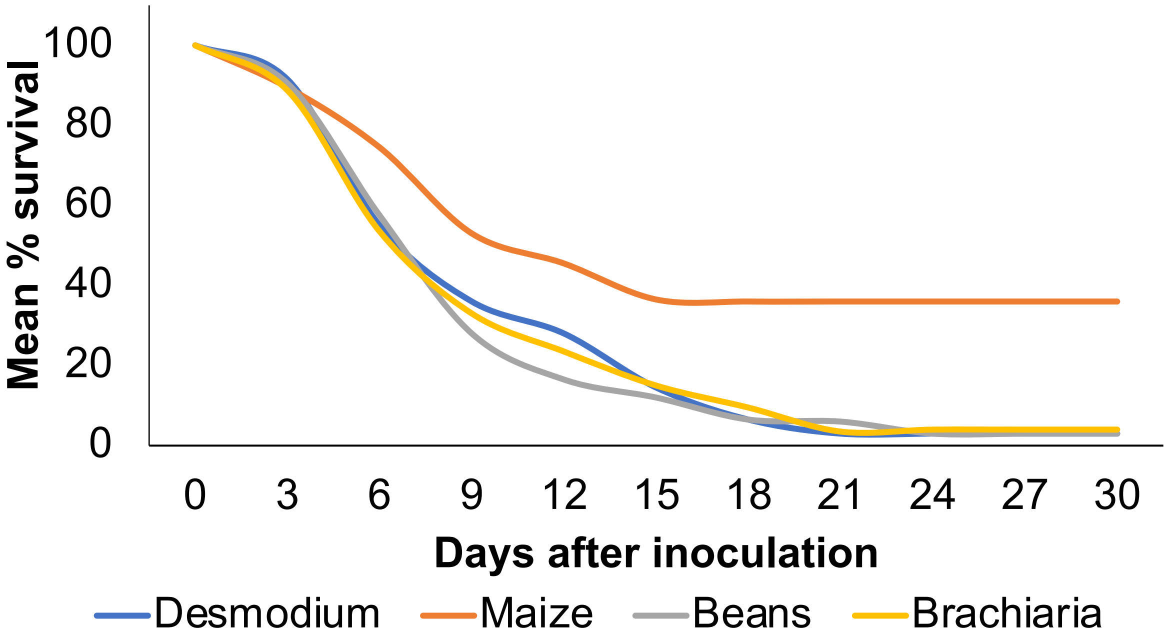
Mechnism of FAW Control

- Antibiosis
- Antixenosis
- Physical barrier
- Plant signaling


Maïs
Haricot
Desmodium
Brachiaria



0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
Leaf area consumed cm2
a
b
c
d
Maize
Beans
Desmodium
Brachiaria
Plant



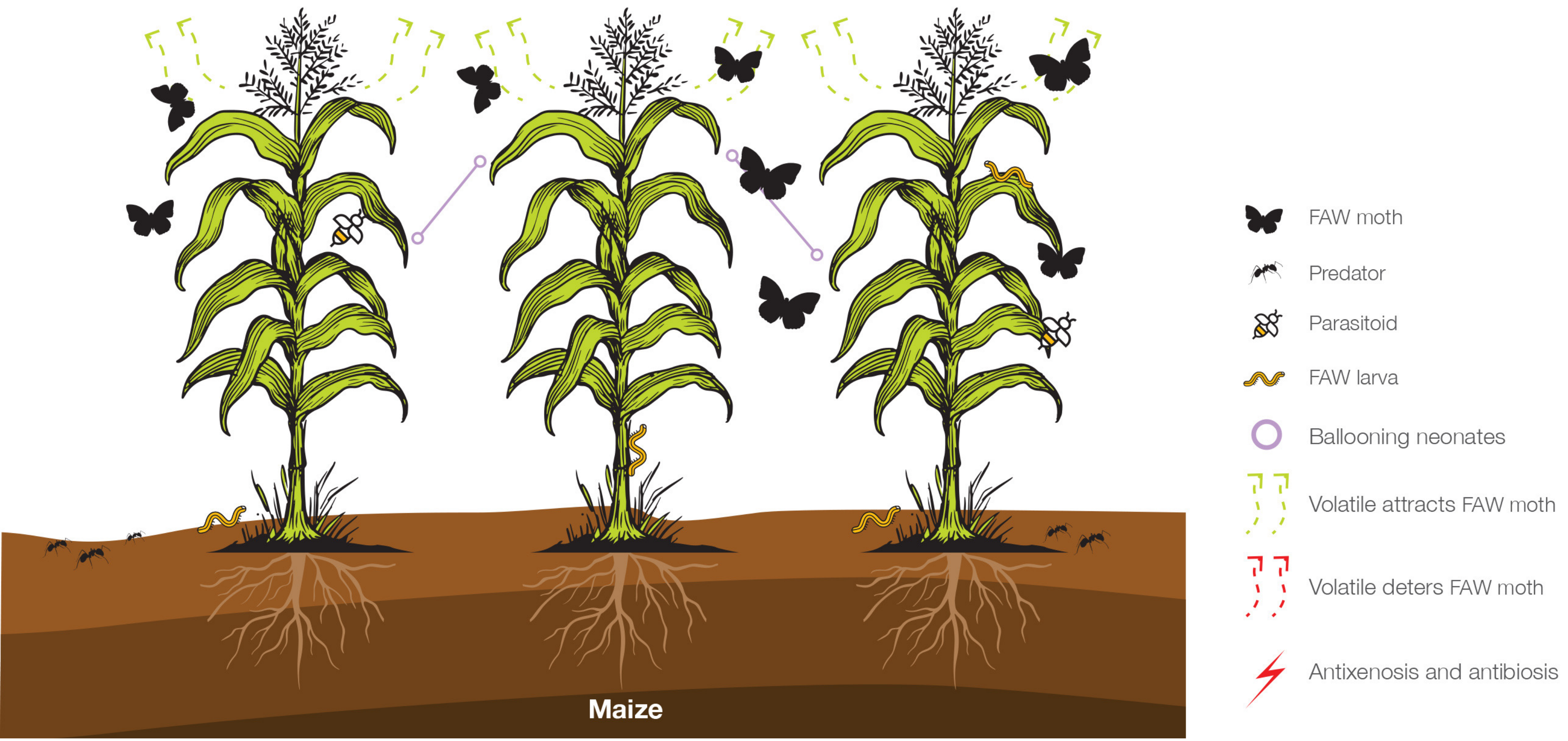
Mean % survival
100
80
60
40
20
0
0
3
6
9
12
15
18
21
24
27
30
Days after inoculation
Desmodium
Maize
Beans
Brachiaria

A: Desmodium

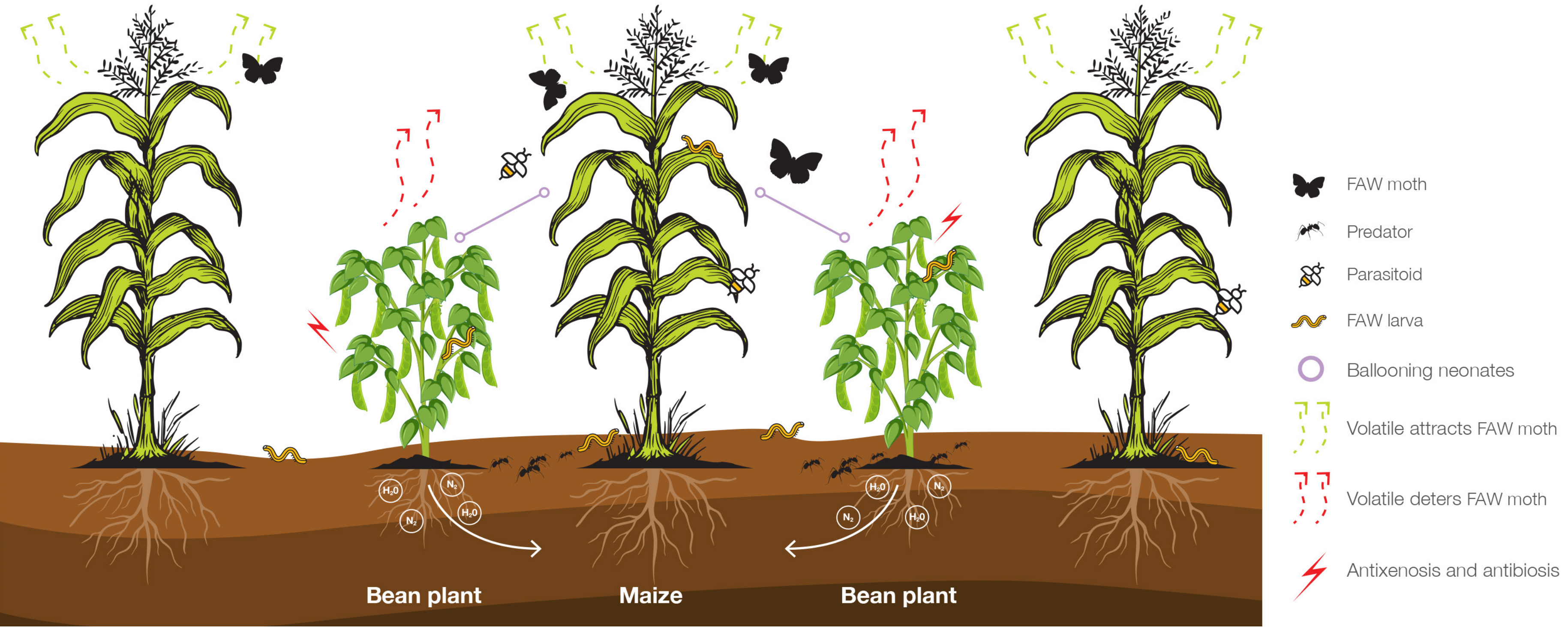
B: Bean

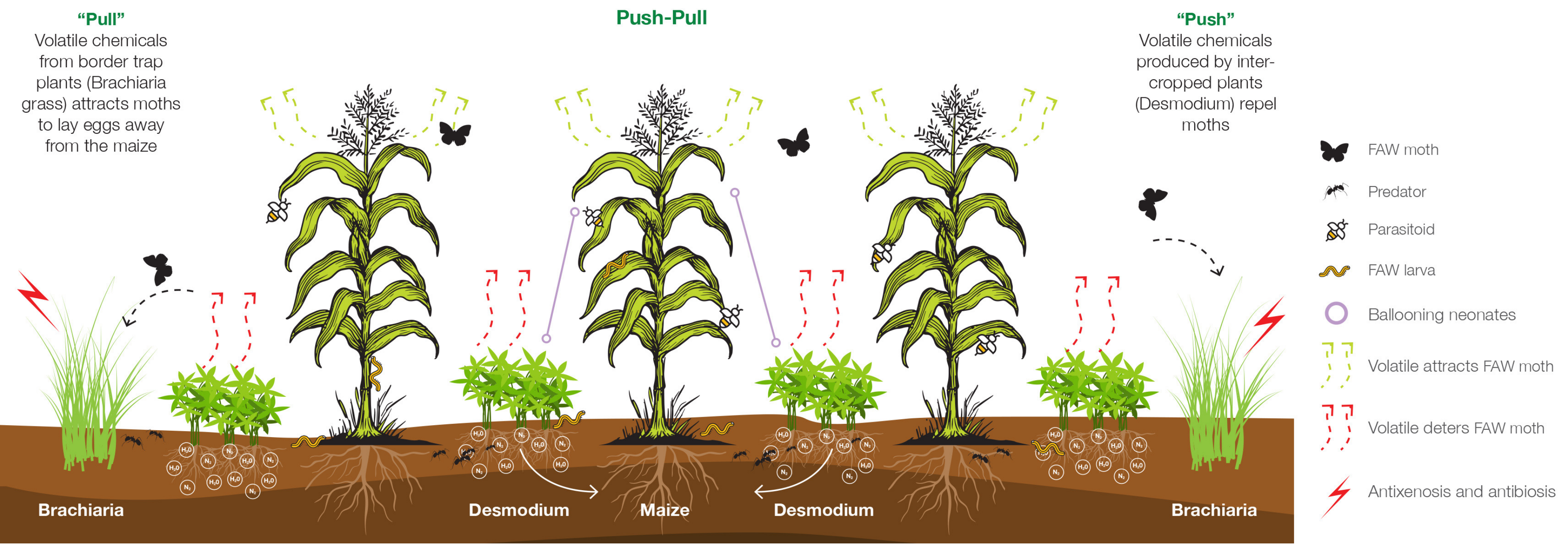
C: Maize

Maize monocrop



Maize-legume intercropping





"Pull"
Volatile chemicals from border trap plants (Brachiaria grass) attracts moths to lay eggs away from the maize
Push-Pull
"Push"
Volatile chemicals produced by inter-cropped plants (Desmodium) repel moths
Brachiaria
Desmodium
Maize
Desmodium
Brachiaria
FAW moth
Predator
Parasitoid
FAW larva
Ballooning neonates
Volatile attracts FAW moth
Volatile deters FAW moth
Antixenosis and antibiosis

Sokame et al

FAW Dispersal in maize fields

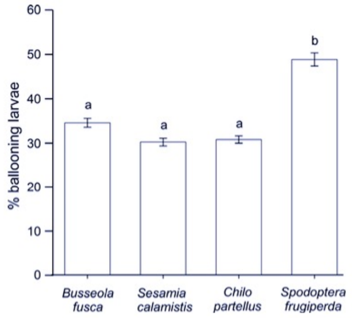


Figure 2 Mean (± SE) percentage of larvae of fall armyworm (*Spodoptera frugiperda*) and three stemborer species leaving maize plants by ballooning. Means capped with different letters are significantly different (Tukey's test: P<0.05).

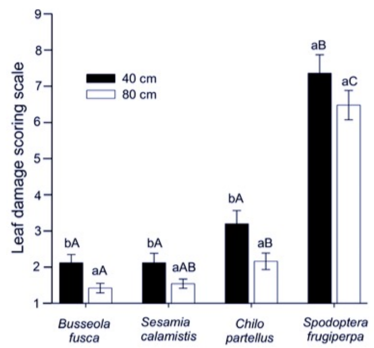
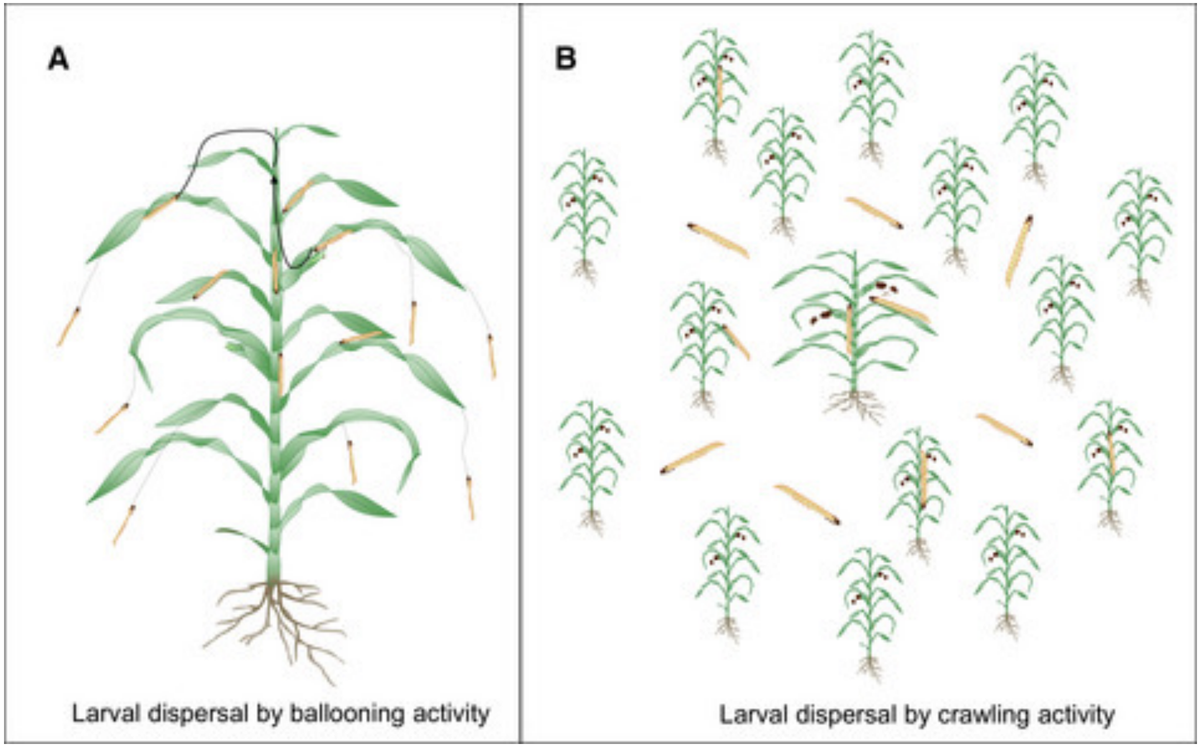


Figure 4 Mean (± SE) damage score for maize plants in a circle with 40 or 80 cm radius (see Figure 1), damaged by larvae of fall armyworm (*Spodoptera frugiperda*) and three stemborer species. Means within a species capped with different lowercase letters, and within a radius capped with different uppercase letters, are significantly different (Tukey's test: P<0.05).



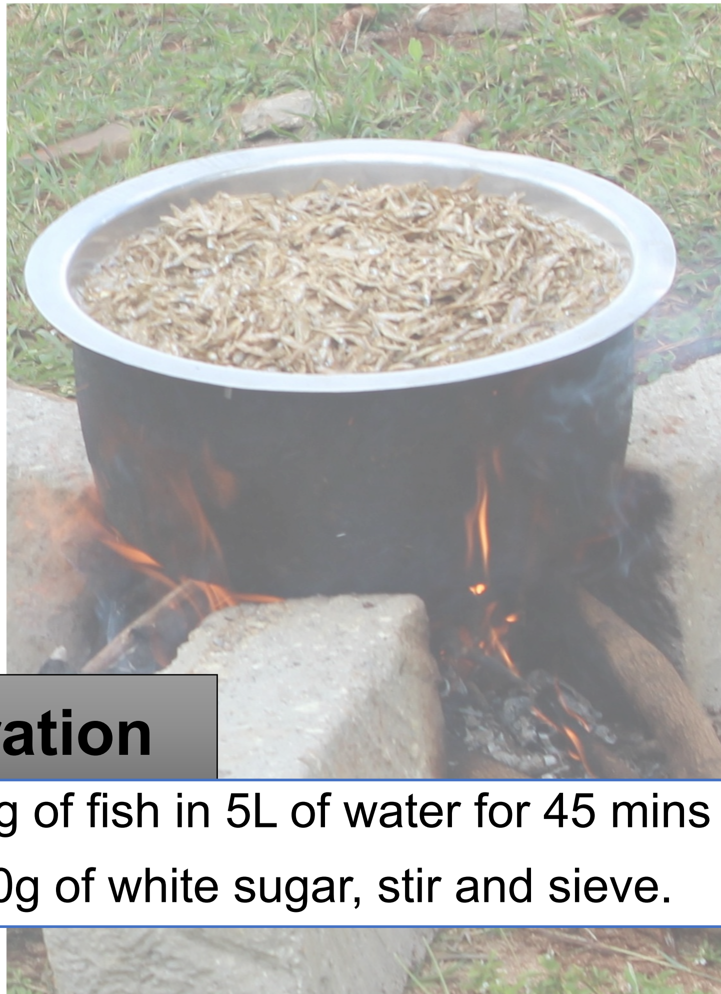
Why this study

- ❖ Fish soup+sugar has been used as one of the indigenous methods by smallholder farmers in East Africa (Malawi, Kenya) to reduce damage caused by fall armyworm.
- ❖ Small pelagic fish, *Rastrineobola argentea* ("omena")

- ❖ To ensure the continuity of these practices for scaling and future generations, we need to understand the scientific rationality by;

1. Confirming farmers' assertions on their efficacy.
2. Explaining mode of actions.
3. Optimizing their efficacy.

Methodology



Preparation

- ❖Boil 2 kg of fish in 5L of water for 45 mins
- ❖Add 450g of white sugar, stir and sieve.

Methodology cont’

Layout:

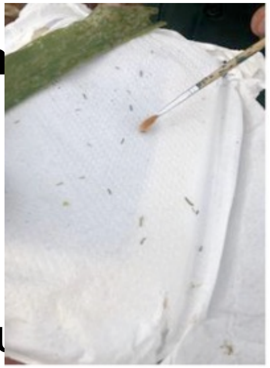
❖ 12 blocks with 5 potted plants

❖ Randomized Complete Block design

Artificial infestation

❖ 30-50 eggs per plant

❖ 4-week-old maize



Treatments:

1. 100% fish soup+su
2. 50% fish soup+sugar
3. 10% fish soup+sugar
4. Water/control

Treatment application:

❖ 15L-Knapsack hand pump

Data collection:

❖ After treatment application for 14 days

❖ Damage, recovery, plant height, chlorophyll content

Results

Effect of fish soup application on foliar damage and recovery of maize plants

Plants treated with fish soup+sugar solution had less FAW damage and high recovery rate while plants under control treatment showed damage continued and no recovery

Infested crops at the beginning of experiment

(day2)

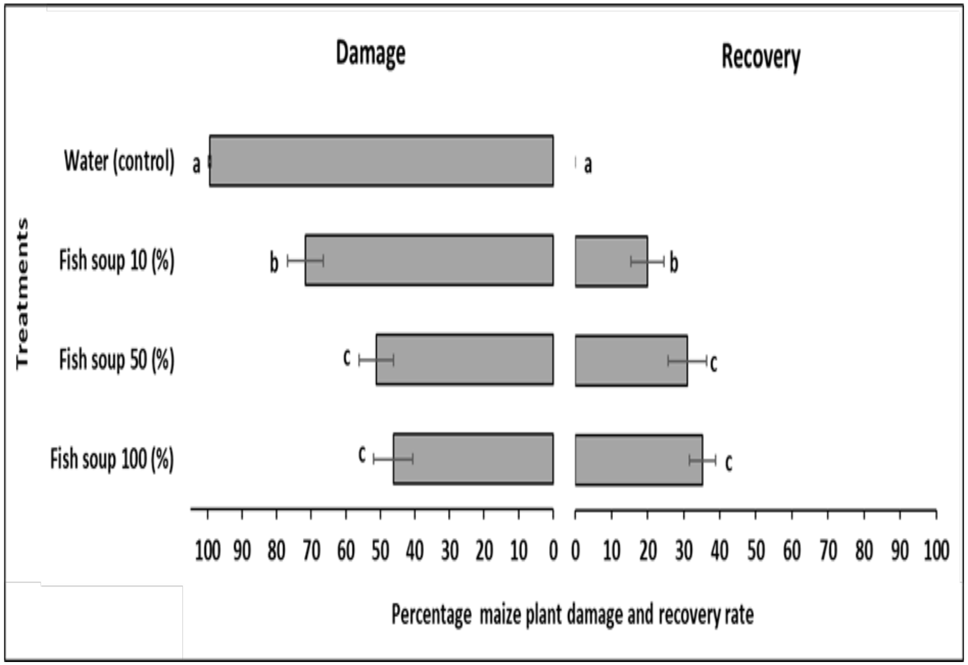
Recovered crop after treatment with soup. Yellow spots are previous lesions

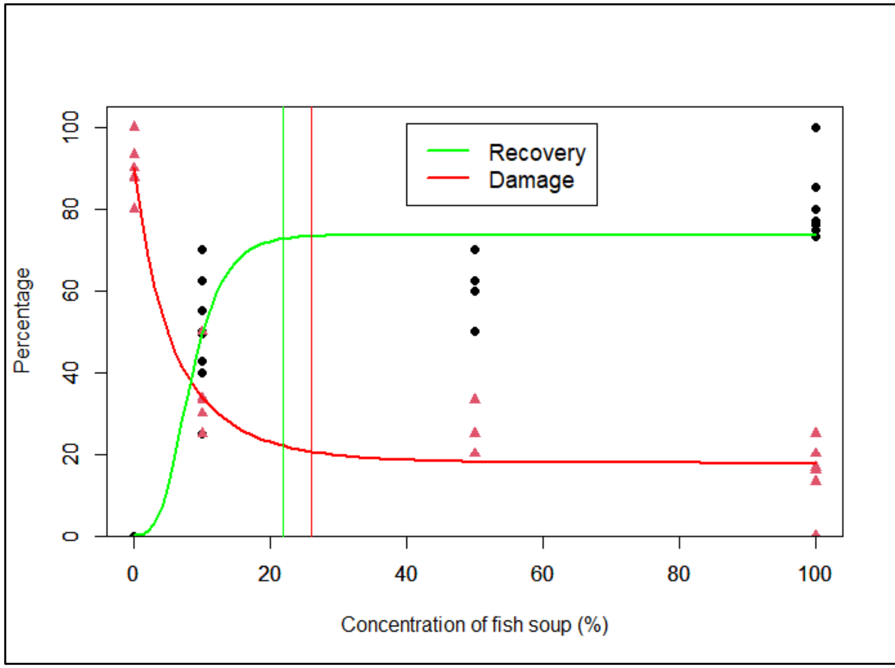
(Day 14)

Control crops continued damaged

(Day 14)

Correlation between recovery and damage





Preparation

- Boil two kilograms of sun-dried fish (*Rastrineobola argentea*) in 5L of water for 45 minutes.
- Add 450g of white sugar, stir, sieve and allow to cool.
- Prepare a series of dilutions of 100%, 50% and 10% by adding water.
- Apply on crops.

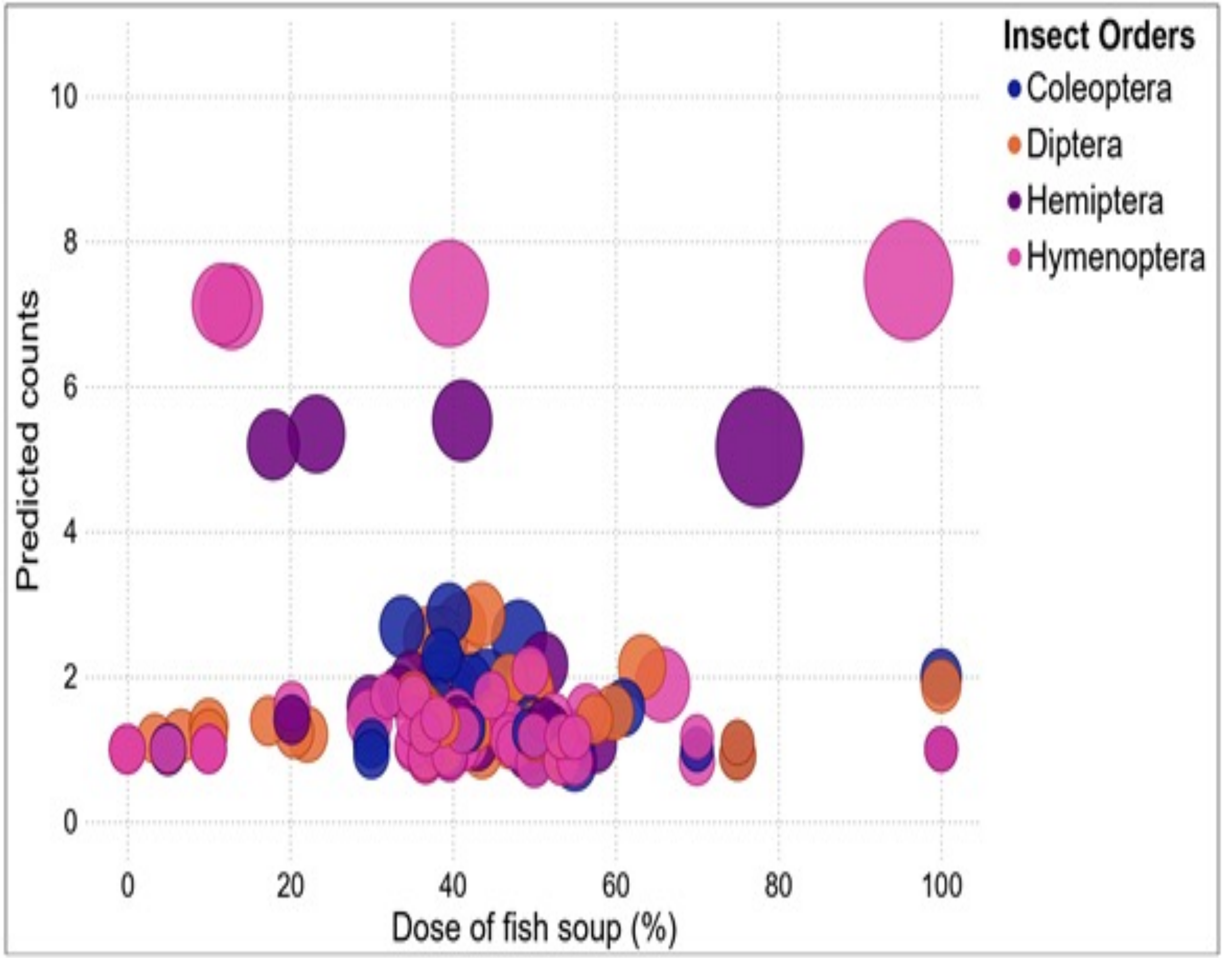
Results

- Maize plants treated with fish soup attracted more abundant and diverse orders of insects than maize treated with water only.
- Ants and wasps (Hymenoptera), flies (Diptera), lady bugs (Coleoptera) and true bugs (Hemiptera) were the main four taxonomic orders of insects observed.
- Their abundance occurred as follows: 1096, 475, 426, and 253, with a Shannon-Weiner diversity index of 4.8, 5.3, 4.0, and 5.5, respectively.

Insect order	Treatment type	Abundance	Species richness	Shannon-Weiner diversity index	Evenness
Coleoptera	Fish soup (10%)	71	41	3.4	0.9
	Fish soup (50%)	95	56	3.8	0.9
	Fish soup (100%)	149	79	4.1	0.9
	Control	93	51	3.7	0.9
Diptera	Fish soup (10%)	164	102	4.4	1.0
	Fish soup (50%)	105	68	4.0	0.9
	Fish soup (100%)	89	48	3.6	0.9
	Control	60	39	3.5	0.9
Hemiptera	Fish soup (10%)	30	14	2.5	0.9
	Fish soup (50%)	50	23	2.7	0.9
	Fish soup (100%)	79	27	3.0	0.9
	Control	84	17	2.2	0.8
Hymenoptera	Fish soup (10%)	278	93	3.9	0.9
	Fish soup (50%)	210	49	2.9	0.8
	Fish soup (100%)	400	62	3.0	0.7
	Control	118	55	3.7	0.9

Insect orders diversity across concentrations.

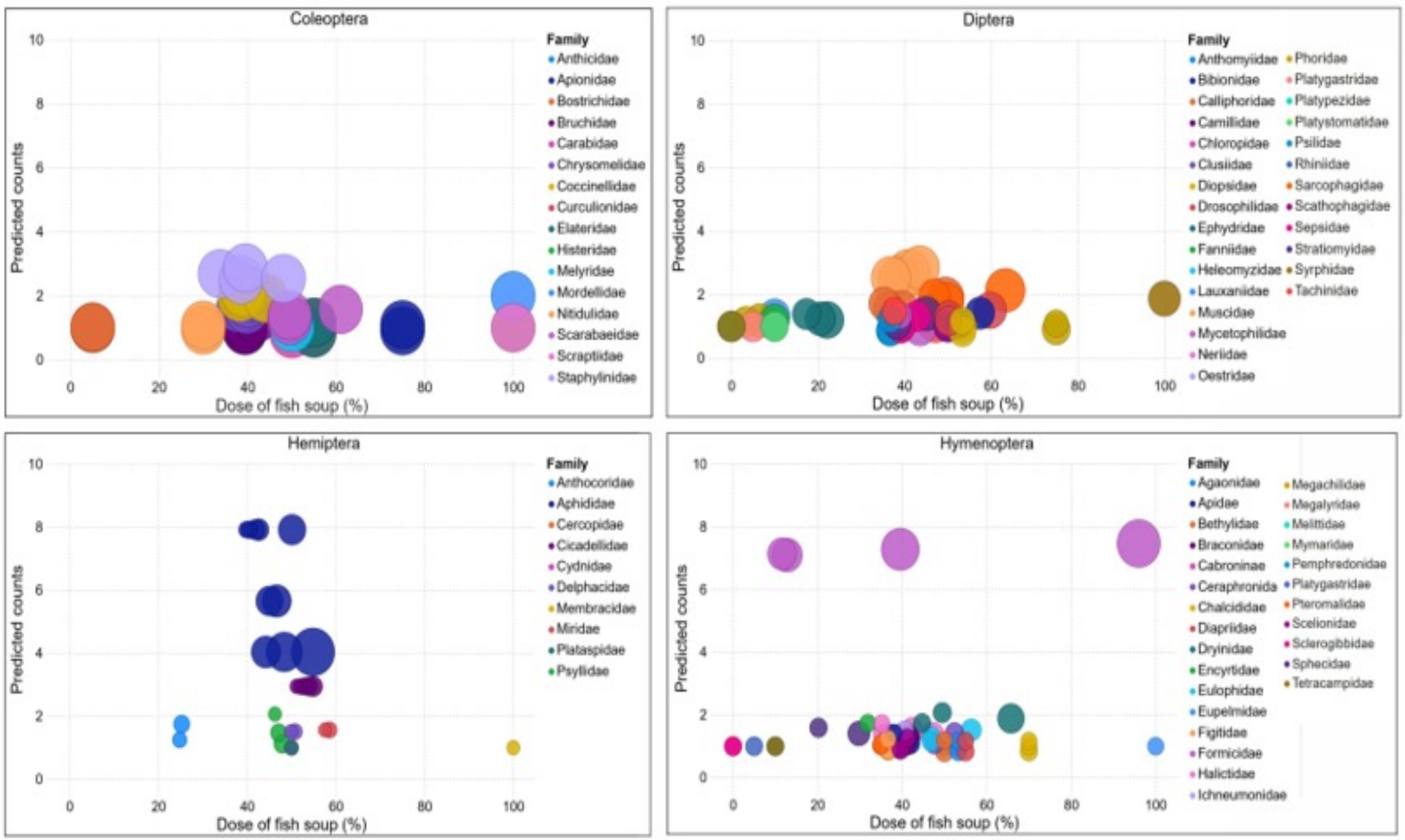
- A probit regression confirmed that the number of insects in different orders varied across fish soup concentrations
- The highest frequency of Coleopterans, Dipterans, Hemipterans and Hymenopterans are recorded at 30-60% concentration of fish soup.



Diversity of insects visiting FAW-infested maize plants

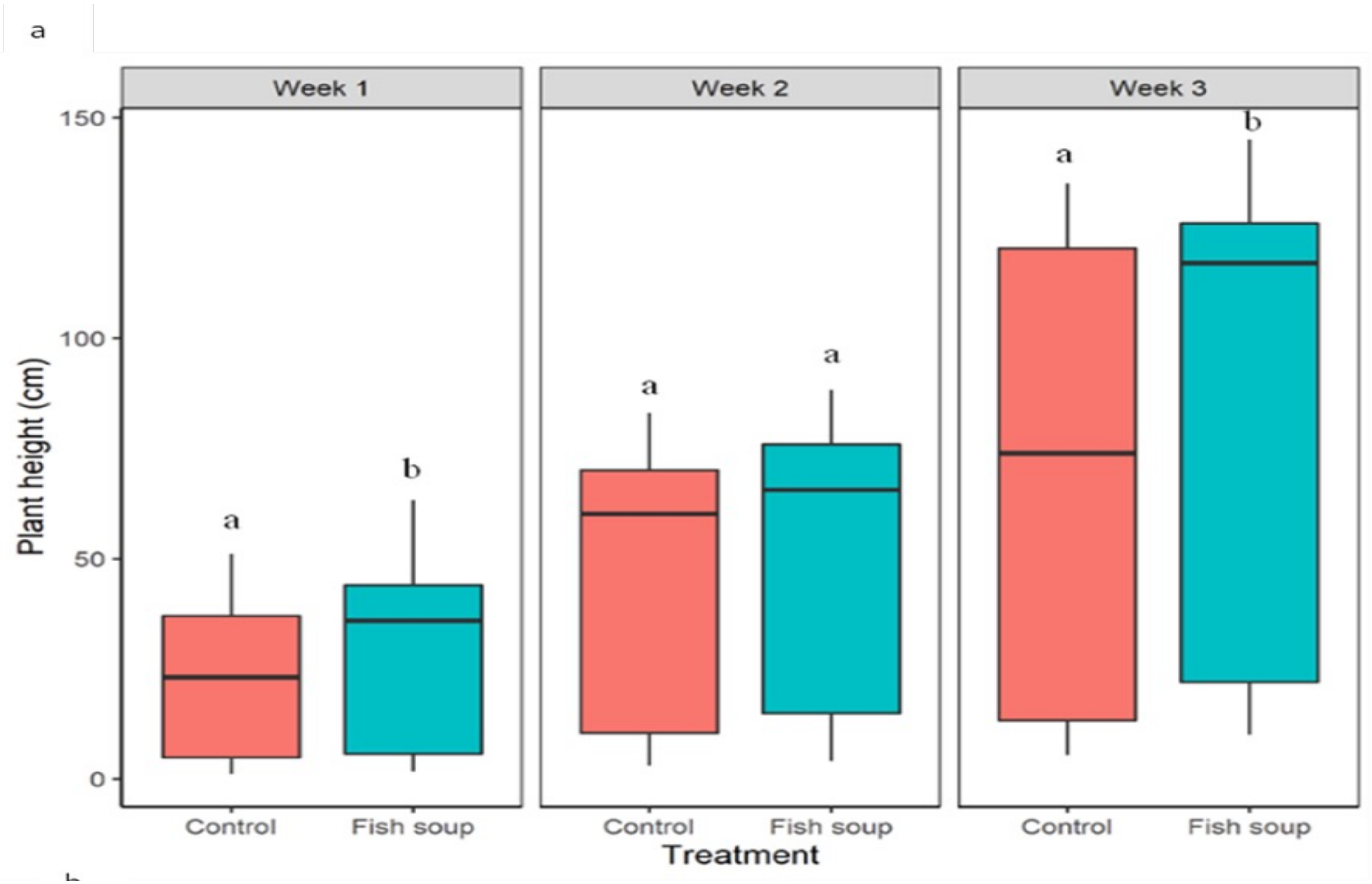
- Unlike the dipterans, the abundance and diversity of coleopterans and hemipterans increased with the fish soup concentration.
- The abundance and diversity of hymenopterans were least affected by fish soup concentration.
- The most abundant insect families were Formicidae, Aphididae, Muscidae, Coccinellidae, Chrysomelidae and Dryinidae.

Insect families across different concentrations of fish soup.

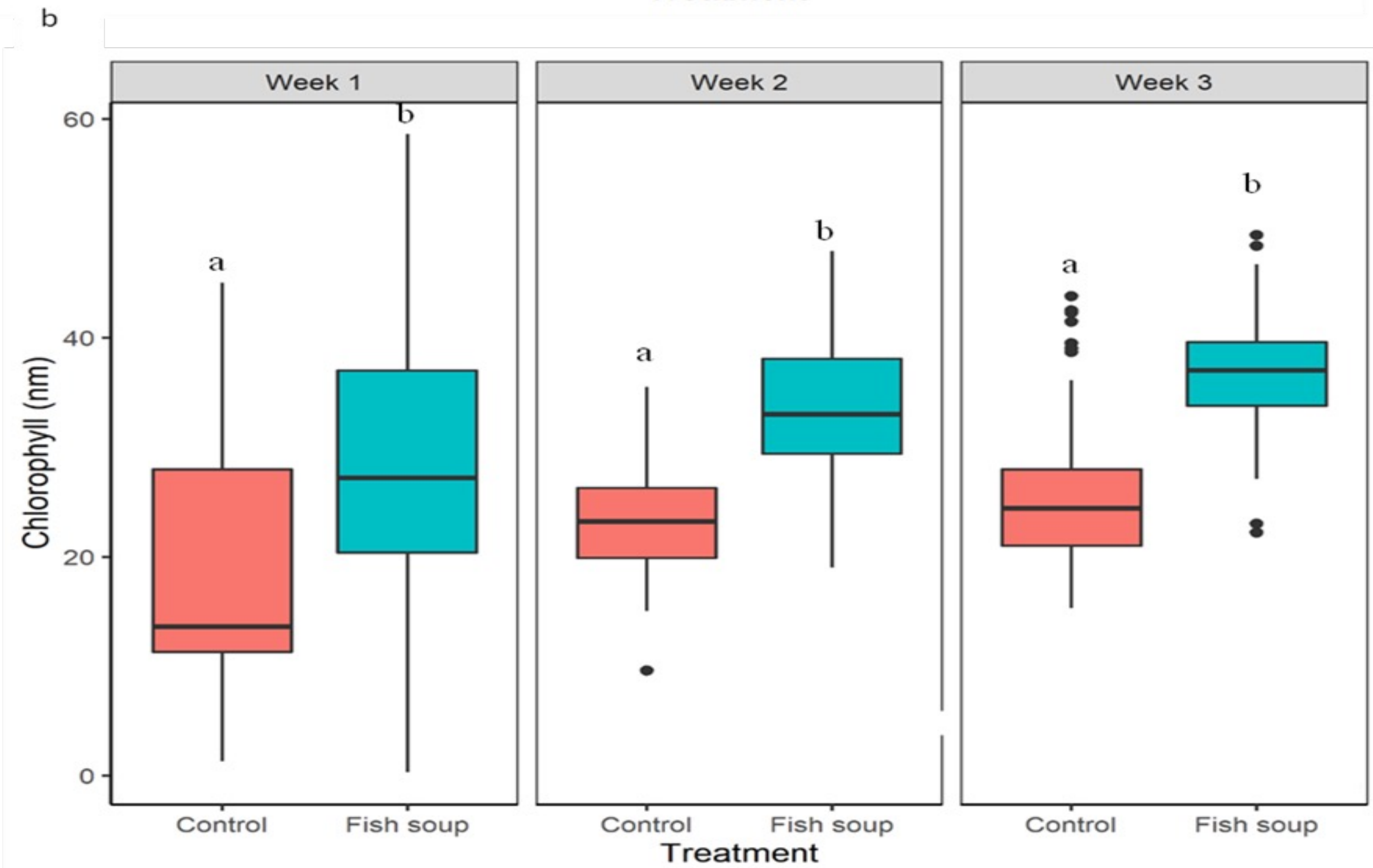


1a
1b
1c
1d
1e
1f
1g
1h
1i
1j
1k
2a
2b
2c
2d
2e
2f
2g
2h
3b
3c
3d
3e
3f
3g
3h
3h
4
5
6a
6b
6c
7
8
9a
9b
10
11a
11b
12a
12b
13
14
15
17
18
19a
19b
21a
21b
22
23a
23b
23c
24a
25a
25b
26
27

Effect of fish soup on maize plant Height



Effect of fish soup on maize plant Chlorophyll content



Conclusions

- This study confirms farmers assertions that fish soup+sugar are effective indigenous methods against FAW.
- Fish soup+sugar reduce FAW damage to plant while promoting recovery of FAW-infested plant.
- At least 22% of fish soup+sugar solution is needed to spray infested maize plants
- Fish soup serves as a liquid manure that enhances crop health (plant height and chlorophyll) against fall armyworm damage.

Recommendations

- ❖Field trials with farmers are needed to assess and validate the effect of fish soup+sugar solution on management of FAW, plant growth and yield parameters.

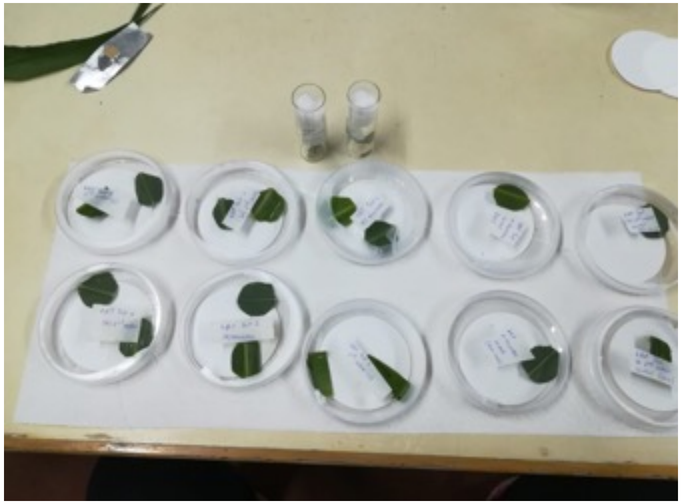
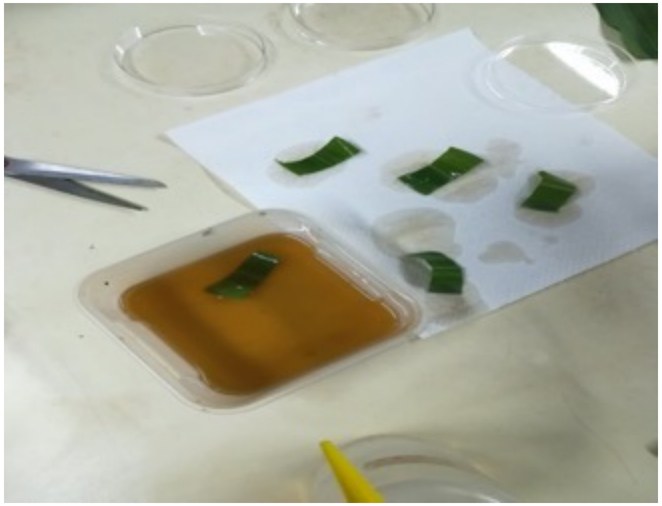
.

Conclusions

Based on these observations, we conclude that the use of fish soup for fall armyworm management deserves particular attention.

Field validation studies, economic analysis, product development, and optimisation are required.

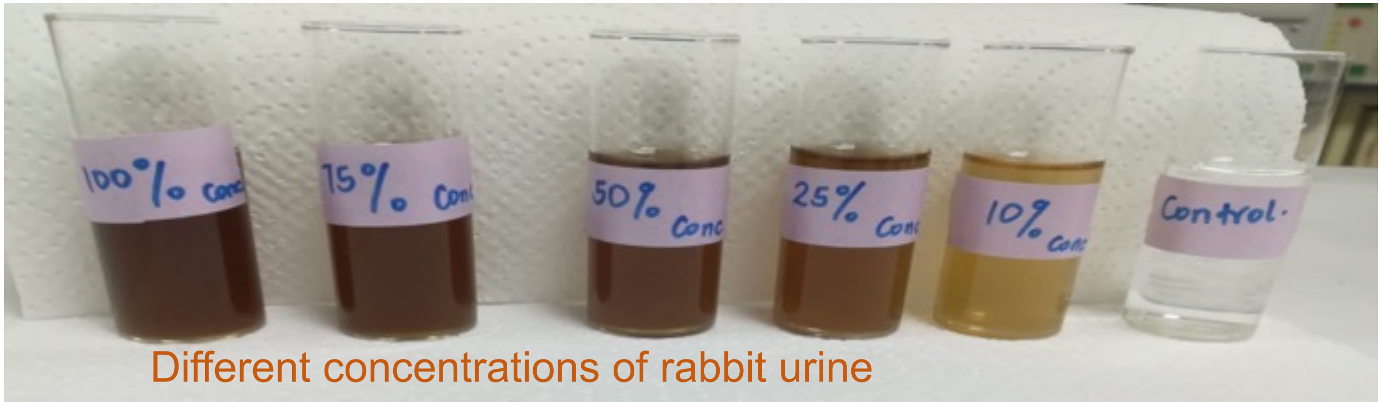
Larval settlement, orientation, arrest and dispersal

Petri

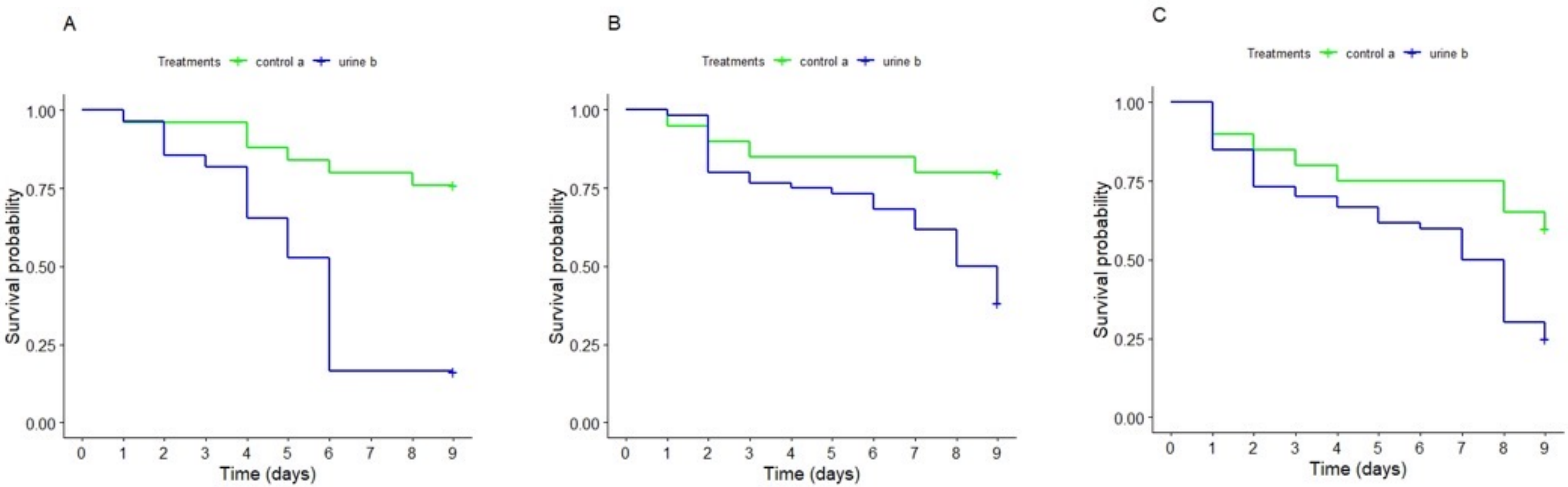

Petri dishes arranged in a reverse photo booth

Larval dose-response



Dose-damage response (LD_{50}) and regression slope and fiducial limits (FL) of FAW fall armyworm *Spodoptera frugiperda* developmental stages feeding on maize treated with rabbit urine.

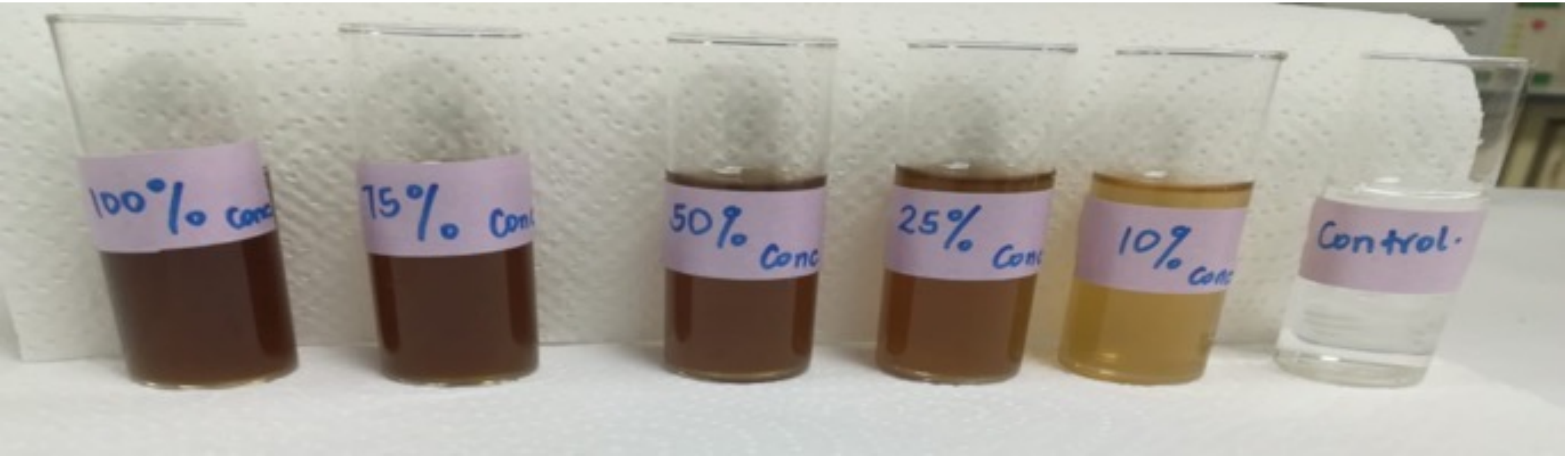
Stages of Spodoptera frugiperda	Slope (± SE*)	LD_{50} (± %FL)
Neonates	1.51 ± 0.01	48 (42, 57)
2nd Instar	4.61 ± 0.02	94 (90, 99)
3rd Instar	2.24 ± 0.01	55 (50, 60)



Kaplan-Meier survival distribution curves of fall armyworm neonates (A), second instar larvae (B) and third instar larvae (C) exposed to rabbit urine or distilled waters (control).

Larval Survival

Larval dose-response

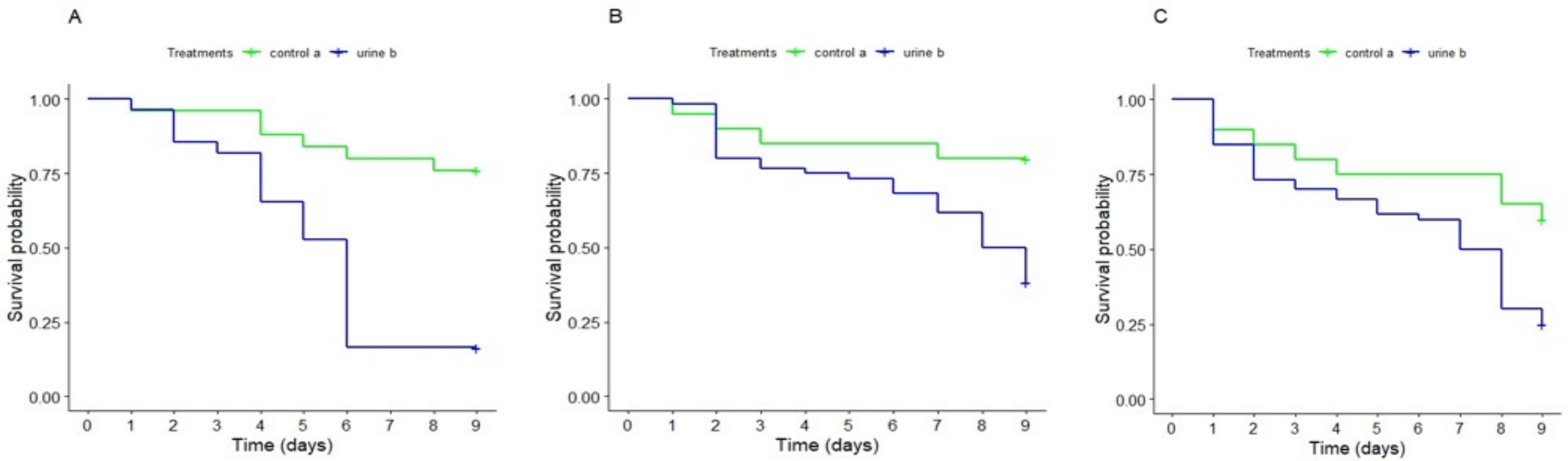


Different concentrations of rabbit urine

Stages of Spodoptera frugiperda	Slope (± SE*)	LD_{50} (± %FL)
Neonates	1.51 ± 0.01	48 (42, 57)
2nd Instar	4.61 ± 0.02	94 (90, 99)
3rd Instar	2.24 ± 0.01	55 (50, 60)

Dose-damage response (LD_{50}) and regression slope and fiducial limits (FL) of FAW fall armyworm *Spodoptera frugiperda* developmental stages feeding on maize treated with rabbit urine.

Larval Survival



Kaplan-Meier survival distribution curves of fall armyworm neonates (A), second instar larvae (B) and third instar larvae (C) exposed to rabbit urine or distilled waters (control).

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

EUROPEAN UNION

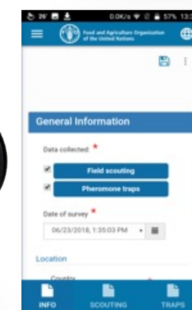
Informed decision
- Plan
- Prioritize
- Prepare

Pheromone Trapping

Effective Field Scouting

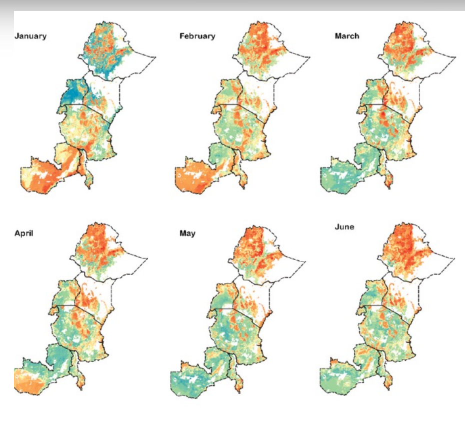
Adult and larvae scouting

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



Data Transmission using FAMEWS

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



Newsletter
Modelling and dissemination

Global Ecology and Conservation 35 (2022) e02056

Contents lists available at ScienceDirect

Global Ecology and Conservation

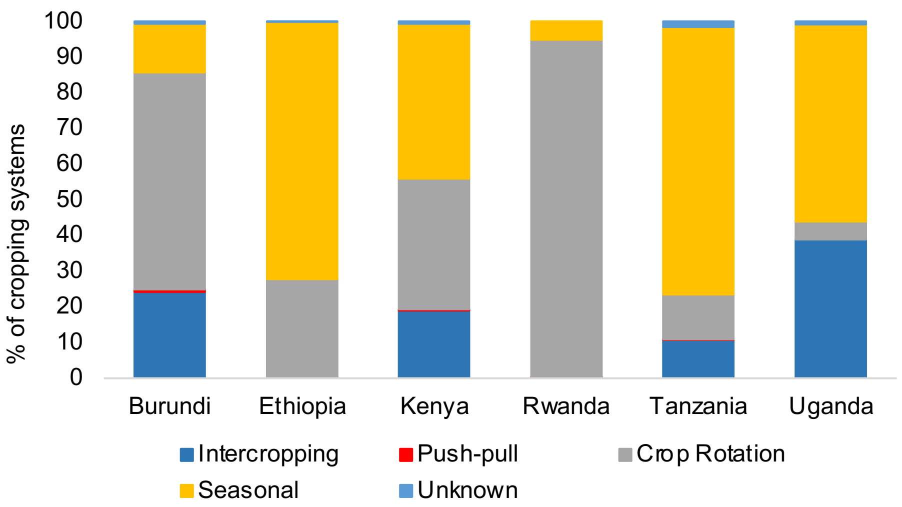
journal homepage: www.elsevier.com/locate/gecco

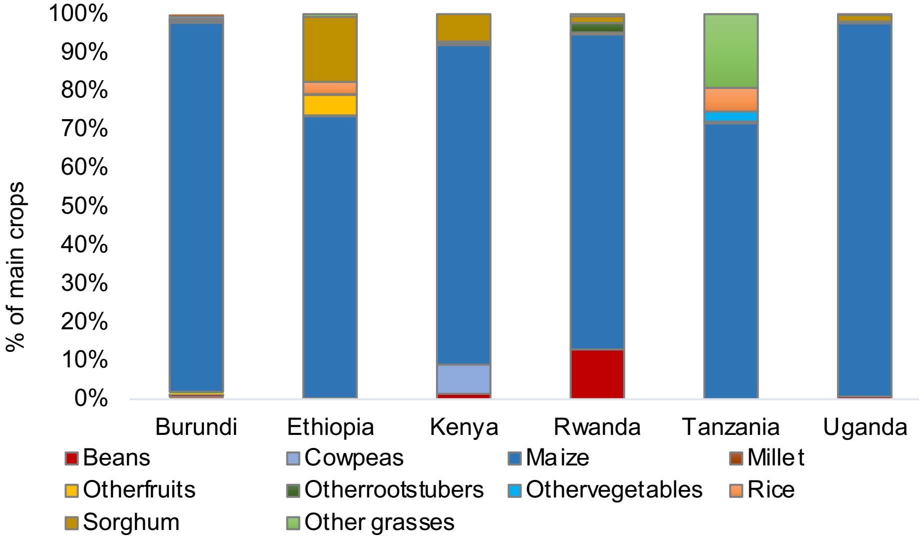
ELSEVIER

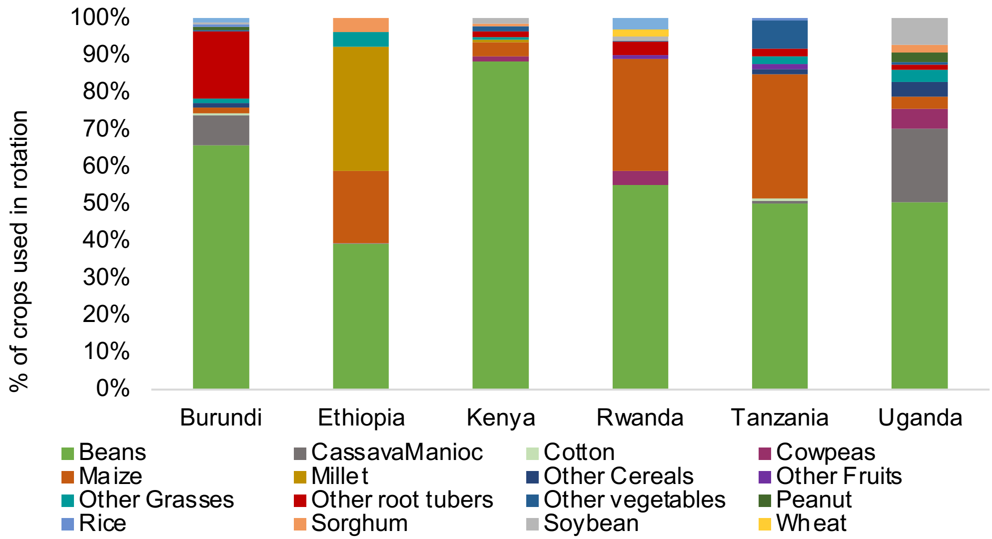
Harnessing data science to improve integrated management of invasive pest species across Africa: An application to Fall armyworm (*Spodoptera frugiperda*) (J.E. Smith) (Lepidoptera: Noctuidae)

icipe

Cropping Systems: Main and Rotation in East Africa



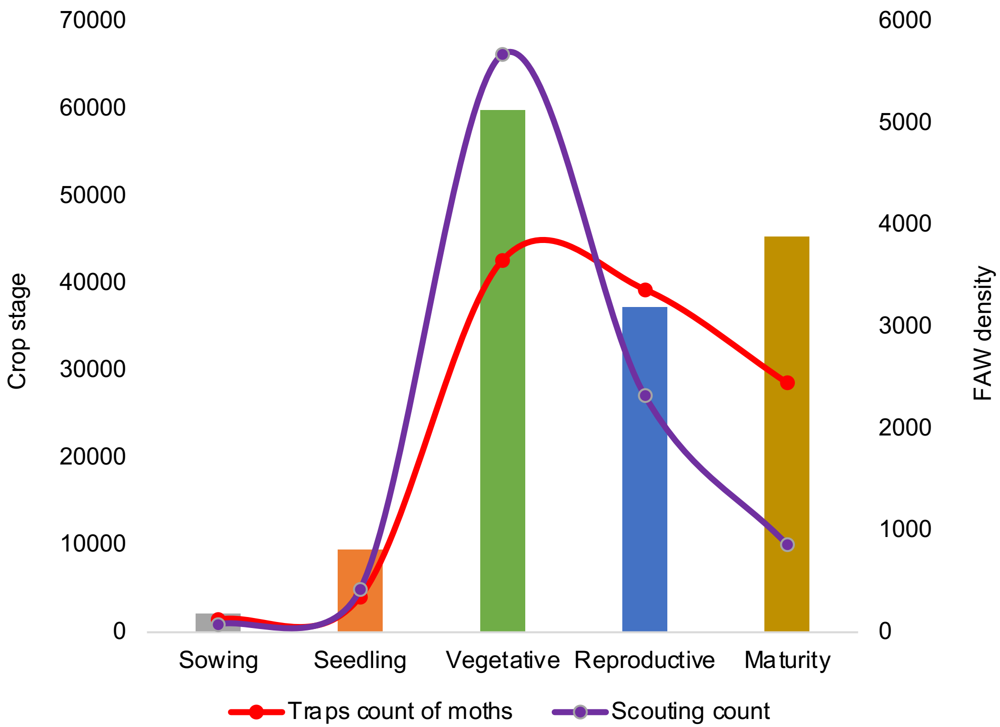


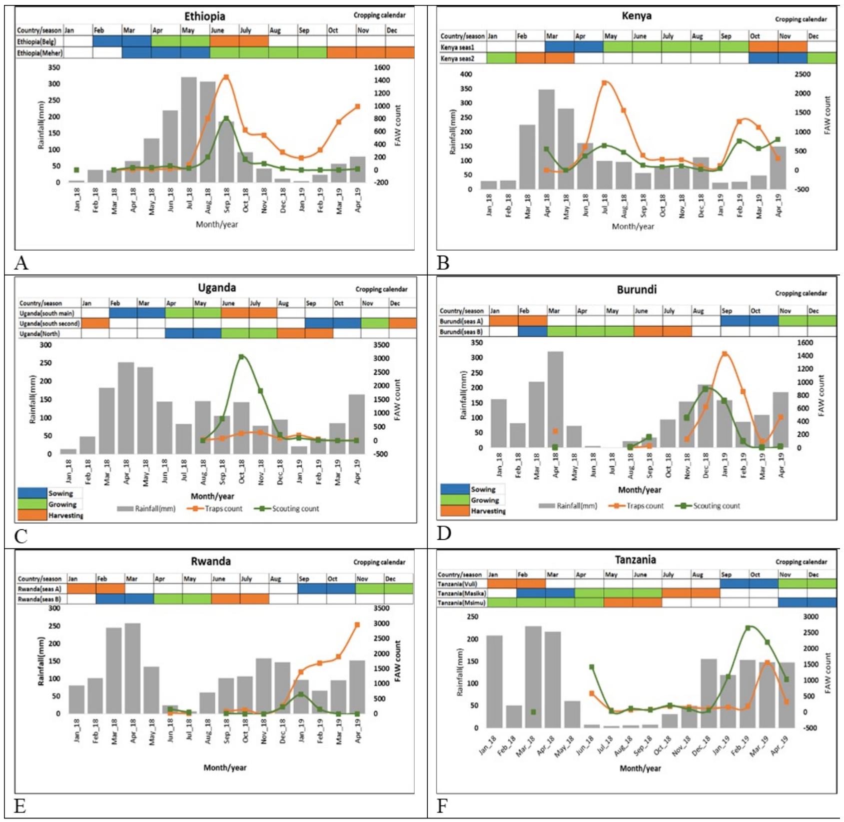


The farming and cropping systems are very diverse in East Africa and these have a direct bearing on FAW incidence.

icipe

Crop stage and Rainfall influence on FAW dynamics in a season length





Rainfall (Water availability + Mechanical control) and Soil health are important factor influencing FAW incidence and crop performance.

Donor Acknowledgement

Direct Financial Support to *icipe* from:-

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Agency for Development and Cooperation SDC

Sida

Foreign, Commonwealth & Development Office

Government of Kenya

Federal Democratic Republic of Ethiopia

African Union

ASI Make it Happen

AWARD African Women in Agricultural Research and Development

Australian Government
Australian Centre for International Agricultural Research

Austraining International

Bayer

Bertha Foundation

Bill & Melinda Gates foundation

BBSRC bioscience for the future

Government of the Republic of Benin

Government of Burkina Faso

British Council Institutional Links

Newton Fund

BioInnovate Africa

biovision

Biovision Africa Trust

Cambridge Africa

BMZ Federal Ministry for Economic Cooperation and Development

CIM Centre for International Migration and Development
a joint operation of GIZ and the German Federal Employment Agency

cirad Agricultural Research for Development

Government of Côte d'Ivoire

Conservation International

CNHR Consortium for National Health Research

CS&S Code for Science & Society

DAAD Deutscher Akademischer Austausch Dienst
German Academic Exchange Service

DANIDA

DFG Deutsche Forschungsgemeinschaft

ECC-SDCOH

Embrapa

ETH zürich

FAO Fiat Panis

FiBL

Ford Foundation

FNSNF

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Government of Ghana

Google.org

Grand Challenges Canada
Grands Défis Canada

IAEA

IDRC CRDI

IFAD Investing in rural people

IFS International Foundation for Science

iie

impaxio

IRD Institut de Recherche pour le Développement France

Innovate UK

IVCC Combating Insect Borne Disease

JRS Biodiversity Foundation

Fondation L'Oréal

Government of South Korea

JIRCAS Japan

Keele University

mastercard foundation

Max Planck Institute for Chemical Ecology

The McKnight Foundation

Ministry for Foreign Affairs of Finland

moz://a

Government of Mozambique

National Academy of Sciences

National Geographic Society

NIH National Institutes of Health

NRF Kenya National Research Fund

NSF

Netherlands Directorate-General for International Cooperation.

NWO

Open Philanthropy

PELUM Association
Networking for a greener Africa

R. Geigy-Stiftung

Russell IPM Integrated Pest Management

Norad

The Rockefeller Foundation

The Royal Society

rss remote sensing solutions

Scottish Funding Council
Comhairle Maoineachaidh na h-Alba

Government of Rwanda

Government of Senegal

switchafrica green

The World Bank IBRD • IDA | World Bank Group

twas

UNEP

University of Glasgow

USAID From the American People

USDA

Vetenskapsrådet

VolkswagenStiftung

wellcome

World Federation of Scientists

World Health Organization

World Trade Organization

WSD

www.icipe.org

icipe