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Fall Armyworm Management for Maize Smallholders in Malawi:
An Integrated Pest Management Strategic Plan

USAID FROM THE AMERICAN PEOPLE
United States Department of Agriculture Foreign Agricultural Service
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Oregon State University
CRS CATHOLIC RELIEF SERVICES
CIMMYT International Maize and Wheat Improvement Center
CGIAR RESEARCH PROGRAM ON Maize

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An Integrated Pest Management Strategic Plan

Summary of an In-country Consultation
February 2019

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Partners

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List of Acronyms & Abbreviations

ADD	Agricultural Development Division
APPSA	Agricultural Productivity Program for Southern Africa
Bt	*Bacillus thuringiensis*
CADECOM	Catholic Development Commission of Malawi
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CRS	Catholic Relief Services
DADO	District Agriculture Development Office
EPA	Extension Planning Area
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAW	fall armyworm
FFS	Farmer Field School
HHP	highly hazardous pesticide
IPM	integrated pest management
KULIMA	Kutukula Ulimi m'Malawi (Chichewa for "Promoting farming in Malawi")
ml	milliliter
NGO	non-governmental organization
NPV	nuclear polyhedrosis virus
PCI	Project Concern International
PHI	pre-harvest interval
PPE	personal protective equipment
REI	re-entry interval
TV	television
UBALE	United in Building and Advancing Life Expectations
US	United States
USA	United States of America
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

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Purpose of this IPM Strategic Plan

The purpose of this strategic plan is to lay a foundation for increased use of integrated pest management (IPM) for reducing economic, health, and environmental risks and hazards posed by current fall armyworm (FAW) management practices by maize smallholders in Malawi. The plan outlines other major maize pests in addition to FAW, current management strategies, and critical pest management needs, as informed by farmer and extension worker focus groups. This plan is based on the IPM Strategic Planning consultation method used in the Western US (Murray and Jepson, 2019).

This plan serves a number of important functions. It can be used to enhance understanding of current practices with respect to pest management in maize-based cropping systems in Malawi, including the current use of pesticides, cultural practices, and biological control. The plan also includes comprehensive and detailed lists of stakeholder-derived critical needs across multiple sectors, which can be consulted and acted upon as a part of the FAW response in Malawi.

The document begins with an overview of maize production in Malawi, including background on the invasion of FAW. The remainder of the document is an analysis of current management strategies as reported by the focus group participants. Current management is presented by crop growth stage in an effort to assist the reader in understanding whole-season management practices. The critical pest management needs are presented by crop stage and within thematic groups covering pesticide risk management, research, extension education, and regulatory issues.

Note: *Pesticide active ingredient and trade names for certain pesticides are used throughout this document as an aid for the reader. The use of ingredient or trade names in this document does not imply endorsement of specific products by the authors of the report or by the organizations publishing this report.*

Executive Summary

In an effort to assess current status and identify critical challenges and priorities related to the management of fall armyworm (*Spodoptera frugiperda*; FAW) in the maize production systems in Malawi, a comprehensive in-country consultation was conducted. The consultation included four focus groups with farmers and extension agents from two southern Malawi districts as well as short informative meetings and interviews with agro-dealers, researchers, government officials, and aid/support organizations.

Key Findings

Farmers: Farmers have only limited access to education about IPM for effective management of FAW or any other pest. Specifically, farmers lack basic information about FAW biology and behavior that would enable them to target planting dates and management interventions, including pesticides and the timing of treatments. A significant proportion of farmers do not have the resources to buy seed or other inputs, and for those that do, affordable, validated, and low-risk alternatives are not generally available.

Farmers are applying synthetic/chemical pesticides with high risks to human health, birds, mammals, aquatic species, and pollinators without the use of personal protective equipment (PPE) or application equipment. Pesticide selection is limited by what is available in the marketplace, which does not always correspond with current recommendations. Availability itself is limited by product costs, farmer demand, and a lack of critical information and capacity in the evaluation, recommendation, and procurement pathways. Farmers need training on pesticide selection and use, based on risks and efficacy, as well as training on effective IPM alternatives including locally derived and accessible management methods.

Women make up the majority of the agricultural labor force in Malawi (reported to be as high as 80% in some areas), which places a disproportionate burden of risk on this population and requires a more targeted effort to address capacity development among women farmers.

Extension: Malawi has a very well-structured extension delivery system, with expertise in topical areas including water and soil conservation, fisheries, agricultural production, and livestock. Extension workers serve 29 districts across the country, through 8 Agricultural Development Divisions (ADDs) at the regional and subregional level, District Agriculture Development Offices (DADOs) at the district level, and Extension Planning Areas (EPAs) and sections at community level.

However, the capacity within this system is severely limited by a 40% vacancy in field positions and lack of programmatic resources (e.g., travel and information dissemination programs) for effective and thorough engagement of the farmers. Organizations and agencies providing agricultural support need to partner more closely with extension to best leverage existing resources and avoid duplication of effort, which also directly impacts extension capacity.

In order to support pesticide risk reduction within the currently recommended FAW management scheme, capacity development of extension personnel is needed in the areas of pesticide selection based on risk and efficacy; pesticide risk management, including application and safety; and IPM program development and delivery, including biologically and locally derived management strategies. Extension workers themselves carry out pesticide applications during pest outbreaks and are exposed to high health and safety risks and hazards because they do not have access to PPE.

Research: Current FAW research goals at Bvumbwe research station, the main site of pesticide efficacy trials and the source of government procurement recommendations, are well aligned with a reduced-risk approach to FAW management, but these goals are inhibited by challenges related to insufficient funding, infrastructure, equipment, and personnel. Additional training in pesticide science (including methods for evaluating pesticide efficacy and toxicity) and risk (including impacts to human health, environment, and natural enemies) would contribute effectively to research targeting reduced-risk approaches to FAW management.

Regulatory: Malawi pesticide regulatory decisions should take into account the lack of access to PPE among farmers, and also a lack of application equipment. Product evaluation should include assessments of product efficacy against target pests, toxicity risks to human health and the environment, and labeling that supports end-user risk management (e.g., native-language labeling with clear instructions for pesticide dilution and application).

Agro-dealers: Agro-dealers lack training in pesticide science and properties including efficacy and risk management. Pesticides are stocked based on farmer demand, which is influenced largely by word of mouth and affordability. Capacity development for agro-dealers will contribute to a more science-based pesticide selection process, which will reduce both pest incidence and pesticide risks.

See also “Pesticide Risk Management in Malawi: Key Findings” (p. 5).

Overall Recommendations

Multiple strategies are needed for advancing IPM for FAW management in developing countries. Key among these is a transition from the use of high-risk pesticides to lower-risk pesticides, because use of the former represents a major barrier to IPM adoption and poses significant health and environmental hazards.

Our practical recommendations include:

- **Evaluate, register, and recommend only low-risk pesticides that can be used safely and without PPE.**
    - To limit access to and use of high-risk pesticides, research, regulatory, and government agencies, including the pesticide control board in Malawi, should develop criteria for low-risk and affordable pesticides, in partnership with local regulatory authorities. Only pesticides meeting these criteria should be evaluated, registered, and recommended for inclusion in government advisory documents. Mechanisms should be developed for review and revocation of registration for high-risk pesticides that are incompatible with smallholder farmer limitations and IPM strategies.
    - To validate pesticide efficacy and raise awareness among farmers, extension workers could be tasked with evaluating candidate low-risk pesticides locally (once registered), in conjunction with locally adopted IPM practices.
- **Develop and strengthen communication pathways that advance IPM, and human and environmental health, within current institutional structures.**
    - Promote stronger collaboration between researchers, extension, and farmers, including live and virtual platforms and opportunities for increased communication and interaction.

  - Conduct meetings with importers, agro-dealers, and extension workers to encourage farmers to request, and agro-dealers to stock, low-risk, efficacious pesticides, and to align recommended pesticides with what is used.

- **Strengthen research and extension infrastructure in addition to farmer and trainer training programs.**
  - Ensure that NGOs and other agencies partner closely with extension to best support and leverage existing capacity.

- **Institute mechanisms for monitoring progress toward lower-risk pesticide use and IPM adoption.**
  - Conduct regular surveys on pesticide use patterns, grower-rated efficacy, and IPM alternatives, and utilize data to set research and regulatory priorities and to promote effective non-pesticide approaches. Surveys could include sales from agro-dealers, use among farmers, level of access to low-risk pesticides in the marketplace, and needs assessments for IPM practices and levels of adoption.
  - Track status and trends in pesticide hazards and risks among registered products, recommended products, and currently used products: three categories that have little overlap in practice.
  - Based on surveys and tracking, report challenges and barriers to progress to government entities that evaluate and register pesticides so that adjustments can be made in pesticide availability and access.

- **Build on local knowledge, and include locally derived strategies in research and efficacy trials.**
  - Engage farmers and extension workers in identifying practical solutions that account for their extreme resource and information constraints. Obtain ideas for practical and effective management as much as possible from those that resource-restricted farmers are already pursuing and testing.
  - Lower-risk control methods, including the use of locally derived botanicals, are already being tested by farmers using a farmer innovations approach such as that promoted by the UBALE (United in Building and Advancing Life Expectations) project. Farmers in learning centers have demonstrated readiness to assimilate new knowledge. Integrating these lower-risk, locally tested methods into formal research trials is critical for identifying practical solutions.

- **Prioritize capacity development across sectors (e.g., research, extension, farmers, agro-dealers) in pesticide science and selection including efficacy, toxicity, application safety (application method, dilution, PPE), and impacts to natural enemies.**
  - Conduct country-wide pesticide risk management training and information campaigns that include researchers, extension workers, farmers, agro-dealers, NGOs, and other agencies working on agricultural issues.

- **Continue to support research toward the development of improved maize varieties with native genetic resistance to FAW, and ensure that these are accessible to farmers with very limited resources to purchase seed.**

[photos: "sprayer" and "application"]

Pesticide Risk Management in Malawi: Key Findings

We include here some specific findings related to the current status of pesticide use in FAW management in Malawi in an effort to elicit targeted responses aimed at pesticide risk reduction. Specific needs and recommendations related to pesticide risk management are outlined in later sections and tabulated in the Appendix.

Pesticide procurement and distribution without adequate safety guidance: Before the FAW invasion, the government had occasionally undertaken African armyworm spraying campaigns with the extension service, but had not distributed pesticides to maize farmers. In 2017/18, approximately 18,000 liters of pesticides, including the organophosphate pesticide chlorpyrifos, were purchased by the Malawi government for distribution in response to the FAW invasion. For 2019, that number rose to 30,000 liters. Information about pesticide handling and safety did not accompany this pesticide distribution, and there is a general lack of understanding of the risks associated with the use of pesticides.

Lack of personal protective equipment: PPE is not available/accessible to either farmers or extension workers, who often apply pesticides on behalf of the Malawi government. Extension workers report that only about 1–2% of farmers are using any type of PPE. Agro-dealers report that there is a lack of understanding of the importance of PPE, and that very few farmers are asking for gloves or protective gear. Farmers did not report using any PPE. These items are not stocked in agro-dealer shops and would not be available even if requested by farmers or extension workers. Farmers reported experiencing pesticide health impacts including dizziness and burning skin and eyes.

Toxicity of products in use: The two most commonly used pesticides in maize were reported to be (1) profenofos, an organophosphate that is not approved by the EU and is no longer registered in the USA following a US Environmental Protection Agency determination that the human and ecological risks outweighed the benefits of use, and (2) cypermethrin, a synthetic pyrethroid associated with documented FAW resistance (Yu, 1992; Al-Sarar *et al*., 2006; Mota-Sanchez & Wise, 2019). Neither of these products are on the current Malawi government recommended list, and both of them carry risks associated with use, including risks to human health, birds, mammals, aquatic species, and pollinators (Jepson *et al*., 2014; Jepson *et al*., 2018).

Farmer's application method for pesticides: Cypermethrin is most commonly applied by the farmers in Malawi using water bottles with holes in the lid to sprinkle the pesticide directly into the whorl, using minimal dilution. Profenofos is commonly applied using straw brooms that are dipped into the diluted product and splashed onto leaves.

Labels and packaging: Pesticide labels in Malawi are written in either English or Portuguese (for products brought in from Mozambique, which is common), and most farmers cannot read the information on the labels. Pesticides are usually sold in 1-liter or higher packaged quantities, when the need for many smallholder farmers, and their ability to afford the product, is much less. Calculations on dilution and area are a challenge for agro-dealers, extension workers, and farmers, and government advice only includes recommended concentrations and not application rates. We found toxic pesticides (e.g., pirimiphos-methyl) for sale in unlabeled containers for individual use.

Pre-harvest and re-entry intervals: There is very little awareness of the existence or importance of pre-harvest intervals (PHIs) or re-entry intervals (REIs) associated with the use of pesticides.

Scouting and thresholds: Extension workers and farmers report treatment of FAW when it is found to be present rather than using scouting or threshold-based treatment models to guide treatment decisions (Huesing *et al*., 2018).

Demand-driven system: Pesticide sales are demand-driven, and agro-dealers buy what farmers are asking for, not necessarily what they know works and/or is safe for use without protective equipment. There is no formal education program serving agro-dealers, which leaves them feeling unable to advise farmers on either pesticide efficacy or safety.

Safe disposal: It was reported by extension agents and the agro-dealers that we consulted that expired pesticides are commonly used, and that there are no known options for safe pesticide/container disposal. Further, empty pesticide containers are considered to be an asset, and they are commonly used to store food products (e.g., salt, sugar, etc.). Metal bottles, such as the ones in which cypermethrin is commonly packaged, are especially desired for these purposes. While a container disposal project successfully incinerated close to 350 tons of pesticides, there is only one incinerator for pesticide/container disposal in the whole country, which leaves most pesticide users without safe options for disposal.

Consultation Method

The consultation included discussion, interviews, and focus groups with the following:

FAO Malawi: Review of the history of the FAW outbreak, the government and agency response, and current FAW management projects supported by World Bank APPSA, EU KULIMA, and FAO AGP Farmer Field School (FFS) programs.

Malawi Ministry of Agriculture, Irrigation and Water Development, Director of Crop Production: Review of the history of the FAW outbreak from the Malawian government perspective, development of the response plan, discussion of current programs and planning process for the future, summary of the extension service structure, and discussion of capacity-building and regulatory needs.

USAID Malawi Mission: Summary of needs for Mission, UBALE project, and Malawian government partners; discussion of current World Bank projects.

Ministry of Agriculture, Irrigation and Water Development, Department of Agricultural Research Services—Bvumbwe Agricultural Research Station: Review of FAW research response, including efficacy trials for currently available pesticides; discussion of research priorities for FAW and needs for support and capacity building.

Implementing partners—CRS (Catholic Relief Services), UBALE, Save the Children, and PCI Njira: Review of Farmer Learning Centers; comprehensive summary of maize crop production including insects, diseases, weeds, and typical management responses; review of FAW impacts on the ground and the nature of the pesticide marketplace.

Agro-dealers: Three agro-dealer shops were visited in Blantyre and Chikwawa districts, where questions were asked regarding FAW products preferred by farmers; examination of packages and labels; review of available PPE; discussion of agro-dealer capacity needs. Three agro-dealers also attended our Blantyre extension focus group, as described below.

Extension consultations:

- Blantyre District Extension consultation: Focus group session with extension workers included 17 extension workers/implementing partners (5 female and 12 male) and three agro-dealers.
- Chikwawa District Extension consultation: Focus group session with extension workers included 18 extension workers (5 female and 13 male) and implementing partners from CADECOM (Catholic Development Commission of Malawi).

Extension focus group discussions were focused around the following themes:

- Relationship and patterns of engagement with farmers, the scale of their districts, and farmer client population sizes.
- Review of FAW management approaches and the role of extension in farmer support.
- Discussion of farmer needs for FAW management.
- Discussion of extension worker and agro-dealer practical, logistical, and capacity-building needs.

Farmer consultations:

- Blantyre District farmer consultation: Focus group session with 15 farmers (10 female, 5 male), all members of UBALE Farmer Learning Center.
- Chikwawa District farmer consultation: Focus group session with 36 farmers (23 female, 13 male), all members of UBALE Farmer Learning Center.

Farmer focus group discussions were focused around the following themes:

- Discussion of FAW impacts, management approaches, use of pesticides, and application methods.
- Crop-stage-based review of insect, disease, and weed management and crop production practices.
- Review of farmer needs.

Note: *We would like to thank all of the individuals who have provided information to support this report. We would also like to acknowledge our CRS colleagues for groundwork and interpretation, as well as the extension workers and farmers who generously gave their time and feedback.*

Maize Production in Malawi, and FAW Incidence: An Overview

Maize is a top subsistence crop in Malawi, largely grown by smallholder farmers for home consumption, and with little use as a cash crop. For cash, some farmers also grow pigeon pea, groundnut, tobacco, cotton, and a variety of vegetables. However, food security in Malawi largely depends on sufficient maize production, which accounts for more than half of the caloric intake of households. While there are improved hybrid varieties available in the marketplace, most farmers (reported as 60–70% of farmers) cannot afford these and are using saved seed from previous years' unimproved varieties.

The country largely depends on rainfed agriculture, and maize is grown to coincide with the rainy season. Drought years can greatly impact food security and have been experienced in recent years to varying degrees. Each year, anywhere from 1 to 6.5 million Malawians are classified as food insecure and receive food aid from the Malawi government. That number is around 3 million at present.

In September of 2016, FAW, with a particular preference for maize, began to be reported in the maize fields in Malawi. At the same time that FAW was emerging as a national crisis, approximately 6.5 million Malawians were classified as food insecure and receiving food aid.

With already very constrained resources, the Malawi government needed to articulate a response to this invasive pest. With a low capacity for IPM at this stage in the invasion, the initial response was pesticide-driven. Readily available pesticides in the marketplace, primarily pyrethroids and organophosphates, were identified and tested for efficacy against FAW, and those with acceptable efficacy were then distributed to Malawi farmers beginning in 2017. Since 2017, pesticides including chlorpyrifos and cypermethrin have been distributed across the country for use against this pest.

There are currently six pesticides recommended by the Malawi government as efficacious against FAW: chlorpyrifos, flubendiamide, indoxacarb, deltamethrin, and a combination product containing emamectin benzoate + lufenuron. However, all of the farmers and extension workers consulted reported the use of only two main products: cypermethrin and profenofos. Despite treatment efforts, it is currently estimated that yield losses from FAW are approximately 10%.

In 2017, FAO in Malawi and other organizations advocated for an IPM approach to FAW management. There is currently a 5-year plan drafted by the Malawi government that includes training for farmers and extension workers and additional research including biological control methods. However, significantly more funding is needed to carry this out successfully.

Pest Management Activities by Maize Crop Stage

The following sections outline current pest management activities in maize, organized by major crop stages. The four main crop stages identified by farmers to aid in discussion of management activities are:

Preparation to planting (September–October)

Emergence to vegetative growth (November–January)

Flowering to maturity (January–April/May)

Harvest and post-harvest (April/May–postharvest storage)

In addition to FAW, other major maize pests and their management are included throughout the following sections. These are listed here alphabetically by common name, with species designations from locally relevant literature):

- African armyworm (*Spodoptera exempta*)
- Elegant grasshopper (*Zonocerus elegans*)
- Millipedes (*Omopyge* spp., *Spirostreptus* spp., *Tibiomus* spp. [all reported in Uganda])
- Stalk borer (*Busseola fusca*)
- Termites (*Ancistrotermes latinotus, Macrotermes* spp., *Microtermes* spp., *Odontotermes* spp., and *Pseudacanthotermes militaris* all damage maize in S. Malawi)
- White grub (*Phyllophaga* spp.)
- “Beetles” (unknown spp.)
- Mice (*Mastomys natalensis*, *Arvicanthis* spp., *Gerbilliscus* spp., and others)
- Birds (*Quelea quelea* and others)

- Weeds (*Eleusine indica, Nicandra physaloides, Commelina benghalensis, Dactyloctenium aegyptium, Bidens* spp., *Vernonia* spp., *Rottboellia exaltata, Rhynchelytrum* sp., *Hibiscus* sp., *Acanthospermum hispidum*, and others).

Preparation to planting: (September–October)

Field activities, pests, and pest management activities:
Clearing
Ridging
Plowing
Mulching
Weeding (hand, hoe)
Fertilizer (manure)
Cultivation
Planting (using sticks to insert seed)
Irrigation

November through March is the rainy season in Malawi, and it is the main season for maize production. In southern regions, a second season of production begins after the first season's harvest in the spring; irrigation schemes are developed to support a second harvest.

In preparation for planting, the land is cleared with hoes or slashers. Compost is applied as a mix of crop residue from previous field clearings and manure.

Some farmer learning centers are experimenting with planting methods to improve water storage, including the use of planting pits with up to 4 plants in each pit.

While there is some intercropping of maize with pigeon pea or groundnut, this is not the norm. Some farmers rotate maize with soybean and use cowpea as a cover crop.

Critical Needs from Preparation to Planting:

- Climate change is considered a major challenge, with inadequate or irregular distribution of rainfall, often leading to drought that greatly impacts production. Diseases and pest pressure are other major challenges. Early-maturing varieties are desired now because of the effects of climate change and the risk of drought.
- Low/poor soil fertility is a challenge. Fertilizers are unaffordable for many farmers. Practical, accessible strategies for improving soil fertility are needed.
- Most farmers cannot afford certified seed/improved varieties and rely on saved seed from previous years. This has negative impacts on yield. Increasing access to certified seed of improved varieties would increase food security.
- Control methods for FAW that can be applied before or at planting are needed, including seed treatment, resistant varieties, and other strategies.

Emergence to vegetative growth (November–January)

Field activities, pests, and pest management activities:
Second fertilizer (after germination)
Banking (placing soil around plantings)
Monitoring for pest presence
First and second weeding
Mulching

Pests and Management:

Fall armyworm: FAW is managed in maize when first noticed. Farmers and extension workers reported multiple management strategies, none used alone, and cultural methods used in combination with pesticides.

Cultural control:

- Farmers apply sand, ash, or soap directly into the whorl.
- Farmers physically remove and kill the insects they can find.
- Farmers use crop residue (often from maize but also from other crops) to mulch fields for moisture retention and rain protection. Farmers feel this might also provide some benefit in management of FAW.
- Fish soup: farmers apply small amounts of fish soup, which attracts ants that feed on the FAW larvae.

Biological control and biopesticides:

- Locally derived **neem** (*Azadirachta indica*) solution (applied approximately 3 times/month).
- Locally derived **velvet bean** (*Mucuna pruriens*) solution (applied approximately 3 times/month).
- *Note*: *Neorautanenia mitis* extracts were reported to be used by FAO, but were not mentioned in consultations with extension workers or farmers.

Chemical control:

- **Cypermethrin:** widely used; applied directly to the whorl weekly for approximately 8 weeks or until stalks begin to dry. Minimal dilution is reported. Most common application method is use of a water bottle with a punctured lid. Efficacy varies by region but, overall, farmers and extension workers do not consider this an effective method of control as a stand-alone treatment. Resistance has been noted by extension workers.
- **Profenofos** (**Snocron**; also found as product name **Armycrone**): used in 1 ml product to 1 liter water ratio, applied every 2 weeks for approximately 8 weeks. Most commonly applied to foliage using straw brooms dipped in product solution.
- **Chlorpyrifos:** Agro-dealers reported sales of chlorpyrifos for FAW management, but it was not used by our focus group participants, who reported cypermethrin and profenofos as the preferred products.
- **Indoxacarb** (**Steward**)**:** not accessible, too expensive; agro-dealers do not stock this product.
- **Flubendiamide** (**Belt**)**:** not accessible, too expensive; agro-dealers do not stock this product.

Note: Continuous rain seems to suppress FAW levels and can be beneficial during the first cropping season. Second-season, irrigated maize production during the drier season does not benefit from this natural suppression and thus requires more intensive management solutions.

Beetles: managed with weekly applications of cypermethrin

Elegant grasshopper:

- Physical killing
- Trapping pits
- Chemical control: cypermethrin

African armyworm:
Chemical control (applied by extension workers): cypermethrin

Stalk borer: Stalk borer can be an issue with late plantings in January/February but is not as serious an issue as FAW.

- Sand
- Cypermethrin
- Trichlorfon (Dipterex; metrifonate) (powder form)

White grubs: difficult to control

Termites: difficult to control

Millipedes: no management reported

Mice: clearing field borders to avoid mice entering from adjacent areas

Birds: scare tactics—flags, metals

Weeds:
Very few growers are using herbicides, but some use:

- Glyphosate (Roundup)
- Topramezone, dicamba (Stella Star)
- Terbuthylazine, pendimethalin (Bullet)

Critical Needs from Emergence to Vegetative Growth:

- More information is needed by extension workers on pest biology and epidemiology to support farmer education programs.
- Research is needed on more effective, reduced-risk control options against FAW.
- Among farmers using pesticides, it was estimated that as many as 98–99% were applying pesticides without PPE. Farmers we consulted reported impacts including burning skin and eyes. More education is needed regarding the importance of PPE, but without increased accessibility or other solutions, effective management options should be prioritized that do not require the use of PPE to ensure safety.
- FAW is known for its resistance to cypermethrin; alternative management should be prioritized for effective and sustainable management.
- Farmers were not aware of the potential for natural predators such as parasitic wasps. Education is needed on the value of beneficial insects and how to protect them.
- Scouting is not reported to be a common practice among most farmers. FAW is most commonly treated when noticed, rather than having treatments based on a specific percent infestation level because farmers do not feel comfortable taking risks. Education on methods for scouting and the rationale for thresholds needs to be more widespread.
- FAW larvae are easier to manage when young, but difficult to control at late stages: this also applies to the stage of crop growth when FAW is treated. More education is needed to ensure that farmers plant the maize crop early, undertake scouting, and manage FAW as early as possible.
- Pesticides have become the main management tool, but pesticides are not affordable for most farmers as a long-term or sustainable strategy. Farmers would like more recognition and additional research trial data for the alternative, accessible control methods some of them are already testing in farmer learning centers, including locally derived methods such as neem, soap, soil, fish soup, etc.

- Increase research on the use of locally derived botanicals, including efficacy, proper dilution, application rates and timings, etc.
- The amount of pesticides received through government procurement is inadequate relative to the need. If lower-risk pesticides are to be procured and distributed, ensure that there is adequate supply.
- Develop farmer loan or credit programs to assist in the purchase of improved seed and other inputs so that these are readily available at the beginning of the season.
- FAW moths travel freely from unsprayed maize fields into adjacent fields. If fields are different ages, this can intensify the problem. Identify best timing for planting, and encourage area-wide planting and management programs.

Flowering to maturity (December/January–April/May)

Field activities, pests, and pest management activities:
Weeding
Banking (placing soil around plantings)
Monitoring for pest presence
Cultivation of adjacent fields for other crop plantings
Storage preparation: bags, granary storage, etc.

Pests and management:

Mice: trapping with baits

Critical Needs from Flowering to Maturity:
- Farmers are interested in strategies for increasing yield and enhancing soil fertility during crop growth.

Harvest and post-harvest (April/May–postharvest storage)

Field activities, pests, and pest management activities:
Harvest: Once mature, cobs are left to dry on the stalk and harvested once dry, approximately one month after cobs have matured. Dried cobs are either cut from the stalks at harvest, or whole stalks are pulled up and cobs removed later. Stalks left in the field are later burned or cut for compost or livestock feed.

Sweet potato is commonly grown, following maize.

In the southern regions, a second maize crop is planted following harvest and grown with irrigation.

Pests and Management:

Weevils: postharvest losses to weevils are a major issue for Malawi farmers and were reported to be as high as 30–40%. Damage can begin in the field on drying cobs and continues in storage.

Cultural control:
- Airtight bags are being marketed to prevent weevil infestation. These are expensive, so not commonly used, but are desired by farmers.

Chemical control:
- **Pirimiphos-methyl**, marketed as Actellic: applied to stored maize, including bags; one application.

Rodents: Many people store dried cobs in their homes, where rodents can become a problem.

Chemical control:

- Some use **aluminum phosphide** (Phostoxin) or other rat granules. These are commonly used in homes.

Critical Needs for Harvest and Post-Harvest:

- Farmers and extension workers reported that used pesticide containers are considered to be a valuable asset in households for storing sugar, salt, or other food items, and that information on their safe use and disposal is not available. Education is critical, and methods are needed for safe disposal of empty containers as well as expired/unused/obsolete pesticides.
- Increase access (through subsidy, etc.) to airtight bags marketed to prevent weevil infestation of stored maize and reduce unprotected use of Actellic for weevil control. With reported losses of stored yield as high as 30–40%, improved and reduced-risk maize storage options could greatly increase food security.
- Most farmers do not know what to do after harvest to best protect drying/stored cobs. Education is needed in this area that addresses the impacts of environment on stored products, including temperature, humidity and moisture content, and pests including borers.
- Aflatoxin contamination of crop produce is a major issue in Malawi that most farmers are not aware of. These toxins, produced by fungi, can contaminate agricultural crops in the field, at harvest, and during storage. People can be exposed to aflatoxins by eating contaminated plant products or inhaling dust generated during handling. These toxins are associated with an increased risk of cancer. More education is needed on aflatoxin management.

Other pest/crop issues of importance:

Aphids (mostly a pest of legumes, also of cabbage, tomato, pumpkin, and sweet potato)

- Chemical control: **cypermethrin, dimethoate**

Spider mites (tomatoes, cotton; a worsening problem)

- Chemical control: **carbaryl** (Sevin)

Cutworm (multiple crops)

- Treated seed available for cutworm control

Bedbugs

- **Chlorpyrifos** used on beds, floors, walls, etc. to control bedbugs

Cypermethrin is also used in sorghum (once weekly for 2 months to manage FAW), sweet potato, tomato, and cabbage using similar timings (once-weekly application). **Carbaryl** is also commonly used in these crops.

Top-Priority Critical Needs

Pesticide Risk Management

- US regulatory decisions on pesticide registrations are not transferrable to African countries, where US assumptions of end-user risk management do not apply. Government decisions on pesticide recommendations and procurement, and Malawi pesticide regulatory decisions, should take into account the lack of access to PPE and lack of adequate application equipment. Product evaluation should include assessments of product efficacy against target pests and toxicity risks to humans, wildlife, aquatic species, and pollinators.
- Pesticide labeling should support end-user risk management, and labels should appear in native/predominantly spoken languages with clear instructions for application and dilution. If this is not possible, agro-dealers should be equipped with sufficient information to advise farmers on efficacy and risks.
- Capacity development is needed regarding safe pesticide management, including safe application methods, accurate dilution and acreage calculations, application rates, re-entry intervals (REIs), and safe disposal of pesticides and pesticide containers.
- Highly hazardous pesticides such as acetochlor and chlordane were found for sale in agro-dealer shops. High-risk chemicals such as dimethoate, carbaryl, and chlorpyrifos were reported as commonly used for other pests. Chlorpyrifos was reported as being used on and around beds and walls as control for bedbugs. Aluminum phosphide (Phostoxin) was reported as a product used for suicide. An understanding of the risks and hazards posed by pesticides is essential to protection of human health among new and uninformed pesticide users, but more importantly, these pesticides should not be accessible to smallholder farmers without access to PPE or safety/risk management information.
- The low cost of higher-risk, broad-spectrum products vs the high cost of lower-risk products is a critical issue that needs to be addressed in order to support a transition to lower-risk pesticides.
- The majority of farmers and farm laborers are women, which means more women are subjected to the negative impacts of using pesticides without safety information or equipment. A more targeted effort to address capacity development among women farmers is critical to human health protection among this sensitive group.

Research Priorities

- Identify and test lower-risk, combination management strategies that work within the current capacity of most of the population and protect both farmers and the crop (such as combining treated seed, pheromone trapping, and neem).
- Evaluate effective seed treatments for FAW control that can be made accessible to smallholder farmers.
- Research the biology, behavior, and ecology of native FAW parasitoids and evaluate their efficacy in FAW management.
- Conduct efficacy testing for locally derived cultural control options: application of neem, fish soup, soap, ash, etc.
- Screen local and improved maize varieties for native genetic resistance to FAW.
- Identify IPM-compatible and low-risk insecticides to replace currently recommended/commonly used products, which were put forward as a "quick-fix", but some of which carry considerable risks to humans and the environment.
- Evaluate the potential for maize-based intercropping and companion planting systems for FAW control.
- Develop a model for estimating FAW yield losses to be used by agricultural officers.

Needs for Extension

- Protective Equipment: One of the top needs discussed for extension agents is protective clothing and proper equipment. Extension workers are often relied upon for pesticide applications, but have no access to PPE.
- Functional sprayers: In some districts, extension workers share only one sprayer between them, and this is often in disrepair. Workers end up using water bottles to make applications, and do not have protective clothing.
- Mobility: Because of the 40% vacancy rate, agents are serving large numbers of farmers (a ratio of 1 extension worker to 2000–3000 farmers is not uncommon) across large geographic areas (30- to 50-km radius) with difficult terrain. Extension workers estimate being able to reach only 20–60% of their clientele. In many cases, 14–15 workers are sharing 1–2 vehicles, which are often in disrepair. Most are given bicycles, but this is impractical given the distance, number of farmers, difficult terrain, and the need to transport chemicals and equipment. Extension workers often use their own money to hire public transport. Solving these transportation issues is a priority to best utilize existing capacity.
- Training: Extension agents need more training on FAW, pest behavior, and best management practices. Extension workers are also not fully aware of available efficacious pesticides against FAW with low risks to human and environmental health. This is an area where increased capacity is needed and desired.
- Mobilize extension and NGOs (in partnership) to help educate farmers about pesticide risks and efficacious, lower-risk products.
- NGOs often have more resources supporting work directly with farmers. Rather than duplicate the work of extension, it is important that NGOs include extension workers as much as possible in capacity development activities and farmer outreach and education activities.
- Prioritize filling the vacancies in extension.
- Extension agents benefit from master training activities, but do not have the resources (for travel, accommodations, etc.) to then disseminate these trainings to the farmers they serve. Resources are needed to support extension outreach and engagement efforts.
- Develop a formal communication method to more frequently and quickly disseminate the latest research information to extension workers. Make use of existing communication tools such as WhatsApp to regularly disseminate relevant information.

- Increase access to demonstration plots for teaching and learning to aid extension in educational delivery of critical topics.
- Promote a stronger collaboration between researchers, extension, and farmers, including platforms for increased interaction and communication. Develop a forum (online would be ideal) for extension workers, researchers, and other experts to share knowledge with each other and ask questions.
- Provide professional development/academic opportunities for extension workers. Extension workers are interested in training modules on various topics that could be completed online. Additional training topics of interest to extension workers include:
    - Soil and water conservation
    - IPM
    - Best practices for pesticide handling, storage, application, calculating rates by area, and effective use
    - Integrated approaches to climate change
    - Agro-forestry and sustainable forest management
    - Reporting and data management
    - Nutrition-sensitive agriculture—high-value nutritional crops that can be grown in Malawi with minimal inputs
    - Mobilization of villages to collectively purchase needed inputs

Governmental/Regulatory Needs

- The number one challenge is poverty, which greatly impacts access to information, affordability of inputs, and capacity to manage new invasive pests safely and effectively. More outreach is needed on safe, effective management, but this requires more resources than are currently available for this work.
- Drought and postharvest losses often cause more damage to food security than FAW. Ensuring that resources are directed appropriately across various categories of need will ensure balanced protection of food security.
- Funding is needed to support the government's 5-year plan on FAW management, including increased training for farmers and extension workers and increased research on effective, low-risk treatments, including biological control.
- Fast-track registration for lower-risk products that can be effective and also safely handled without PPE, such as *Bt* biopesticide, nuclear polyhedrosis virus (NPV)-based biopesticide, spinosyns, and commercial neem formulations.
- Rather than procuring pesticides with higher risk profiles, consider subsidizing the cost of newer, lower-risk but higher-cost products to equal that of higher-risk, broad-spectrum pesticides.
- Understanding of the need for IPM has advanced, but delivery of information/education to farmers will remain the main challenge. Utilize existing extension structure with additional resources to address vacancies, training, and mobility of extension agents.
- Response plans should take into account best available research and guidance, but also consider how possible solutions fit with the current experience/limitations of farmers. If researched solutions are not practical or affordable to smallholder farmers with very limited resources, they will not be adopted.
- Many pesticides come across the border unregulated from Mozambique. Attention is needed in terms of pesticide regulation, as well as safety awareness/education.

- Pesticide labels should be printed in local languages to ensure that farmers and agro-dealers can read and understand them. It was reported that most farmers cannot read or understand pesticide labels printed in English, or Portuguese for products coming across illegally from Mozambique.
- Local options for safe pesticide and container disposal are needed, along with education on the dangers of improper pesticide disposal and container reuse.
- Devise methods to ensure that government-procured pesticides are not re-sold by anyone tasked with distributing the products.
- Increase access (through subsidy, etc.) to airtight bags marketed to prevent weevil infestation in order to protect stored maize and reduce unprotected use of Actellic for weevil control. With reported losses of stored yield as high as 30–40%, improved and reduced-risk (and climate-friendly) maize storage options could greatly increase food security and compensate for any losses from FAW.
- Offer pesticides in lower-volume packaging to avoid decanting into smaller containers, which carries a high risk of exposure. This also eases calculations of dilution and acreage.
- Facilitate the formation of credit facility clubs, to enable growers to access loans and credit for seed and other inputs.
- Investigate the potential for area-wide spray programs to improve safety and efficacy.

Needs for Education/Capacity Development

- Educate farmers and extension workers on scouting, thresholds, and treatment timing that prioritizes low-risk management strategies. Despite guidelines to apply pesticides based on infestation rates, most farmers apply pesticides at the first sighting of the pest, and then continue to apply weekly (e.g., cypermethrin) or biweekly (e.g., profenofos) until the crop reaches maturity.
- Educate farmers and extension workers on the principles of biological control/pest predation, using native parasitic wasps as an example.
- Continue to utilize radio/TV/simple brochures and support farmer-to-farmer learning based on current best practices and guidelines; incorporate agro-dealers in trainings and informational delivery; and translate written information into local languages to effectively reach farmers.
- Educate farmers regarding the relative efficacy, once tested, of locally derived cultural management options (e.g., fish soup, soap, ash, neem).
- Develop and provide simple pamphlets using easy-to-understand pictograms to relay information regarding effective IPM strategies for FAW management, including proper pesticide application and timing, and risk management.
- Increase the level of consultation to ensure resources are matching needs. Aid organizations and implementing partners indicate spending a lot of time implementing and not enough time conducting consultations such as this one.
- Provide training for agro-dealers on pesticide management, including target pests, pesticide efficacy, human health and environmental risks, and labels/rates/application methods. While extension workers in the districts we consulted have included agro-dealers in some trainings, this does not seem to be the norm. Agro-dealers need pamphlets or other means to be informed of current research and guidelines for pesticide use and safety.
- Ensure that recommended control measures correspond to the economic and technical limitations of growers. Some of the recommended practices (e.g., push-pull technology) were reported by extension workers and farmers as just not practical due to the expense and level of understanding required.

- Farmers highlighted a number of areas of interest for capacity development, including:
    - Best agronomic practices for production of maize, vegetables, tomatoes, beans, pigeon peas, groundnuts, cassava, and beets
    - Innovative practices for increasing production and managing pests
    - Irrigation management
    - Livestock/dairy production, breeding, and marketing
    - Goat production
    - Fisheries
    - Poultry/layers
    - Crop diversification/drought-tolerant crops
    - Compost production
    - Conservation agriculture
    - Pesticide management, including proper dilution, to avoid crop injury

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Appendix: Malawi FAW Pesticide Risk Management Table

The letters below represent four categories of nontarget risk potentially affected by pesticide use. If a letter appears in the "Risks" column, it indicates that mitigation is needed at commonly used application rates in order to reduce risk. Risks were calculated using the risk assessment tool IPM PRiME. This table does not substitute for any mitigations required by the product label.

A= Risks to aquatics: invertebrates and fish

T= Risks to terrestrial wildlife: birds and mammals

P= Risks to pollinators: risk of hive loss

B= Risks to bystanders: e.g., a child standing at the edge of the field

Any product highlighted in yellow is classified as a "highly hazardous pesticide" (HHP) by the World Health Organization and the Food and Agriculture Organization of the United Nations. These products may pose significant risks to human health or the environment, and risk reduction measures may not be effective in mitigating these risks.

Pesticides used	Risks requiring mitigation	Preparation to planting	Emergence to vegetative growth	Flowering to maturity	Harvest to post-harvest & storage	Target pest(s)	Comments
		Average reported number of applications per crop stage					
Compounds used against FAW in maize							
Azadirachta indica (neem): farmer-made solution; non-standardized			~3			FAW	Spot treatment when FAW detected
Chlorpyrifos	A,T,P,B		1			FAW *& domestic bed bugs*	Government procurement
Cypermethrin	A,P		8			FAW; beetles; African armyworm; *Zonocerus elegans* *& 8 FAW sprays in sorghum* *& weekly sprays against FAW and aphids in legumes, cabbage, sweet potato, tomato, pumpkin*	Widely available, less effective against FAW
Deltamethrin	A,P					FAW	Not widely used
Emamectin benzoate	A,P					FAW	Co-formulated with lufenuron; Not widely used
Flubendiamide						FAW	Not used (cost)
Indoxacarb	P					FAW	Not used (cost)
Lufenuron	A,P					FAW	Co-formulated with emamectin benzoate; not widely used
Profenofos	A,T,P,B		4			FAW	Widely available and used
Velvet bean (*Mucuna pruriens*) (farmer-made solution; non-standardized)			~3			FAW	Spot treatment when FAW detected

(Continued on page 23)

(continued from page 22)

Pesticides used	Risks requiring mitigation	Preparation to planting	Emergence to vegetative growth	Flowering to maturity	Harvest to post-harvest & storage	Target pest(s)	Comments
		Average reported number of applications per crop stage					
Compounds used against FAW in maize							
Aluminum phos-phide	P,B				1	Rodents	In storage (possible field use)
Dicamba			1-2			Weeds	Very limited use
Glyphosate			1–2			Weeds	Very limited use
Pendimethalin	T		1–2			Weeds	Very limited use
Pirimiphos-methyl	A,T,P,B				1–2	Weevils	Late season in field, and in storage
Trichlorfon	A,T,P		1–2			Stalk borer	
Additional compounds referred to in report as used in other crops or settings							
Carbaryl	A,T,P					Spider mite	Tomato, cotton
Dimethoate	A,T,P,B					Aphids	Cabbage, tomato, pumpkin, sweet potato, legumes

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