Food and Agriculture Organization of the United Nations

Integrated management of the Fall Armyworm on maize

A guide for Farmer Field Schools in Africa

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The guide was drafted by Anne-Sophie Poisot (FAO Plant Production and Protection Division), Allan Hruska (FAO Plant Production and Protection Division), Marjon Fredrix (FAO Plant Production and Protection Division) and Koko Nzeza (FFS trainer). Allan Hruska (FAO Plant Production and Protection Division) provided overall technical guidance and inputs. The following people contributed sections of the guide: Keith Cressman (FAO Plant Production and Protection Division, on scouting and trapping), Tamsin Davis and Roger Day (CABI, on biology and ecology of FAW); Georg Goergen (International Institute of Tropical Agriculture – IITA, on biological control), Allan Hruska (FAO Plant Production and Protection Division, on plant compensation, biological control and local practices), Francesca Mancini (FAO Plant Production and Protection Division, on synthetic insecticides), George Phiri (FAO Malawi, on biopesticides), Helda Morales (El Colegio de la Frontera Sur – ECOSUR, on plant diversity and agro-ecology), Sevgan Subramanian, Charles Midega, Girma Hailu and Saliou Niassy (International Center of Insect Physiology and Ecology – ICIPE, on botanical pesticides and the Push-pull technology). The section on Integrated Pest Management (IPM) principles in FFS is adapted from FAO's "Community Based Rice IPM Programme Development: a Facilitators' Guide".

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The present guide will be updated regularly, as we learn more about how to sustainably manage FAW in the context of African smallholder cropping systems. Additional regular technical updates of FAW will be found at: www.fao.org/food-chain-crisis/how-we-work/plant-protection/fallarmyworm/en. We look forward to hearing from you on how to improve future versions of this document. Corresponding author: AnneSophie.Poisot@fao.org.

Acronyms and abbreviations

AAW	African Armyworm
AESA	Agro-EcoSystem Analysis
BCA	Biological control agents
ECOSUR	El Colegio de la Frontera Sur
ETL	Economic Threshold Levels
FAO	Food and Agriculture Organization of the United Nations
FAW	Fall Armyworm (*Spodoptera frugiperda*)
FF	Farmer Facilitator
FFS	Farmer Field School
ICIPE	International Center of Insect Physiology and Ecology
ICRAF	World Forestry Center
IPM	Integrated Pest Management
IPPM	Integrated Production and Pest Management
IITA	International Institute of Tropical Agriculture
LP	Local Practice
MEL	Monitoring, evaluation and learning
MT	Master Trainer
NGO	Non-governmental organization
NPV	Nuclear Polyhedrosis Virus
TMT	Training of Master Trainers
TOT	Training of Trainers

Background

The Fall Armyworm (*Spodoptera frugiperda*), FAW, is an insect native to tropical and subtropical regions of the Americas. FAW larvae (photo) can feed on more than 80 plant species, including maize, rice, sorghum, millet, sugarcane, vegetable crops and cotton. FAW can cause significant yield losses if not well managed. It can have several generations per year and the moth can fly up to 100 km per night. FAW was first detected in Central and Western Africa in early 2016 (Benin, Nigeria, Sao Tome and Principe, and Togo) and further reported and confirmed in the whole of mainland Southern Africa (except Lesotho), in Madagascar and Seychelles (Island State). By 30 January 2018 FAW had been detected and reported in almost all Sub Saharan African countries, except Djibouti, Eritrea, and Lesotho. The pest having been detected in Sudan raises the alert for Egypt and Libya.

FAW is expected to spread further in Africa. The modality of introduction, as well as FAW's capacity of biological and ecological adaptation across Africa are still speculative. FAW is a damaging transboundary pest that will continue to spread due to its biological characteristics and high volumes of trade between African countries. Farmers will need substantial support to sustainably manage this new pest in their cropping systems using Integrated Pest Management (IPM).

The Food and Agriculture Organization of the United Nations (FAO) has taken a lead role in convening partners and in organizing consultation meetings resulting in a region-wide multi-stakeholder "Framework for the Coordinated Management of Fall Armyworm in Africa". One of FAO's key next steps for FAW work in Africa is "to support the design and implementation of a sustainable and ecological pest management programme for smallholder farmers in Africa, after looking at the experiences of the farmers and researchers from the Americas" who have been living with the pest for several hundred years. Promising management practices will be tried and adapted in the field using Farmers' Field Schools (FFS) that involve farmers and farmers' organizations across Africa, in collaboration with research and advisory services. Experiences and successes will be documented and shared to refine management options for African conditions.

In fact, farmer education and community action are critical elements in the strategy to sustainably manage FAW populations. That is why Farmer Field Schools will be used to support implementation of an integrated ecological and sustainable FAW management strategy. FFS is an intensive farmer education approach promoted by FAO and many organizations worldwide, establishing platforms for farmers to learn, experiment and exchange, currently used in over 90 countries for a wide range of topics after nearly three decades since they first started.

As part of the FAW management strategy to reach rural communities affected by FAW, FFS will be combined with mass information campaigns, rural radio, participatory videos, community action plans for FAW management and short field courses for farmers and rural advisors based on experiential learning.

A FAW curriculum development workshop was organized July 21-25 2017 at Swiss Spirit International Hotel in Accra, Ghana, for the four sub-Saharan African regions, under the overall and the technical supervision of FAO. The workshop was organized back to back with a FAW international expert meeting from 18-20 July 2017 (www.fao.org/3/a-bt622e.pdf), with participation of scientists from Africa and the Americas. The workshop brought together 28 participants, mainly senior FFS trainers with skills on maize and/or integrated pest management (IPM), and researchers and resource persons on FAW and IPM.

Technical information and discussions during this workshop contributed to the development of the field guide for integrated and sustainable management of FAW on maize. Partners including CABI, ICIPE, IITA and ECOSUR Mexico also contributed sections to the guide.

The first part of the guide summarizes basic technical information on FAW; the second part describes in more detail how to integrate FAW management in a FFS, reflecting FFS experiences from West, Central, Southern and Eastern subregions of Africa and the recommendations of technical resource persons from the Americas and elsewhere.

This guide puts emphasis on management of FAW for maize as the preferred host plant of FAW. However FAW can feed on over 80 plants. Most of the information in this guide can be adapted for other crops. The guide does not provide detailed information on maize cultivation, which will vary depending on the specific context. Existing FFS curricula on maize provide a basis which is available to FFS trainers and facilitators, and which reflects findings from national research and farmers innovations that are giving good results in specific contexts. This guide focuses on providing resource material and ideas on how to integrate FAW into FFS training. More training manuals and resources on FFS are available on the website of the Global FFS Platform at www.fao.org/farmer-field-schools/en

Additional and updated information on FAW in Africa can be found here: www.fao.org/food-chain-crisis/how-we-work/plant-protection/fallarmyworm/en

PART A

TECHNICAL INFORMATION ON THE FALL ARMYWORM

A.1 Frequently asked questions on the Fall Armyworm

1. What is the Fall Armyworm (FAW)?

The Fall Armyworm (*Spodoptera frugiperda*), is an insect pest of more than 80 plant species, causing damage to economically important cultivated cereals such as maize, rice, sorghum, and also to vegetable crops and cotton. It is native to tropical and subtropical regions of the Americas. It is the larval stage of the insect that causes the damage. FAW reproduces at a rate of several generations per year, and the moth can fly up to 100 km per night.

2. What is the difference between the Fall Armyworm and the African Armyworm?

They are closely related, but have different behaviours and ecologies. FAW rarely displays the "Armyworm" behaviour of larvae massing and "marching" across fields. As a native to Africa, the African Armyworm faces a complex of natural biological enemies (predators, parasitoids, diseases). The FAW probably arrived in African unaccompanied by its natural enemies, allowing their populations to increase even more unchecked than normal.

3. Is maize affected by FAW safe to eat?

FAW mostly eats the leaves of maize. Occasionally it will infest ears as well. Usually such ears are not consumed by humans. While direct damage from FAW doesn't affect the food safety of the maize, it could make the maize more susceptible to aflatoxin presence.

4. Is the current situation going to get worse?

The adult female moth of FAW is a strong flyer and will continue to spread across the continent, and possibly beyond. Populations of FAW may continue to build, as they find more host plants to multiply on, and in the absence of the complex of natural biological enemies (general predators like ants and earwigs, specialized parasitoids) and a host of entomopathogens (virus, bacteria and fungi).

5. Is there an impact on trade?

Exports of crops that are host plants for FAW from African countries with confirmed presence of FAW will come under new scrutiny from importing countries that haven't reported FAW.

6. What can be done (by extension, agriculture department, the farmers, etc.)?

There are many experiences and recommendations for managing FAW from the Americas. African farmers will need access to information and resources to sustainably manage FAW.

7. What alternative crops can farmers be advised to grow?

Maize is the crop most infested now in Africa. As a staple crop, it is unlikely that farmers and their families will want to abandon maize. There are ways of managing FAW in maize, as demonstrated in the Americas.

8. What products can be used to control FAW, and when and how should they be applied?

FAO is working with member countries from around the world to determine the recommendations for farmers' actions, including pesticides that are effective, yet with low risks to humans and the environment. These recommendations are made nationally.

9. Can FAW be eradicated from Africa?

Unfortunately no. The adult female moth of the Armyworm is a strong flyer and has rapidly spread across Africa, infesting crops (maize has been the most important to date) in probably millions of hectares of crops. It is far too widespread and numerous to be eliminated.

10. If the FAW is native to the Americas, aren't there experiences and practices that can be applied in Africa?

Definitely. There is a wealth of management experience and research from the Americas that can be shared and tried in Africa. FAO is actively promoting South-South Cooperation to bring this experience and knowledge to Africa.

11. What pesticides should be used to control FAW?

Pesticides may be needed to control FAW locally. The most effective, lowest-risk, economical, accessible and easily used by smallholders (without sophisticated machinery) need to be determined within each country and across the continent. It's not just a question of the most effective pesticide in a research station, the specific recommendations (active ingredient, formulation, type and timing of application), and their costs and benefits to smallholder farmers must be determined.

12. When should pesticide applications begin in maize to protect it from FAW?

Only when justifiable. Low levels of infestation at certain stages of maize growth may not cause much yield loss. The economic or action threshold must be determined and recommended for each stage of maize growth and for each type of pesticide and application techniques. Costs can vary tremendously. To economically justify their use, the costs of pesticide use must be equal to or less than the value of the additional yield that farmers receive for taking action. The prices that farmers receive for their harvest must also be correctly valued.

13. Are aerial applications of pesticides recommended for the FAW?

No. The destructive life stage (the larva) digs deep into the whorl of maize occasionally, making aerial applications of very low efficacy, while spreading pesticides over large areas of non-target habitat.

14. Is the use of biological control a possibility for the FAW in Africa?

There are many biological organisms that can help control FAW. Some may be naturally occurring in Africa (general predators, parasitoids and some entomopathogens), and some might need to be introduced from the Americas (specialized parasitoids, predators and certain strains of entomopathogens). The use of botanicals is also an appealing option.

15. Is GMO maize the solution to FAW in Africa?

While GMO maize is already being used in South Africa, it is generally only accessible by larger commercial farmers who have access to capital, resources and stable markets for their maize. Over 98 percent of maize farmers in Africa are smallholders, growing maize on less than 2 ha of land and typically saving seed to plant the next crop. The use of purchased inputs, including seed, is low. Given the high cost of transgenic maize seed, the lack of adequate supply channels, and lack of economic incentives for smallholders to grow maize (due to the low and volatile prices received) there is a low probability that the technology would be used in a sustainable manner by smallholder maize farmers in Africa. Even for commercial maize farmers in Africa, the long-term benefits of transgenic maize were put into doubt when, within two years of deployment, the maize stem borer began to show resistance to Bt maize in South Africa, and was later confirmed.

16. What are the next steps for FAW work in Africa?

FAO is currently supporting the design and testing of a sustainable pest management program for smallholders in Africa. First steps are to look at experiences of farmers and researchers from the Americas. Then, the best recommended practices will be tried and adapted in the field via Farmers' Field Schools. The best recommendations will then be communicated and shared with farmers, farmers' organizations and governments across Africa.

A.2. Biology-ecology and identification of the Fall Armyworm

A.2.1 Recognizing and understanding the Fall Armyworm

Recognizing FAW is the first step for management. The pest is new to Africa, and farmers need to be able to recognize FAW, and distinguish it from other pests. Below are pictures of the different development stages of FAW, from egg to larvae, pupae and adults.

1. Egg mass of *S. frugiperda*

Eggs are pale green or white at the beginning, get covered in scales, and turn clear brown to brown before hatching. They hatch within 2-3 days.

2. Neonate larvae

Neonate larvae.

3. Larvae from 1st to 5th stage

There are 6 larvae stages. Young larvae are pale colored. They become brown to pale green, then turn darker at the latest stages. The larvae stages last 12 to 20 days (depending on ambient temperature and other environmental conditions).

4. Larvae of *S. frugiperda* at 6th stage

Half-grown or fully grown caterpillars are the easiest to identify. The larvae are generally characterized by 3 yellow stripes on the back, followed by a black, then a yellow stripe on the side. Look out for four dark spots forming a square on the second to last segment (photo). Each spot has a short bristle (hair). The head is dark; it shows a typical upside down Y-shaped pale marking on the front.

5. Pupa stage

The pupa is dark brown and hides in the soil, more rarely in the stalk. Pupa lives 12-14 days before an adult emerges.

6. Adult moth stage

The moth is 3 to 4 cm wide. Its front wings are dark brown while the rear wings are grey white. It will live 2 to 3 weeks before dying

Fall Armyworm: Life cycle and damage to Maize

The Fall Armyworm lifecycle includes egg, 6 growth stages of caterpillar development (instars), pupa and moth.

This diagram illustrates the lifecycle, showing where the Fall Armyworm is usually found on maize plants at any given stage.

DAY 6-14

GROWTH STAGES 4-6

By stage 3-6 it will have reached the protective region of the whorl, where it does the most damage, resulting in ragged holes in the leaves.

Feeding on young plants can kill the growing point resulting in no new leaves or cobs developing.

Often only 1 or 2 caterpillars found in each whorl, as they become cannibalistic when larger and will eat each other to reduce competition for food.

Large quantities of frass (caterpillar poo) present.

When this dries it resembles sawdust.

If the plant is older and has already developed cobs then the caterpillar will eat its way through the protective leaf bracts into the side of the cob where it begins to feed on the developing kernels (seeds).

DAY 3-6

GROWTH STAGES 1-3

After hatching the young caterpillars feed superficially, usually on the undersides of leaves. Feeding results in semitransparent patches on the leaves called windows.

Young caterpillars can spin silken threads which catch the wind and transport the caterpillars to a new plant.

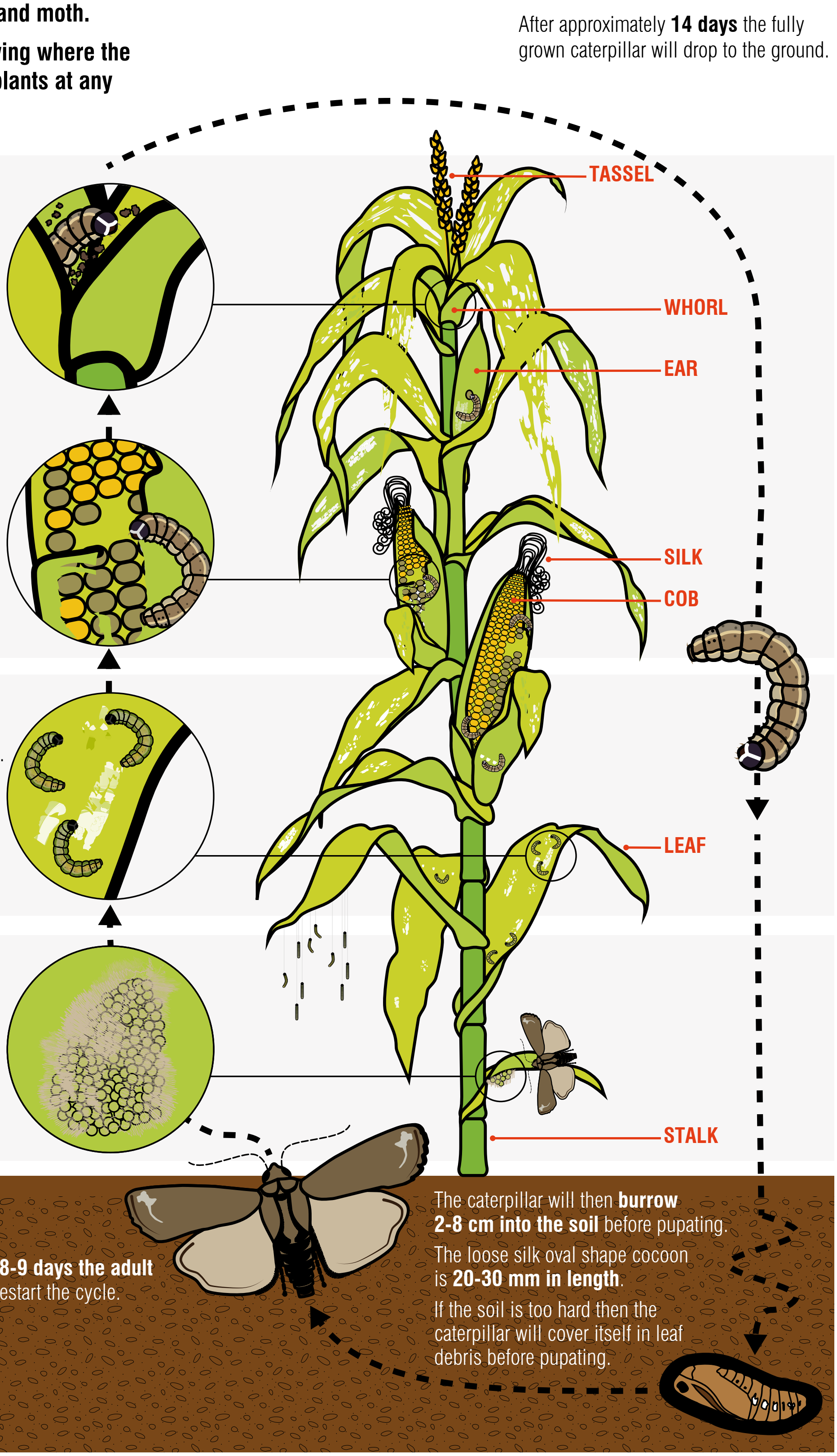
The leaf whorl is preferred in young plants, whereas the leaves around the cob silks are attractive in older plants.

Feeding is more active during the night.

DAY 1-3

100-200 eggs are generally laid on the underside of the leaves typically near the base of the plant, close to the junction of the leaf and the stem. These are covered in protective scales rubbed off from the moths abdomen after laying.

When populations are high then the eggs may be laid higher up the plants or on nearby vegetation.



Under warm conditions, a female moth can lay 6 to 10 egg masses of 100 to 300 eggs each, giving a maximum of 1 500 to 2 000 eggs in her lifetime of 2-3 weeks. As for other pests, most eggs will not develop into adults due to mortality in different parts of the lifecycle.

In tropical America, FAW is an established pest, and outbreaks in which populations reach densities that can cause important damage are rare. Natural enemies keep FAW populations at low levels under normal circumstances, and smallholder farmers have learnt to manage the pest. However, FAW populations do increase rapidly when area of maize cultivation expand. This is what the FAW population mostly respond to.

In Africa, FAW infestations are occurring in "outbreak" style in many maize-production areas – i.e. large populations of the pest are found in the fields and cause damage. As the pest is new to Africa, natural enemies are still rare, though some local species seem to be able to feed on FAW and reduce its populations. It is possible that FAW is now reaching "peak" levels in Africa. Within a few years, as natural enemy populations catch up and spread, a lower equilibrium population of FAW could be present in Africa. It is therefore important to preserve and enhance natural enemy populations in Africa. Unlike FAW in the Americas, or the African Armyworm (AAW), FAW in sub-Saharan Africa may not develop a migratory pattern. Most likely, given our understanding of the pest in the Americas, we expect that FAW populations will be resident over much of Sub-Saharan Africa, surviving on maize and on other plants during periods without maize; but in some cooler or drier areas, it may become migratory. We just don't know for now.

Recognizing FAW and learning about life cycles in the FFS

TIPS:

- Collect different stages of FAW in the field. Work in small groups describing the different stages, how to recognize them, where to find them on the plants and discuss how stages are linked.
- Set up an 'insect zoo" to study the life cycle of the FAW.
- Collect natural enemies of FAW in the field; set up 'insect zoos" to study predation or parasitization.

See section A.3.5 on Biological control plus section B.6.1 and B.6.2 on Insect zoos (under Special topics) for details!

Feeding behaviour and damage: In the lifecycle graph on the next page, more information is provided on the different stages of FAW, and where to find them on the plant.

Although FAW larvae can feed on more than 80 species of plants, they prefer maize, as well as, rice, cotton, groundnut, sorghum and vegetables.

The favourite spot of the caterpillar stage of the FAW is curled up in the whorl of a maize plant, where it feels protected and chews and grows on its favourite food – tender, young maize leaves. As they chew away, the leaves continue to grow out, leaving ragged, half-chewed leaves that are typical of FAW-infested maize fields.

Sometimes, but much less often, FAW can act as a young plant cuter, if high populations of the caterpillar are present on weeds or other host plants in fields adjacent to newly-planted maize fields. This Armyworm-like action by FAW is rare, but can occur. At very high population levels FAW can also penetrate maize ears, causing direct damage to the harvest. But again, this is rarer than the typical behaviour of burrowing down into the whorl to eat leaves.

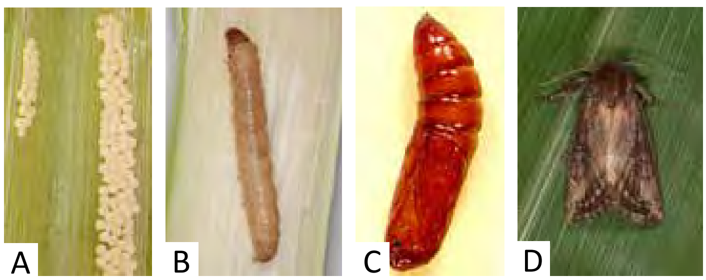
8 to 14 days old larvae can cause severe damage to maize plants, especially when the growing points of young plants are eaten. Early vegetative-stage FAW infestation can cause more leaf damage and yield losses than late vegetative stage infestation. Fortunately, maize plants can significantly recover (compensate) from early growth stage damage on leaves and short duration defoliation. When the FAW population is high on a plant, the adult larvae might occasionally move to the tassel and the ears, reducing the quality of the produce at harvest.

Heavy rains can wash young larvae off leaves, and drown those in the whorl.

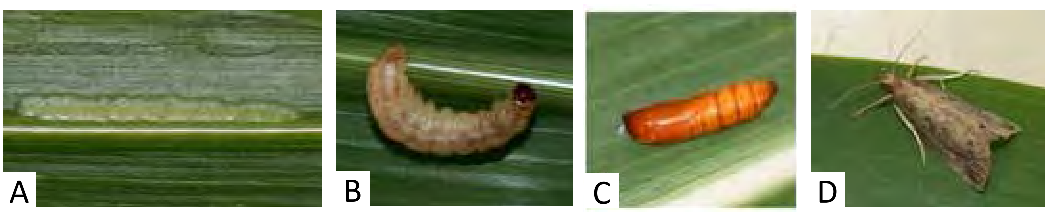
A.2.2 Differentiating the Fall Armyworm from other worms

Other pests of maize are present in Africa which resemble to some degree the FAW. You can differentiate them by learning to identify the worms themselves at their different stages, and the type of damage they produce.

Below are different species of maize stalk borers and their life stages. The most important stem borers pests on maize are *Busseola fusca*, *Chilo partellus* and *Sesamia calamistis*. *Busseola fusca* is mostly present in the highlands, whereas *Chilo partellus* is widely present in the lowlands. *Sesamia calamistis* is present in both low and highlands.



Busseola fusca: A) Egg (not easily visible, between the leaf sheath and stem); B) Larva; C) Pupa (frequently inside the stem); D) Adult (not easily visible, flying over at night). *Photos: Calatayud P.-A.*



Chilo partellus: A) Egg (on maize leaves); B) Larva; C) Pupa (frequently inside the stem); D) Adult (not easily visible, flying over at night). *Photos: Calatayud P.-A.*

Sesamia calamistis: A) Egg (not easily visible, between the leaf sheath and stem); B) Larva; C) Pupa (frequently inside the stem); D) Adults: male top; female bottom (not easily visible, flying over at night). *Photos: Calatayud P.-A. and icipe.*

The main differences between stem borer infestation and FAW infestation are:

- the big holes left by the FAW. Generally, "big holes" as observed for FAW are not present in stemborers attacks (for both young and old larvae)
- the stem borer damage is characterized by a typical dead heart which is easy to see when the maize is young (Photo Series 2D)
- when stem borers larvae are getting old, they are less present in the whorl contrary to FAW; but they can be found in the maize stem, leaving holes in the stems with visible frass (Photo Series 2C).

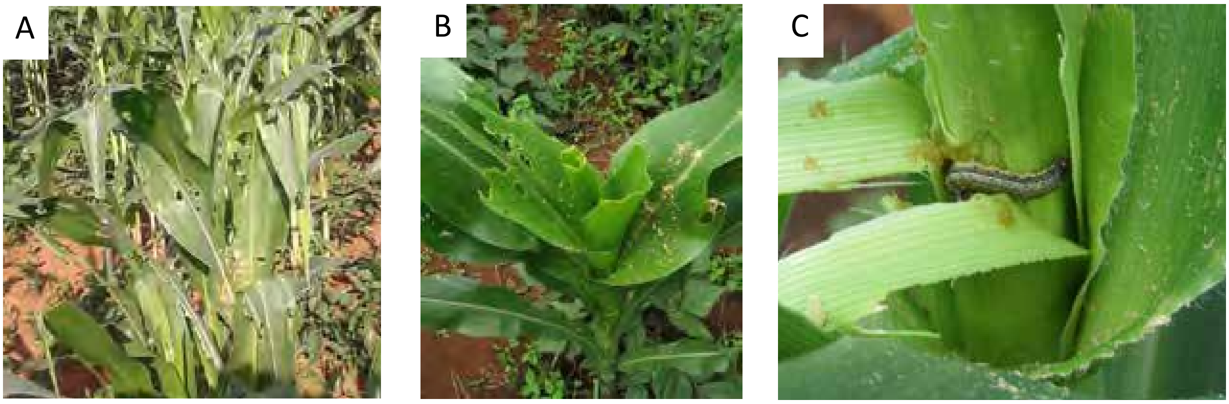


Photo series 1: Some leaf damage symptoms caused by the Fall Armyworm

A) Leaves with windowing and shot holes caused by early instars of FAW;
B) Extensive defoliation of leaves with fresh frass in the whorl, note the absence of dead heart;
C) Defoliation by FAW larvae in the whorl.
Photos: K. Cressman, Subramanian Sevgan, icipe.

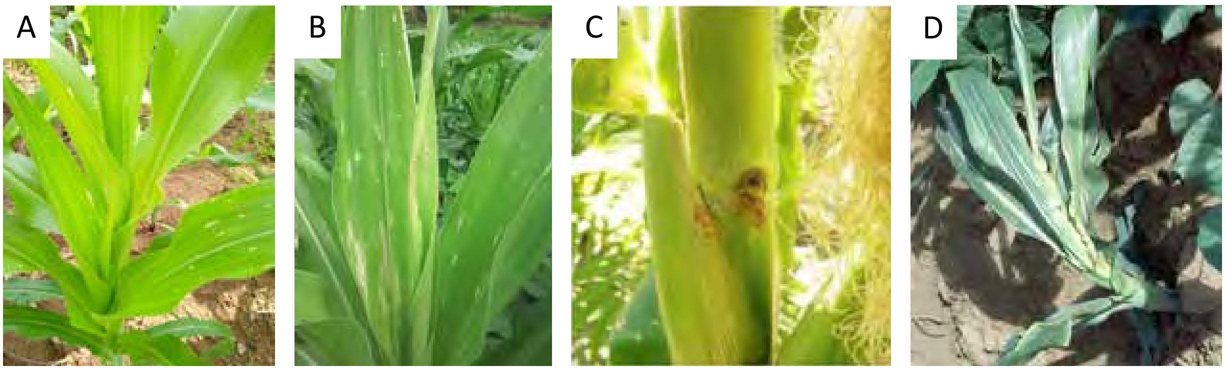


Photo series 2: Damage on the maize plants due to Lepidoptera stemborers

A & B): Typical damage on the leaves left by young caterpillars when they feed on the leaf surfaces; C): Hole left by the caterpillars when they are getting older and start boring the maize stem to feed inside the plant's stems; D): Deadheart caused by the feeding activity of stem borer caterpillars into the maize stems of young maize plants. *Photos and source: Calatayud P.-A. & Agbodzavu, 2013.*

A.3. Promising management options for the Fall Armyworm

The most promising options for the management of FAW by African smallholders are presented below, building on experiences from the Americas and latest research available in Africa, reflecting IPM strategies. These can be tested out in FFS as appropriate.

A.3.1 Seeds and varieties

Seed treatment might prevent early damage of the seedlings after germination.

Longer-term solutions of resistant or tolerant maize varieties might have potential, but are several years off.

FAO recognizes that crop improvement through innovative technologies, including both conventional breeding and modern biotechnologies, is an essential approach to achieving sustainable increases in crop productivity and thus contributes to food security. Scientific evidence has shown that modern biotechnologies offer potential options to improving such aspects as the yield and quality, resource use efficiency, resistance to biotic and abioticstresses, and the nutritional value of the crops.

FAO is also aware of the public perception and concerns about the potential risks to human health and the environment associated with genetically modified organisms (GMOs). FAO underlines the need to carefully evaluate the potential benefits and possible risks associated with the application of modern technologies. FAO emphasizes that the responsibility for formulating policies and making decisions regarding these technologies rests with the Member Governments themselves. The responsibility for formulating policies and making decisions regarding GMOs lies with the individual Governments. So FAO does not interfere in the policies or decisions, including those related to GMOs, of its Member Governments and so it has no position regarding the development, testing or commercial release of GMOs in any specific country. On request, FAO provides legal and technical advice to governments on areas such as the development of national biotechnology strategies and the development of biosafety frameworks.

Regarding the potential use of GM (genetically modified) maize to control the FAW in Africa, FAO considers that it is yet too early to draw conclusions. Bt maize has been demonstrated to decrease damage from FAW, but FAW populations in the Americas have evolved resistance to some Bt maize varieties.

Nevertheless, more work still needs to be done including conducting trials and collecting data. It must be kept in mind that the Bt maize grown currently in some parts of Africa is used primarily for controlling the maize stem borer insect and not FAW.

Maize has been genetically engineered by incorporating genes from the bacterium Bacillus thuringiensis (Bt) that produce insecticidal proteins that kill important crop pests. The use of Bt maize has resulted in some cases in reduced insecticide use, pest suppression, conservation of beneficial natural enemies and higher farmer profits. However, such benefits may be short-lived. Insect populations are able to adapt to Bt proteins through the evolution of resistance. Despite efforts to delay the selection for resistance, many cases of field resistance evolution among maize pests have been demonstrated in Bt maize, including in the Fall Armyworm (*Spodoptera frugiperda*) in the Americas, and in South Africa in the maize stem borer (*Busseola fusca*).

While transgenic maize has provided some transitory benefits to commercial maize farmers, the context for the vast majority of African maize farmers is quite different. Over 98 percent of maize farmers in Africa are smallholders, growing maize on less than 2 ha of land and typically saving seed to plant the next crop. The use of purchased inputs, including seed, is low.

Given the cost of transgenic maize seed, the lack of adequate supply channels, and lack of economic incentives for smallholders to grow such maize (due to the low and volatile prices received), there is currently a low probability that the technology would be used in a sustainable manner by smallholder maize farmers in Africa. Even for commercial maize farmers in Africa, the longterm benefits of transgenic maize were put into doubt when, within two years of deployment, maize stem borers began to show resistance to Bt maize in South Africa.

A.3.2 Crop management

Management of FAW in maize fields begins with prevention.

- **Planting dates:** avoid late planting, and avoid staggered planting (i.e. planting of fields at different dates in the same area), as this would continue to provide the favoured food of FAW locally (i.e. young maize plants). This is one of the most important recommendations for smallholders. In line with this, in January 2018 some FFS farmers in Kenya reported significant yield losses to FAW on late-planted maize plots, compared to adjacent plots which were planted earlier. See also the FFS Field Study in section B.4.4 on “Effects of planting dates on fall armyworm infestation and yield loss”.
- **Good soil health and adequate moisture** are critical: they are essential to grow healthy plants, which can better withstand pest infestation and damage. Also, unbalanced inorganic fertilization of maize (especially excessive nitrogen use) can increase oviposition by female FAW. See the Box in this section, and the FFS Field Study in section B.4.5 on “Effects of nitrogen fertilization rates and manure on levels of fall armyworm infestation and yield loss”. See references in Bibliography for training material proposing FFS activities on soil health.
- **The efficacy of managing crop residues** to break the life cycle of FAW generations is not well established by research. This practice is also time-consuming; it also runs counter other recommendations to maintain soil cover to improve soil health for sustainable production.

Don't panic! Maize plants can compensate significant damage by the Fall Armyworm

Damaged plants can scare farmers. Never before have they seen this type of damage, where the insect eats through so much of the leaves. Farmers know about stem borers, but because they aren't often seen (hidden in the stems), they don't often scare farmers like this new pest, the Fall Armyworm.

The spectacular-looking damage is very photogenic. The combination of farmers' nervousness, media alarmism, and politicians' quick reaction to do something has led to some bad decisions, including the use of Highly Hazardous Pesticides. Some older pesticides, which have long been banned in other parts of the world due to demonstrated human health impacts, are still available and used in some African countries. Some of the older pesticides don't work, because FAW has developed resistance to them[1].

Such panicky responses are likely when the farmers and others don't understand the potential impact of FAW damage. **The quick response to sight of significant-looking damage is to assume that it will cause dramatic yield reduction. But that's not necessarily true.** In fact, we know that in most cases FAW does NOT cause "total destruction". In most cases the leaf damage does cause some yield reduction, but it is probably far less than what farmers without experience with the pest believe.

Maize has been selected by humans for thousands of years to yield well, even in face of damage to insects, pathogens and other threats. These eons of selection have resulted in **maize plants that have considerable capacity to compensate for foliar damage.**

The response of maize yield to FAW infestation has been studied in the field a number of times in the Americas. A review of these studies shows that while of concern, **FAW damage in maize is not devastating.** While a few of the studies show yield reductions due to FAW of over 50 percent, the **majority of the field trials show yield reductions of less than 20 percent**, even with high FAW infestation (up to 100 percent plants infested). Maize plants are able to compensate for foliar damage, especially if there is good plant nutrition and moisture. **While FAW needs to be managed sustainably by farmers, it is not cause for panic.**

In FFS, we can examine our maize's ability to compensate for defoliation by conducting a Special Topics experiment (see section B.6.7). The experiment will look at the impact of defoliation of maize plants at different growth stages on grain yield.

1. For FAO guidance on which pesticides used on FAW in Africa might be Highly Hazardous Pesticides, see FAO Guidance note on Reducing risk from pesticides at: http://www.fao.org/food-chain-crisis/how-we-work/plant-protection/fallarmyworm/en

../cont.

Fall Armyworm populations are affected by plant quality

An important factor that effects FAW populations is the quality of the plant. The nutritional quality of plants affects not only plant growth and plant capacity to compensate for foliar damage by pests; but it also influences indirectly herbivore (i.e. FAW) growth and mortality and infestation levels. Several studies have shown the effect of fertilization on maize on FAW larval growth and mortality, but sometimes there is even a difference in the TYPE of fertilizer. Several studies have shown a difference between chemical fertilizer and organic fertilizer (manures).

The differences between the two types of fertilizers have been observed on:

- FAW larval growth
- Presence of natural enemies
- FAW larval mortality
- Maize infestation levels (percentage [%] of plants infested)

In Brazil, chemical fertilizer resulted in significantly higher levels of FAW infestation in maize than treatments with no fertilizer used, or organic fertilizer.

In FFS, we can compare different treatments, for instance: No fertilizer vs. chemical fertilizer vs. organic fertilizer (manure). We then measure Infestation rates; levels of natural enemies/parasitized larvae; and yields.

See the FFS field study in section B.4.5 on “Effects of nitrogen fertilization rates and manure on levels of FAW infestation and yield loss”.

A.3.3 Plant diversity

A.3.3.1 Diversity on farm reduces Fall Armyworm infestation and supports natural enemies

Another very important aspect of prevention of FAW infestations is by maintaining plant diversity on farms.

Even if many female moths are flying about, if she doesn’t lay her egg masses on maize plants, or if very young larvae don’t move onto maize plants, then the maize won’t be infested by FAW.

FAW moths prefer maize to lay her eggs. In large monocultures of maize, she just flies about, laying her eggs in a sea of maize.

When maize is intercropped with other crops or there are other plants nearby that she doesn’t like, she is more likely to move on, skipping maize plants that may be mixed in with the plants she doesn’t like.

This is the first step in good FAW management – reduce oviposition on maize plants! Farmers in Central America have noticed that when they plant maize together with other crops such as beans and squash (their traditional "milpa" systems), they have less pest attacks.

Agroecologists have documented that polycrops may be effective because of four main reasons or mechanisms:

- One possible explanation is that **a diversity of plants in the same field confuses FAW,** and it is difficult for it to find its preferred host plant (maize), eating less or laying fewer eggs.
- Another reason is that the female **FAW moth doesn't "like" certain plants** because of the chemicals they emit. These volatile compounds are the "push" effect in push-pull systems, which "push" pest species away from certain plants while they are "pulled" to others because the plant chemicals make them more attractive (see section A.3.3.2 on Push-pull). So planting maize near other plants that "push" FAW moths away is the first step in preventing FAW infestation.
- A third possible explanation is that **polycropping may provide natural enemies** (parasitoids and predators) with resources such as nectar; water; or a place to hide, and those natural enemies will control FAW.
- A fourth rationale for the intercropping is that it **increases soil organic matter**, and in the case of legumes it increases Nitrogen, which improves plant health, making it more able to compensate for FAW damage (see section A.3.2 on Crop Management and Box p 15 on plant compensation ability).

We know that especially plants that bear flowers for a long period of time, such as many "weeds" or some medicinal or plants used as condiments, do provide nectar to parasitoids and predators of FAW. In Mesoamerica, plants such as *Tagetes lucida, Coriandrum, Sonchus olerace, Ruta* and onions, attract beneficial insects.

Suggested experiments on plant diversity for FFS

- Try using different maize varieties and/or intercropping maize with other crops (for instance with cassava, which is not a host plant of the FAW)
- Observe which plants growing near or in your maize fields are attracting natural enemies, and how you can manage them to reduce FAW populations, without interfering with maize growth.
- Consider stimulating the growth of 'weedy" plants in certain rows in between the crop, or to grow them around the plot.

Trees are also important for pest management. Trees allow birds to perch, and many birds prey over larvae including FAW. In Africa, many farmers are growing maize in agroforestry systems (MIAF). It could be important to document if the MIAF plots have less FAW attacks than maize grow in a monocrop.

A.3.3.2 Push-pull technology

Push-pull is a habitat management strategy developed and implemented to manage pests such as stem borers, striga weed and address soil degradation, which are major constraints in maize production in Africa. The technology entails using a repellent intercrop (Desmodium as a "push") and an attractive trap plant (Napier/Brachiaria grass as a "pull").

The Napier grass planted around the maize farm:

- attracts stemborers and FAW to lay eggs on it;
- but it does not allow larvae to develop on it due to poor nutrition; so very few larvae survive.

At the same time, Desmodium, planted as an intercrop:

- emits volatiles that repels stemborers or FAW, and
- secretes root exudates that induces premature germination of striga seeds and kills the germinating striga; so this depletes seed banks of striga in maize farms over time;
- covers the ground surface between maize, thus smothering weeds
- enriches the soil with nitrogen, preserves soil moisture and protects the soil from erosion.

The Desmodium and Napier/Brachiaria grass grown in Push-pull farms also:

- provide valuable biomass as fodder for livestock, which can translate into increases in dairy products like milk.

"Push-pull climate smart" (combination of Desmodium Greenleaf and Bracharia cv Mulato II):

- is designed for dry and hot conditions to address the challenges posed by climate change
- Brachiaria grass grows fast with less water, and has been found to tolerate dry conditions better than Napier grass.

Push–pull is an effective and efficient low-cost technology as it addresses some major constraints faced by smallholder farmers. The multiple benefits of this technology can result in an overall and significant improvement of farmer's food security and livelihoods.

Observations on FAW (*S. frugiperda*) by at least 250 farmers who had adopted the climate-smart Push-pull technology in drier areas of Kenya, Uganda and Tanzania indicated reduction of FAW larvae per plant and subsequent reduction in plant damage. Further surveys on climate-smart Push-pull and monocropped maize farms indicated 82.7 percent reduction in average number of larvae per plant and 86.7 percent reduction in plant damage per plot in climate-adapted push-pull compared to maize monocrop plots.

Impacts of Push-pull on FAW infestation

A Sole maize with high levels of FAW infestation in Kenya

B Push-pull plot free of FAW infestation in Kenya

C High levels of FAW infestation in sole crop of maize in Uganda

D Climate smart Push-pull plots relatively free of FAW infestation in Uganda

Photo credits: A and B © Charles Midega, icipe; C and D © Girma Hailu, icipe

Hence, Push-pull technology appears effective in controlling FAW, with associated maize grain yield increases under the conditions tested. This technology could be immediately deployed for management of the pest in East Africa and in areas with similar conditions. Further testing in other agroecological zones is needed (Midega et al. 2018).

The push-pull technology is a specific application illustrating the general principle of the role of plant diversity on insect populations. There may be other plants (including crop species) that can be used to 'push' or 'pull' FAW and its natural enemies.

A.3.4 Mechanical control and local controls

A very important management option for smallholder farmers in Africa, based on the experience of smallholders in the Americas, is to visit their fields regularly, and **crush egg masses and young larvae*** ("use your fingers, not pesticides"). Farmers should visit fields twice a week during vegetative stage, especially in periods of heavy oviposition by FAW, and once a week or every 15 days in later stages.

Some smallholder farmers in the Americas report using **ash, sand, sawdust or dirt** into whorls to control FAW larvae. Ash, sand and sawdust may desiccate young larvae.

Dirt may contain entomopathogenic nematodes, Nucleo-polyhedrosis Virus (NPV), or bacteria (such as *Bacillus sp.*) that can kill FAW larvae.

Smallholder maize farmers in Central America and FFS farmers in Africa also report using **lime, salt, oil and soaps** as control tactics. Lime and ash are very alkaline.

They also use **local botanicals (neem, hot pepper, local plants)** and some farmers report success.

> **Why should farmers visit fields frequently?**
>
> FAW egg masses take 2-3 days to hatch in most African temperatures. So during periods of heavy infestation, by visiting fields at least twice a week, you can crush egg masses between your fingers before they hatch. This is easier and less costly than dealing with hundreds of bigger larvae a few days later. Field observation also help farmers to check the overall state of crop development, soil moisture, presence of other pests and diseases….

Other farmers recycle the naturally-occurring entomopathogens, by collecting the larvae killed by virus or fungi, grinding them, straining the body parts out (leaving just the fungal spores or viroid particles), mixing this filtrate with water and spraying it back into the whorls of infested plants (see also the following section on biological control).

Some FFS farmers report effectively pouring **water in the maize whorl** to drown the larvae.

Other farmers in Central America and FFS farmers in Africa use **sugary sprays, oil or lard, 'fish soup' or other material to attract ants and wasps** to the maize plants. The predatory ants are attracted to the lard, oil, bits of fish parts, or sugar; once on the maize plants, they also find and eat FAW larvae.

Finally, FFS farmers for instance in Benin, reported **picking larvae to feed them to chicks** for poultry production.

FAW are also edible for human consumption. In countries where insects are consumed, they can be a good complementary source of protein for local population.

Very little formal "scientific" studies have been carried out on these local controls, but many farmers including in Africa report success with them. They should be further tried by farmers under their local conditions.

** It is important however, that mechanical controls such as crushing egg masses and picking larvae do not interfere with children's regular attendance at school.*

A.3.5 Biological control of the Fall Armyworm

A.3.5.1 Naturally-occurring bio-control agents

The Fall Armyworm has many naturally-occurring 'natural enemies' or 'farmers' friends'. These biological control agents are organisms that feed on FAW.

In the Americas, and probably in Africa, these natural enemies can be active during all development phases of FAW, i.e. in the egg, larval, pupal and adult stage. **Natural enemies have the potential to substantially reduce the FAW populations and hence the damage caused by FAW.**

Their impact however depends on a number of factors including the diversity of organisms being active, their life-style, local presence, numerical and timely abundance, host specificity, agronomic practices, pest management methods etc.

A major challenge is to **create conditions to exploit the potential of these beneficial organisms** to their full extend. Broad spectrum pesticides kill many of the farmers' friends. It is important that farmers recognize the pest in all its development stages, its associated natural antagonists, identity possible gaps to be filled in local natural enemy guilds and at the same time sustain their action by adequate management measures in an IPM context.

Biological control should be understood as an integral component of IPM and an important part of mutually compatible pest-suppressing methods aimed at generating higher profits whilst preserving the environment and human health.

Biological control agents (BCAs) include the following: 1) predatory insects and mites, which eat their prey; 2) parasitoids, which are insects with a free living adult stage and a larval stage that is parasitic on another insect; and 3) parasites and microbial pathogens, such as nematodes, fungi, bacteria, viruses and protozoa, which cause lethal infections.

Parasitoids of the FAW

Parasitoids are organisms whose adults lay eggs inside or attached to a single host organism. For their development, the resultant larvae feed on the tissues of the host until they are fully grown and pupate. The larvae of parasitoids always kill their host as the outcome of their development.

The majority of parasitoids known to be associated with the FAW are wasps, and less frequently flies.

Species that have undergone an adaptation process to the FAW display a narrow host range.

Such co-evolved parasitoids can exert a strong impact on populations of the FAW and are thus good candidates for use in biological control programmes.

During inventories in the Western Hemisphere, about 150 different parasitoid species were found to be associated with the FAW in various crops.

The following are some of the most common parasitoids known to be well adapted to the FAW in the Americas:

Telenomus remus Nixon (Hymenoptera: Platygastridae)

- **Identification:** minute wasp of about 0.6 mm size with black shiny body. The wings are transparent and have reduced venation. Female antennae have 11 segments whereby the last 5 are enlarged forming a club. Males have 12 antennal segments of equal size.
- **Behaviour:** The species behaves as an egg parasitoid, i.e. females *T. remus* are attracted to FAW egg masses where they oviposit. Offspring of the parasitoid develop within eggs of FAW of which they then emerge as adults.
- **Life cycle:** over their lifetime females are able to parasitize some 120-130 FAW eggs. The development of immatures takes about 10 days at 28^{0}C and thus about 40 generations are produced per year.
- **Importance:** *T. remus* is reported to be highly effective in several South American countries with parasitism rates above 80 percent depending information sources.


Left: Telenomus remus ovipositing (© L. Buss, University of Florida)
Right: FAW egg mass (© G. Goergen, IITA)

Chelonus insularis Cresson (Hymenoptera: Braconidae)

- **Identification:** parasitoid of about 5 mm size characterized by a carapace-like abdomen. A white band medially divided can be observed at the base of the abdomen. Wings bear numerous veins. Antennae of both sexes are filiform and have 16 segments or more.
- **Behaviour:** *C. insularis* is an ovo-larval parasitoid. Females oviposit in eggs of FAW but larvae start their development in later instars of the caterpillar. When mature, parasitoid larvae exit their host and build a silken cocoon to pupate.
- **Life cycle:** each female can parasitize about 600 FAW eggs. At 28-30^{0}C the parasitoid is able to develop within 20-22 days and females can live for about 12 days.
- **Importance:** *C. insularis* is the most common among FAW parasitoids in the Caribbean as well as in Central and South America.

Chelonus insularis ovipositing on FAW egg mass (© C. J. Stuhl, USDA)

Cotesia marginiventris Cresson (Hymenoptera: Braconidae)

- **Identification:** Male and female average 3 mm in length. While the head and thorax of adults are black, the abdomen is tan. The antennae are long segmented and slighter shorter than the body length. Females can be recognized by a very short ovipositor at the tip of the abdomen.
- **Behaviour:** *C. marginiventris* is a solitary larval parasitoid of noctuids. On the FAW, Cotesia adult females attack preferably 1st and 2nd caterpillar instars, on which a single egg is usually laid. Shortly before pupation the full grown parasitoid larva leaves its host and spins a white cocoon of 4 mm size, of which an adult wasp will emerge a few days later.
- **Life cycle:** The parasitoid needs 12 days to develop from egg to adult at 30^{0}C. In total, 200 to 300 offspring are produced per female. Adults have a lifespan of 22 to 30 days.
- **Importance:** *C. marginiventris* is less sensitive than other parasitoids in environments sprayed with chemical insecticides. It is adapted to subtropical and warm temperate areas. Attracted to host volatiles, it can persist at low FAW population densities using alternate hosts, thus it is a better competitor than *Chelonus insularis.*

Left: *Cotesia marginiventris* adult (© Fernández-Triana J.)
Right: Foraging on FAW caterpillars (© A.S.T. Willener, University of Neuchâtel)

Trichogramma spp. (Hymenoptera: Trichogrammatidae)

- **Identification:** There are numerous species of the genus *Trichogramma* known to develop inside the eggs of the FAW and of many other Lepidoptera. Typically *Trichogramma* spp. are tiny wasps less than 0.5 mm long. Adults are mostly orange, brown or even black. Antennae are short, clubbed in females and hairy in males.
- **Behaviour:** Adult females lay their eggs inside FAW eggs. Along with the larval development they gradually turn darker and are almost black when the parasitoids pupate. Adults emerge by chewing an exit hole on the FAW egg.
- **Life cycle:** The parasitoid completes its development in about 8 days at 28^{0}C. Females can parasitize up to 120 moth eggs and live for 6-7 days.
- **Importance:** In Latin America *Trichogramma* spp., in particular *T. pretiosum* and *T. atopovirilia,* are commonly mass-reared on alternative hosts in local mass production units and commercialized for inundative field releases.

Trichogramma pretiosum parasitizing eggs of FAW (© Heraldo Negri)

Fly parasitoids: *Archytas, Winthemia* and *Lespesia* (Diptera: Tachinidae)

- **Identification:** Several fly species of the family Tachinidae are able to develop on FAW caterpillars. Attacks by such parasitoids can be detected either when small maggots are visible in presence of FAW caterpillars, or tiny white eggs are observed on their skin. Alternatively fly pupae can be found nearby dead FAW larvae.
- **Behaviour:** For species that lay directly several eggs on the skin of their host, parasitism starts immediately upon penetration of the maggot into its host. Other species await pupation of FAW to intensify their host feeding and complete their development. Despite frequent superparasitism, only a single fly develops per caterpillar.
- **Life cycle:** larvae *Lespesia archippivora* (Riley) completes their development within 13 to 17 days. Fly females can lay up to 204 eggs during their life time.
- **Importance:** About one third of parasitoids inventoried from the Americas belong to the family Tachinidae. While these often target several species of Lepidoptera attacking maize including other noctuids, they are also found on diverse host plants of the FAW.

Left: *Winthemia trinitatis* Thompson ovipositing on FAW larvae (© I. Cruz, Embrapa).
Right: eggs deposited on the host abdomen (© I. Cruz, Embrapa)

In Africa, because of the relatively recent introduction of the FAW on the African continent, data on native natural enemies are still very scanty. First field data demonstrate that a few parasitoids species have already accepted eggs and caterpillars of the FAW as a host.

As these data are preliminary, it remains to be verified whether these natural enemies have shifted from African stemborers or earborers to the FAW, or if they represent new associations from other hosts.

The following parasitoids were recovered from the FAW in West, Central and East Africa:

Family	Species	Occurrence
Braconidae	*Chelonus curvimaculatus* Cameron	East Africa
	Chelonus cf *maudae* Huddleston	West Africa
	Coccygidium luteum (Brullé)	East/West Africa
	Cotesia icipe Fernández-Triana & Fiaboe	East Africa
	Cotesia sp.	West Africa
Ichneumonidae	*Charops ater Szépligeti*	East Africa
	Charops sp.	West/central Africa
Platygastridae	*Telenomus* sp.	West/central Africa

Symptoms of parasitism of FAW in the field.
Left: Minute wasps on FAW egg masses.
Right: Eggs differentially discoloured with some empty eggs (*Source: Varella et al. 2015*)

Predators of the FAW

In this category you find natural enemies that kill one or several individuals of FAW during their life time either as larvae or adults. In this case, eggs, caterpillars, pupae or adult FAW are considered as preys. Usually predators are non-selective or generalists, thus they feed opportunistically on more than one host species, sometimes even on their own kind. The following insects belong to generalist predators:

Earwigs (Dermaptera: Forficulidae, Carcinophoridae)

Two species are currently recognized to play a significant role as FAW egg predator in maize crops: *Doru luteipes* (Scudder) and *Euborellia annulipes* (Lucas).

Left: *Doru luteipes* (Scudder) (© I. Cruz, Embrapa).
Right: *Euborellia annulipes* (Lucas) (© I. Cruz, Embrapa)

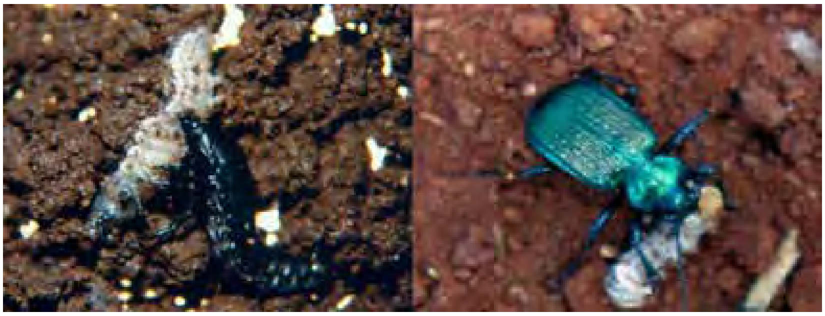
Ladybird beetles (Coleoptera: Coccinellidae)

Both adults and larvae of ladybugs feed on various phytophagous insects such as mites, aphids, scales, mealybugs, eggs and young larvae of Lepidoptera including the Fall Armyworm. *Coleomegilla maculata* DeGeer, *Cycloneda sanguinea* (Linnaeus), *Hippodamia convergens* Guérin Meneville, *Eriopis connexa* Mulsant, *Olla v-nigrum* Mulsant, *Harmonia axyridis* (Pallas) and *Neda conjugata* (Mulsant) are species commonly found in maize fields in the Americas.

From left to right, top: Adult ladybug beetles of *Coleomegilla maculata* DeGeer; male and female of *Olla v-nigrum* (Mulsant, 1866); bottom: *Cycloneda sanguinea* (L.); *Eriopis connexa* (Germar); *Hippodamia convergens* (Guérin-Meneville (© I. Cruz, Embrapa)

Ground beetles (Coleoptera: Carabidae)

Many carabid beetle species occurring in maize cropping are known for their predatory habits both as larvae or adults. *Calosoma granulatum* Perty has been observed to feed on young FAW caterpillars.



Left: *Calosoma granulatum* Perty larva (© I. Cruz, Embrapa).
Right: *Calosoma granulatum* Perty adult (© I. Cruz, Embrapa).

Assassin and flower bugs (Hemiptera: Reduviidae, Pentatomidae, Geocoridae, Nabidae, Anthocoridae)

There are several species of bugs that have been observed to feed on immatures of the FAW. The best known of this category belong to the genera *Zelus* (Reduviidae), *Podisus* (Pentatomidae), *Nabis* (Nabidae), *Geocoris* (Lygaeidae), *Orius* and *Anthocoris* (Anthocoridae).

Top: *Zelus* spp. (Reduviidae) (© I. Cruz, Embrapa).
Bottom, from left to right: *Podisus* sp. (Pentatomidae), *Orius insidiosus* Say (Anthocoridae), *Geocoris punctipes* (Say)(Lygaeidae), (© I. Cruz, Embrapa).

Eusocial, solitary and other predatory wasps (Hymenoptera: Vespoidea)

Spiders (Arachnida: Araneae)

Ants (Hymenoptera: Formicidae)

Ants are often among the most important predators of FAW larvae and pupae. Perfecto (1980) studied the interactions among ants, FAW and pesticides in maize systems in Nicaragua. She found that ants are very important predators of FAW in maize in Nicaragua and that pesticides dramatically reduced the presence and effectiveness of ants a natural biological control of FAW. She placed FAW pupae in the soil in maize fields and found that 92 percent of the pupae were removed within 4 days in fields without insecticide treatments, compared with only 4 percent in fields with insecticidal treatments.

Ants have already been seen attacking and killing FAW larvae in maize fields in Africa.

Some farmers have begun trying to apply lard or fish soup on their maize plants, to see if they can attract ants to their maize fields, so that they will then eat the FAW larvae present.

Birds and bats

Birds and bats have been observed to prey on FAW larvae. Studies in Central America have demonstrated significant impacts of birds on infestation levels of the FAW. Presence of trees or bird perches in or near fields will help attract birds who can prey on the FAW and help control their population.

Despite their importance as natural antagonists, a thorough assessment for predatory wasps, ants and spiders is often neglected because of the difficulty to establish a methodology to accurately assess their impact.

In Africa, though generalist predators such as ladybug beetles, earwigs, predatory bugs, eusocial- solitary- and other predatory wasps, ants and spiders are regularly observed in maize fields, a list of these natural enemies is yet not available.

It is expected that for these major functional groups, forthcoming assessments will reveal many parallels between the pest's area of origin and the newly invaded continent.

How to favour the presence of natural enemies in fields?

Farmers can take many actions to protect and favour populations of natural enemies in their fields (this is called 'conservation biological control"). Measures include avoiding overuse of synthetic insectides that can have detrimental effects on natural enemies; ensuring diverse boundaries around fields including open flowers and shrubs as habitat or food for natural enemies; trees or bird perches in or near fields; if pesticides are considered necessary, selecting products that are compatible with biological control such as Bt and botanicals based formulations, and more.

For more information, see:

- Section A.3.3 on plant diversity
- Section A.3.5 on biopesticides and botanical pesticides
- Special Topic B.6.2 on insect zoos: the role of natural enemies (farmer friends)
- Special Topic B.6.3 on invitig local natural enemies

Entomopathogens

Pathogens (microorganisms that can cause disease) are everywhere. In agriculture, plant pathogens (e.g. fungi, bacteria, viruses, nematodes) affect plants, reducing yield or quality. Also very important, but less perceived by farmers, are entomopathogens – those pathogens that affect insects ('entomo-').

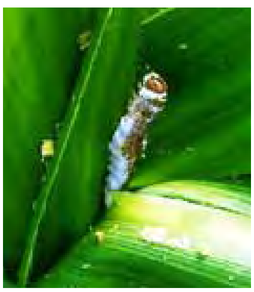
The Fall Armyworm is naturally affected by several different types of pathogens:

- Viruses, in particular Nuclear Polyhedrosis Virus (NPVs) such as the Spodoptera Frugiperda Multicapsid Nucleopolyhedrovirus (SfMNPV)
- Fungi, in particular
  - *Metarhizium anisopliae*
  - *Metarhizium rileyi*
  - *Beauveria bassiana*
- Bacteria, such as the Bacillus surigensis (Bt)
- Nematodes
- Protozoa

Of these, the first three groups are the most common and will be mentioned here. In the Americas these pathogens are important as natural regulators of FAW populations. They have also already been observed killing FAW larvae in the field in Africa, so they are already present, at least in some farmers' fields.

The host-specificity of these pathogens is quite high, usually restricted to a few closely-related insect species. These pathogens do not affect other groups of insects (natural enemies), plants, animals or humans.

FAW larvae naturally killed by viruses and fungi are easily identified in the field. Virus-killed larvae become soft and many hang from leaves, eventually oozing viroid particles and fluids (photo 2). Fungal-killed larvae turn rigid and appear "frozen" on the leaves, eventually turning white or light green, as the fungal spores mature (photo 1). These are the two most common groups of entomopathogens naturally killing FAW larvae in the field.



Symptoms of entomopathogen infection on FAW.
Left and centre: Fungus infected larvae of FAW in Malawi (© Albert Changaya and © Ken Wilson).
Right: Virus infected larvae of the African Armyworm (© Ken Wilson).

Farmers can learn to recognize these 'farmer-friendly' pathogens in the field. They can also multiply them locally. Farmers in the Americas sometimes collect the dead and dying larvae, full of viroid particles of fungal spores (the infective stages of the pathogens), grind them up in kitchen blenders. Then they strain the larval body parts out, mix the concentrated filtrate of virus or fungus with water, and spray them back out into the field, especially directly into maize plants currently infested with FAW.

Entomopathogens can play a very important role in natural regulation of FAW populations in the field. Farmers should learn how to identify the different organisms, understand their biology and ecology, and begin to experiment with them! They are truly farmers' friends!

A.3.5.2 Use of introduced bio-control agents

In addition to **conservation biological control** (relying on and protecting the natural enemies which are locally present, as explained above), other approaches include for instance **classical biological control** (importing natural enemies from elsewhere and establishing them in farmers fields) and **augmentative biological control** (supplementing the numbers of naturally-occurring natural enemies with releases of natural enemies reared in labs or collected in the field; they can be released in large quantities – these are called inundative releases, or beginning with small quantities– these are called inoculative releases).

In Latin America *Trichogramma* spp., in particular *T. pretiosum* and *T. atopovirilia,* are commonly mass-reared on alternative hosts in local mass production units, and commercialized for inundative field releases against the FAW. Release rates totalling circa 100 000 wasps/ha performed in 3 introductions spaced each by 3 days, is a recommended release scheme. In Brazil, control levels are reported as good in conjunction with the use of pheromone traps to monitor thresholds. However a number of constraints such as production technique, susceptibility to weather conditions, threshold adjustment for interventions, transportation to release site, the need for repetitive releases, compatibility with other interventions etc. are limiting a wide application.

As explained above, a number of parasitoids of FAW have already been identified in Africa. Before introductions of the FAW co-evolved parasitoids from the Americas are contemplated, or complex rearing and release efforts of local NEs envisaged, a thorough inventory work and impact assessment of the native guild of natural enemies is necessary.

A.3.5.3 Biopesticides

Biopesticides can be instrumental as part of an IPM approach against the FAW. The term biopesticide comes from"bio", a root word derived from Greek which means "life" while "pesticide" includes all substances or mixture of substances that are intended to suppress pests and prevent the damage or loss that they cause. Biopesticide is a generic term generally applied to a substance derived from nature, such as a microorganism or botanical or semiochemical, that may be formulated and applied in a manner similar to a conventional chemical pesticide and that is normally used for short-term pest control.[2] Thus, biopesticides are "living formulations" that are derived from natural materials originating from plants, animals (including parasitoids and predators), or microorganisms, are often cultured to increase amounts in order to exploit their characteristics of controlling pests.

Broadly, biopesticides may belong to several classes:

- Microbial pesticides or microorganisms – including bacteria, algae, protozoa viruses or fungi
- Pheromones and other semiochemicals; these are chemicals produced by plants and animals (and synthetic analogues of such substances) that influence the behaviour of individuals of the same or other species
- Plant extracts and botanicals (see section A.3.6); and
- Invertebrate Biological Control Agents, or macrobials – including insects, mites and nematodes that are natural enemies, antagonists or competitors of a pest (see section A.3.5.1). This class is sometimes not considered as a "biopesticide" per se.

Compared to broad spectrum conventional pesticides, biopesticides are usually more target-specific and inherently less toxic, and this limits their impact on non-target species, such as other insects, birds and mammals. They usually are biodegradable in the natural environment, thus reducing exposure and environmental pollution as well as reducing chances of pests developing resistance to them.

Microbial biopesticides are particularly relevant for the management of FAW. In this category of biopesticides, the active ingredient is typically the microorganisms themselves or the spores that they produce which are pathogenic to the target pest. For a description of the naturally occurring entomopathogens of FAW, see section A.3.5.1. on Biological control. They may be bacteria, fungi, algae, viruses or protozoans that suppress the target pests, either by producing toxic metabolites that are relatively specific to the target insect pest or closely related species, causing disease and are thus entomopathogenic.

Promotion of biopesticides to manage the Fall Armyworm

Biopesticides, such as those based on the bacteria Bacillus thuringiensis (Bt), fungi (such as Beauveria bassiana) and Baculoviruses have proven to be effective in the management of FAW.

Biopesticides – like any other pesticide – should be registered in the country before use. FAO has developed Guidelines[3] on the registration of microbial, botanical and semiochemical substances for both plant protection and public health uses.

2 International Code of Conduct on Pesticide Management, "Guidelines for the registration of microbial, botanical and semiochemical pest control agents for plant protection and public health uses", FAO/WHO, 2017, adapted from ISPM Pub. No. 3, 1996 (IPPC, 2005).

3 See www.fao.org/3/a-i8091e.pdf

Some of the biopesticides that have been registered to control FAW

Active substance	Target	Crops	Countries registered
Beauveria bassiana strain R444	Lepidoptera, including *Spodoptera frugiperda*	Barley, brassica, maize, sweetcorn, sorghum, tomato, wheat	South Africa (emergency approval in 2017)
Bacillus thuringiensis subspecies kurstaki strain SA-11	Lepidoptera, including *Spodoptera frugiperda*	Maize, sweetcorn, sorghum, wheat	South Africa (emergency approval in 2017)
Baculovirus	*Spodoptera frugiperda*	Unspecified	Pending, Brazil
SFMNPV - Baculovírus *Spodoptera frugiperda*	*Spodoptera frugiperda*	Cereals, Cotton, Sweetcorn, sorghum, Turf	Brazil (monograph B51), USA
Baculovirus	*Helicoverpa armigera* and some other Lepidoptera	All crops where pest present	Global

Other biopesticides registered for control of Lepidoptera are currently being tested for Fall Armyworm. In addition, certain botanical pesticides, such as those based on neem have also shown positive results.

Some of these naturally occurring diseases have been harnessed to produce commercial biopesticide products, such as Bt spray; but their availability in Africa is currently limited.

Substantial success has been recorded worldwide in using specific entomopathogens to control lepidoperan pests such as stem borers, a number of armyworm species as well as *Helicoverpa*.

Key limitations in the use of biopesticides in general include their delayed knockdown effect on pests compared to synthetic pesticides which is more immediate; lack of awareness of their existence; lack of standard recommendations for their use; improper storage conditions impacting the product efficacy; most of them usually have a short life; process of their official registration is often costly and time consuming; and the slow development of research in this area.

Furthermore, utilization of microbial pesticides in IPM of FAW requires scientific studies such as systematic surveys and larval collections and rearing, investigations on their properties as well as modes of action on the targeted insect pest and pathogenicity. The starting point for the scientific studies is local identification of their existence and impact.

Participants in FFS can conduct their own pilot exploration of locally available microbial pesticides which can be incorporated as one of the key tools for the IPM of FAW. It is recommended that trainers develop collaboration with national research centres for further support in the characterization of microbes that will be encountered.

Farmers should be aware that most biological pesticides do not kill pests immediately; but they reduce feeding, which is essential, while insects/larvae die normally in a few days time.


RESERVE
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BIO

A.3.6 Botanical pesticides for Fall Armyworm management

The use of plant-derived pesticides (commonly called "botanicals") in pest management is a cultural practice of most African farmers. It could provide a potential arsenal against the Fall armyworm in Africa.

The mode of action of botanical pesticides is broad and ranges from: repellency, knock-down, larvicidal to anti-feedant, moulting inhibitors and growth regulation.

They have a broad-spectrum activity with generally little or no mammalian toxicity; however some botanical pesticides are highly toxic not only for pests but also for natural enemies and for mammals including humans, for instance tobacco extracts. Pyrethroids will also affect natural enemies.

Farmers generally extract bioactive compounds as a concoction after grinding plant materials using water. Essential oils from bioactive rich plants and powdered forms are also used to some extent.

There are comparative advantages associated with the use of botanicals:

- they are biodegradable and do not accumulate in the environment
- generally less harmful to farmers and consumers (though there are some exceptions); and
- they often are less toxic to natural enemies (predators and parasitoids), hence not disrupting ecosystem services delivered by these natural enemies.

Several plants extracts have been reported to have insecticidal properties against **stemborers** in cereals. These include Neem, *Azadirachta indica*; Persian Lilac, *Melia azadirach*; Pyrethrum, *Tanacetum cinerariifolium*; Acacia, *Acacia* sp; Fish-poison Bean, *Tephrosia vogelii*; Wild marigold, *Tagetes minuta*; wild sage, *Lantana camara*; West African peppar, *Piper guineense*; *Jatropha, Jatropha curcas*; Chillies, *Capsicum* spp; onion, *Allium sativum, Allium cepa*; Lemon grass, *Cymbopogon citratus*; Tobacco, *Nicotina* spp; Chysanthemum, *Chrysanthemum* sp; Wild Sunflower, *Tithonia diversifolia.* etc. (Ogendo et al., 2013; Mugisha-Kamatenesi et al., 2008; Stevenson et al., 2009, 2017).

Preliminary evidence indicates that seeds or leaves of plants of the Meliaceae family (*Azadirachta indica,* i.e. neem and *Melia*) and Asteraceae family (*Pyrethrum*) and other plants such as *Tephrosia vogelii* **or** *Thevetia neriifolia* are showing effecacy in the management of **armyworms.**

This needs to be investigated in further detail against FAW. Potent botanical pesticides need to be further researched. It is critical to further research promising plants, their plant parts (leaf, stem, root or seeds), to optimize extraction methods and to evaluate their efficacy (mortality and repellence).

The capacities of smallholders should be strengthened through to promote preparation, utilization, testing, and adoption of botanical pesticides for FAW management as appropriate.

It is also important to assess the compatibility of botanical pesticides with other pest management options such as pheromones and entomopathogens, in order to optimize low-cost and effective pest management strategies for FAW.

Integration of botanical pesticides with management options such as Push-pull/ intercropping; pheromones, and less toxic synthetic pesticides as a last resort, is critical to achieve effective management of FAW.

Note that trainers and farmers should not assume that botanical pesticides are always harmless to humans and animals. Some can be highly toxic (such as tobacco leaf extract, containing nicotine). Farmers should rely on traditional knowledge about plant toxicity, and take precautions to reduce risks when preparing and using local botanicals especially in first instances.

See special topic on preparation of botanical pesticides in section B.6.10.

Simple tests on pesticide toxicity with farmers

In order to get a sense of toxicity for both botanical and synthetic insecticides on non-target organisms, farmers in FFS spray botanicals (or synthetic pesticides) on natural enemies:

See Special Topic B.6.12 "Effects of pesticides on natural enemies and beneficials".

Special Topics under B.6.11 "Spraying pesticides: pesticide hazards and pesticide risk reduction" provide ideas on activities to conduct with farmers to explore pesticide risks to human health.

These are not scientific methods, but in a training context they can facilitate farmers' awareness of risks.

Botanicals are one category of biopesticides and as such, like any other pesticide, their registration in the country should be promoted. For more information on how to deal with botanical registration issues, please refer to the FAO "Guidelines[4] on the registration of microbial, botanical and semiochemical substances for both plant protection and public health uses".

4 See www.fao.org/3/a-i8091e.pdf

A.3.7 Synthetic pesticides

A.3.7.1 What are pesticides?

Pesticides[5] are substances used to kill or repel insects, diseases, plants, animals (rats, mice…) and other living organisms which are invasive, harmful and cause damage and therefore are considered to be pests.

Pesticides are however also toxic to people and non-target organisms, and pollute the environment. Their handling, use and disposal always require special care.

A.3.7.2 Pesticide toxicity

There are two types of toxicity: acute and chronic toxicity.

Acute toxicity of a pesticide refers to the product's ability to cause harm to a person or an animal from a single exposure event, generally of short duration. Acute effects generally appear promptly, or within 24-48 hours of exposure.

To better understand acute poisoning, farmers can think of the effects of the bite of a venomous snake. People and animal develop a quick reaction after the bite (exposure to the poison). The effects can be reversible, or lead to death depending on the strength of the poison.

These effects are similar to those of other types of poisoning and to other illnesses, and include:

- Headache
- Fatigue
- Nausea
- Vomiting
- Sweating
- Irritation
- Swelling
- Affect metabolism
- Respiratory difficulties
- Seizures
- Dizziness
- Increased heart rate

5 Pesticide means any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or regulating plant growth. In agriculture, pesticides include herbicides, insecticides, nematicides, fungicides, plant growth regulators, and other categories.

- Unconsciousness
- Pain
- Stomach cramps
- Trembling
- Death

Antidotes can be effective if administrated promptly.

Chronic toxicity refers to harmful effects that occur from small doses repeated over a period of time. The main problem with chronic symptoms is that it can take time for them to become apparent, and then, when you do notice them, it is too late to do anything about them.

Pesticides with chronic hazard might cause cancer, immune suppression, damage to kidneys, brain and other organs, diminished intelligence, reduced fertility or damage to the unborn child (baby in the mother's womb).

Chronic toxicity of pesticides concerns farmers and pesticide applicators working directly with the chemicals, but also the community and the general public potentially exposed to pesticide containers and pesticide residues on or in food products, water, and the air.

To better understand chronic toxicity, farmers can think of the effects of smoking over time.

A.3.7.3 Pesticide exposure

When people or animals come in contact with a pesticide they are exposed to their toxicity.

There are three main exposure routes:

- eye and skin contact
- inhalation
- ingestion

You can be poisoned no matter which way pesticides enter your body. The dermal and inhalation routes of pesticide entry are likely to be the most important routes of pesticide applicator exposure. Farmers might breathe pesticide in, splash them on their skin, or expose themselves to pesticide drift.

There are also practices and behaviours that can increase the likelihood of exposure such as smoking, eating and drinking in the field, or applying chemicals against the wind.

Children and pregnant women are particularly susceptible to adverse effects from exposure to pesticides.

Three fundamental steps in pesticide risk reduction

1. **Reduce reliance on pesticides.** Determine to what extent current levels of pesticide use are actually needed. Make optimum use of non-chemical pest management approaches and eliminate unjustified pesticide use.
2. **Select pesticides with the lowest risk.** If use of pesticides is deemed necessary, select products with the lowest risk to human health and the environment from the available registered products that are effective against the pest or disease.
3. **Ensure proper use of the selected products** for approved applications and in compliance with international standards.

Source: Guidance on Pest and Pesticide Management-Policy Development, FAO, 2010

A.3.7.4 Selection of pesticides: are all pesticides the same?

Some pesticides are more toxic than others.

In technical terms, pesticides that have a high acute or chronic toxicity, or hazard to the environment are called highly hazardous pesticides.[6] Under the current prevailing condition of use in African countries, it is advisable to primarily avoid the use of highly hazardous pesticides. Fortunately, only a relatively small share of the products available on the market is highly hazardous and therefore farmers can learn to recognise them, and avoid their use.

Pesticide labels provide important information to recognise the toxicity of a product. This includes instructions for use, content including active ingredients, requirements for personal protective equipment, re-entry intervals, and first aid statements.

Farmers should look for:

Active ingredient – Products are sold with different commercial names, but the important information on the label is the actual chemical that provides the pesticidal action (the poison). This is called active ingredient.

Toxicity Colour code – Some countries have adopted a colour-coded toxicity label on pesticide containers.

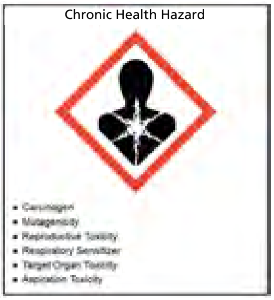
Categorization of pesticides

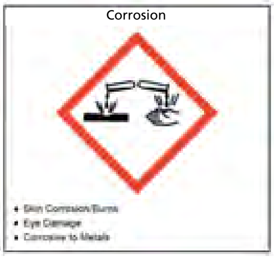
6 The FAO/WHO International Code of Conduct on Pesticide Management defines Highly Hazardous Pesticides (HHPs) as pesticides that are “acknowledged to present particularly high levels of acute or chronic hazards to health and/or the environment according to internationally accepted classification systems. In addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous”.

Pesticides labelled with red and yellow should always be avoided, unless proper conditions of use can be ensured.

Hazard pictograms – Visuals warning about specific high hazard (toxicity) levels to human health and the environment.

Pictograms commonly-used on pesticide-labels under the Globally Harmonized System of Classification and Labelling of Chemicals indicate:





There is a common misconception among farmers that pesticide toxicity determines its efficacy ("the more toxic, the better"). However, important factors that influence pesticide performance are: choosing the right product for the pest, the time and mode of application, water quality, temperature, and more importantly the stage of the target pest (for instance, some insecticides will only be effective on very young larvae).

A.3.7.5 Avoid the use of highly hazardous pesticides on the Fall Armyworm

The use of highly hazardous pesticides (HHPs) to control Fall Armyworm (FAW) has been reported in several African countries. Under the conditions of use prevailing in these countries, HHPs pose great concerns for human health and the environment.

It should be noted that:

- FAO has been mandated by the Council in 2006 and again in 2013 to assist member countries in reducing risks posed by highly hazardous pesticides
- The International Code of Conduct on Pesticide Management under article 7.5 stipulates that *Prohibition of the importation, distribution, sale and purchase of highly hazardous pesticides may be considered if, based on risk assessment, risk mitigation measures or good marketing practices are insufficient to ensure that the product can be handled without unacceptable risk to humans and the environment*
- The fourth session of the International Conference on Chemicals Management (ICCM4) in 2015 called for concerted action to address highly hazardous pesticides (resolution SAICM/ICCM.4/15)
- FAO and WHO have issued the Guidelines on Highly Hazardous Pesticides in 2017 to provide criteria for the identification of highly hazardous pesticides and guidance on risk mitigation.

Definition:

Highly hazardous pesticides (HHPs) are pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as the World Health Organization (WHO) or the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) or their listing in relevant binding international agreements or conventions. In addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous (Code of Conduct).

Criteria:

The FAO/WHO Joint Meeting on Pesticide Management (JMPM) has defined eight criteria to identify highly hazardous pesticides:

1. Pesticide formulations that meet the criteria of **Classes Ia or Ib** of the **WHO Recommended Classification** of Pesticides by Hazard;
2. Pesticide active ingredients and their formulations that meet the criteria of **carcinogenicity Categories 1A and 1B** of the **Globally Harmonized System of Classification and Labelling of Chemicals (GHS)**;
3. Pesticide active ingredients and their formulations that meet the criteria of **mutagenicity Categories 1A and 1B** of the **GHS**;
4. Pesticide active ingredients and their formulations that meet the criteria of **reproductive toxicity Categories 1A and 1B** of the **GHS**;
5. Pesticide active ingredients listed by the **Stockholm Convention** in its **Annexes A and B**, and those meeting all the criteria in paragraph 1 of **Annex D** of the Convention;
6. Pesticide active ingredients and formulations listed by the **Rotterdam Convention** in its **Annex III**;
7. Pesticides listed under the **Montreal Protocol**;
8. Pesticide active ingredients and formulations that have shown a **high incidence of severe or irreversible adverse effects** on human health or the environment.

For criteria 1-7 there are reference lists and related guidance can be found in the Annex 1 of the FAO/WHO Guidelines on Highly Hazardous Pesticides (HHPs). Assessment as to whether an active ingredient of a formulation would fall under Criterion 8 is more complex as this depends on the actual situation in individual countries.

For the selection of pesticides to control Fall Armyworm, criterion 8 is however particularly relevant due to the constraints that many countries face in controlling conditions of use. Some African countries have already taken the appropriate measures to phase out highly hazardous pesticides.

FAO Environmental and Social Risk Management requires that all pesticide use in FAO field activities be considered and cleared by FAO's Plant Production and Protection Division (AGP).

HHPs reported as in use on Fall Armyworm in Africa

FAO has received various indications that the following highly hazardous pesticides have been used or recommended for use to control Fall Armyworm in African countries:

Pesticides	Concentration	FAO/WHO HHPs criteria
Methomyl	>34%	Criterion 1
Cyfluthrin	>22%	Criterion 1
Methyl parathion	>28%	Criterion 1
Endosulfan	All	Criteria 5 & 6
Pesticides that under the prevailing condition of use in African countries might meet criterion 8		
Acephate	All	Not approved in EU for acute consumer exposure and non-target organisms concerns*
Benfuracarb	All	Not approved in EU for high health and environmental concerns*
Carbaryl	All	Not approved in EU for high health and environmental concerns*
Carbosulfan	All	Candidate for listing under Annex 3 of the Rotterdam Convention
Chlorpyrifos	All	Use only by trained and supervised operators through FAO
Cyfluthrin	<22%	
Diazinon	All	Not approved in EU for health and environmental concerns*
Methomyl	<34%	
Methyl parathion	<28%	

*Source: European Commission, Health & Consumer Protection Directorate-General, Review Reports available at EU Pesticides database

In addition, the use of pyrethroids and neonicotinoids has been reported to control Fall Armyworm. It should be noted that resistance development though the use of pyrethroids is a concern for public health in malaria – affected countries. And that the use of neonicotinoids such as imidacloprid pose risks to pollinators where present.

This list is not intended to be an exhaustive list of HHPs in use in the African countries. It is the result of a first assessment of the pesticides that have been reported to be in use or recommended for use on Fall Armyworm and assessed against the FAO/WHO JMPM criteria. It is very likely that other HHPs are currently in use. Some African countries have prohibited the use of these and other pesticides due to the conditions of use.

The options for mitigating risks of highly hazardous pesticides range from ending, restricting or changing formulations or uses. Selection of the most appropriate option will vary from case to case and depend on risk levels and needs, but also on policies and adequacy of institutional infrastructure for pesticide management.

FAO recommends an Integrated Pest Management approach with the use of low-risk pesticides as the last resort. Within the group of low-risk pesticides, bio pesticides are considered to be the best option. However, if there are temporary constraints to the use of biopesticides, low-risk pesticides, e.g. products falling under WHO hazard classes III and U, can be considered.

A.3.7.6 Pesticide contamination of the environment- water, soil, air ... and food.

Some pesticides survive in the environment longer than others and do not breakdown for a considerable period of time. They can be transported by water and air over long distances. This ability is called **"persistence"**. Persistent pesticides tend to bioaccumulate in animals and humans and thus biomagnify (i.e. they concentrate as they move from one trophic level[7] to the next) in the food chain.

Environmental and social issues related to pesticide exposure includes:

- Contamination of drinking water, river systems, groundwater and aquifers
- Poisoning of fish and other aquatic organisms and biodiversity loss
- Long-term persistence in soils impacting rotational crops and beneficial soil
- organisms and loss of ecosystem services
- Poisoning of wildlife (including birds and bees) and biodiversity loss
- Poisoning or contamination of livestock
- Reducing populations of pollinating insects important for crop yield
- Air pollution
- Acute and chronic hazards to human health (farmers, rural communities and consumers)

A.3.7.7 Economic limitations of pesticides as a management option

Spraying insecticides early in the crop cycle are most likely to kill off the natural enemies and may not be economical. The policy by some governments to give away pesticides to maize farmers to combat FAW or to organize spraying squads may be starting smallholder maize farmers on a pesticide treadmill that may well have negative impacts in the medium term.

Effectiveness of insecticides against FAW also greatly depends on the application technique, dose and formulation. Once the FAW is down in the whorl, the insecticides must reach them there. Spraying with backpack sprayers or through aerial spraying without delivering material directly into the whorl is often ineffective.

Cost of pesticides. The vast majority of maize smallholder farmers in Sub-Saharan Africa do not use pesticides on maize. Farmers consume a part of the maize they produce, and those who sell maize to

7 The trophic level is the position that an organism occupies in a food chain – what it eats, and what/who eats it. https://www.sciencedaily.com/terms/trophic_level.htm.

markets often receive a low price. Spraying insecticides several times can dramatically increase the costs of production, making the maize economically unviable.

TIPS - Activities you can do in Farmer field schools:

- Test toxicity of synthetic insecticides and botanical pesticides on natural enemies – see B.6.12.
- Compare costs of FAW management using synthetic pesticides as opposed to IPM methods – see section on Agro-Ecosystem Analysis (AESA) on the IPPM plot vs the Local Practice plot in section B.4.1 and B.5.1
- Discuss decision-making using Economic Threshold Levels - see section B.6.13 under Special Topics on 'Economic Threshold Levels'
- Do exercices with farmers on pesticide spraying and risks – see section B.6 for 'Special Topics' on pesticides

Fall Armyworm Management
SIMPLE GUIDE FOR SMALLHOLDERS

PREVENT

Sustainable management of Fall Armyworm (FAW) starts with prevention. There are actions that farmers can take before or when planting their fields to reduce infestation and impact of FAW in their crops. Key first steps include:

- Use **high quality seed.** The seed should germinate well, be disease-free and be of the variety the farmer wants to plant. Good pest management depends on healthy plants.
- **Avoid late planting or staggered planting** (plots of different ages). When moths are looking for their favourite stage of maize to lay eggs on, if yours is the last-planted plot in an area, it will attract many female moths.
- **Increase plant diversity** in your plots. Maize mixed in plots with cassava or yams or other crops may be less attractive to female FAW moths. Some plant species repel female FAW moths. This is the basis of the 'push-pull' technology: including a plant species that 'pushes' FAW away from maize and to plants that 'pull' them (attract them), where they can be easily controlled.
- Plant diversity can also increase the populations of farmers' friends – those organisms that are naturally in the environment and can kill a high proportion of FAW eggs and larvae. Predators (ants, eagwigs, etc.), parasitoids (wasps that kill FAW), and pathogens (virus, bacteria, fungi, etc. that kill FAW) are in and around farmers' fields. Plant diversity can keep them close to your maize so that they can find and kill the FAW.

MONITOR

Farmers should **visit their fields frequently** to observe, learn, and take action. During the first 40 days after planting, they should walk through their fields every 3-4 days. While doing this, they should observe:

- **General health** of the plants: do they have a nice dark green color (indicating good nutrition)?, do they appear moisture-stressed?, are there signs of damage (from FAW, other insects, or diseases)?, if there is FAW damage, is it current (look into the whorl and see if there are holes in the leaves in the whorl and fresh frass)?, are there FAW egg masses present? Young larvae? are there weeds (especially striga)?, are there farmers' friends present (ants, wasps, larvae killed by pathogens)?
- If you have access to the **FAMEWS** application, input data on the percent of plants currently infested with FAW (follow FAW Guidance Note 2 'Scouting' – which is described in section B.5.2).




KNOW

Maize plants can **compensate for certain levels of foliar damage.** A low percentage of plants infested will not reduce maize yield dramatically.

Farmers' friends (the natural enemies of FAW) can be very important in naturally controlling FAW – studies have found up to 56 percent of FAW larvae naturally killed by farmers' friends. Key to good FAW control is attracting and keeping farmers' friends in the fields. There are actions that can be taken to attract farmers' friends to their fields, keep them there, or harvest and use them.

Chemical insecticides are expensive and dangerous. Their use is probably not economically justifiable for smallholder African maize farmers. Some also present high human health risks. Some older pesticides, which have been banned from use due to human health risks in many countries, are being used by smallholder maize farmers. Many pesticides kill farmers' friends.

ACT

Effective and sustainable FAW management requires **action.** Some of the actions prevent FAW, others are required when something goes wrong in the system and there are high levels of FAW infestation in the field.

One of the simplest actions that farmers can take is **mechanically killing FAW eggs and young larvae.** Eggs are laid in a mass, easily observed on maize leaves. These can be immediately crushed. Likewise, young larvae can be picked off the leaves, before they penetrate deep into the whorl.

Many smallholder farmers try **local solutions** and report satisfaction with these local actions. In addition to the preventive actions, some farmers report success in:

- **"Recycling" pathogens.** When larvae natural killed by virus, fungi or bacteria are observed in the field, they can be collected, taken home, ground (or put through a blender), strained. The liquid that strains through may be full or fungal spores, bacteria, or virus particles that can be diluted and sprayed back into infested plants. This is a free, effective natural bio-pesticide. Many farmers spray into the whorls of infested plants, so as not to waste the natural insecticide.
- **Attract predators & parasitoids.** Ants have been observed to be important natural predators of FAW larvae. They crawl up the plants, into the whorls, and find, and drag out FAW larvae. Some farmers have found that they can attract ants to their maize fields by putting lard, grease from cooked meat, or old fish soup into their maize fields. These substances attract ants to their fields, and then they stay and find and kill FAW larvae in the maize fields. Some farmers use sugar water to attract and feed the wasps that can eat or parasitize FAW.
- Other farmers try and report satisfaction with using a number of **local substances, applied directly to the whorl of infested plants.** Some of the substances that have been tried include: soil, ash, sand, lime, salt, soaps, oils, and extracts from local plants: hot peppers, Tephrosia, Marigold flowers, neem, etc. Farmers can try these and other local solutions and then compare and share the results, to see which work best under local conditions.

Photos: © FAO/K. Cressman

PART B

FARMER FIELD SCHOOLS FOR FALL ARMYWORM INTEGRATED PEST MANAGEMENT

B.1 Key Principles of Integrated Pest Management in Farmer Field Schools

Sustainable agriculture requires that today's production needs are met while improving the production resource base for future generations. Integrated Pest Management (IPM), as a cornerstone of sustainable agriculture, seeks to improve farmer practices to support higher income while improving conservation and management of natural resources and the health of rural communities and consumers.

Integrated Pest Management (IPM) is the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human and animal health and/or the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms (definition from the International Code of Conduct on Pesticide Management, FAO/WHO, 2014).

In order to support this, IPM implementation in Farmer Field Schools is based on four practical principles:

- grow a healthy crop in a healthy farming system
- conserve natural enemies
- observe fields regularly
- farmers become experts

> **IPM – not a 'package", but a decision-making process**
>
> IPM is not a "packaged technology" that is "adopted" by farmers. IPM is a process of decision-making and farming which is gradually improved with greater ecological knowledge, and observation skills.

These principles describe the main actions of IPM implementation through FFS. Specific processes that take into consideration the variation of each field and farm family backup each principle, so that management can be done on a field-by-field, season-by-season basis. Key principles for IPM in FFS are described below:

Grow a Healthy Crop in a Healthy Farming System. This starts with maintaining a healthy soil, including soil organic carbon, soil moisture and structure, and ensuring adequate plant nutrition. Using high quality seeds, and varieties well adapted to the local environment and which are vigorous in the face of pests and diseases is important. Planting time is critical, especially when faced with limited or irregular rainfall. A healthy maize (or other crop) can better withstand diseases and compensate for damage caused by diseases and pests including FAW, so that plant injury does not always lead to yield-losses. Substantial research shows that plants grown in healthy soils are less attractive to pests. So it is not just about an increased ability to compensate for attacks: adding inorganic fertilisers to plants grown in poor soils may actually increase attack rates, as the high levels of free amino acids in the leaves are attractive to pests. Using polyvarieties of maize, intercropping and trap crops and repellent crops can also help reduce FAW infestation. A robust healthy crop in a healthy farming system are the first steps in IPM methods, and foundation for an optimal yield.

Conserve Natural Enemies. In all agricultural ecosystems, there are predators (e.g. insects, spiders, frogs, etc.), parasites, and diseases which attack eggs, larvae, nymphs, pupae, and adult stages of insect pests. These "natural enemies" are the "friends of farmers" and occur naturally in all agricultural ecosystems such as rice paddies, orchards, cereal or vegetable fields. They biologically control most insect pests most of the time. The naturally-occurring predators of FAW (which include ants, earwigs, wasps, etc.), parasitoids (small wasps like *Trichogramma*, *Telenomus* or *Cotesia*), and pathogens (bacteria, virus & fungi) can cause 50 percent natural mortality of FAW or more in the field in the Americas. Some of the local natural enemies are already adopting FAW as their new host. Learning to recognize and manage these natural enemies present in Africa is one major focus of IPM training so that they are not destroyed by unnecessary applications of herbicides, insecticides and fungicides but are allowed to work for the farmer's benefit. This also means that farmers should not aim to eradicate FAW completely in their fields, as it will provide food or hosts for natural enemies, thus helping their populations build up. Trees, diverse field borders (hedges, bushes, simple open flowers such as Apiaceae…) and uncultivated patches around fields are important because they provide habitat and food for natural enemies (birds, bats, insects, spiders…).

Observe Fields Regularly. This is essential to assess soil condition, crop development, diseases, weeds and insect pest infestation levels. In most cases, an experienced IPM farmer does this observation during a short time (usually less than a few minutes per field) while carrying out other crop maintenance activities (irrigation, etc.).

Observations should determine how the crop is growing and if there are diseases or pests causing crop damage that can lead to yield-loss, including FAW. Remember that not all injury causes yield-loss. In a healthy field, natural enemies are usually present and sufficient to keep pests at low numbers. Weather conditions, soil health and nitrogen levels, and plant health will determine if diseases will subside or become more serious. IPM Farmers must be knowledgeable of these factors to properly and economically manage crops. In some cases natural enemies, plant resistance, plant vigour, and plant compensation cannot prevent yield-losses from weeds, rats, insects, or diseases. Proper assessments must be made to effectively and profitably manage the use of inputs such as labour, quality seed, varieties, fertilizers, drainage systems, community organizing and pesticides in order to ensure profitable production. Observation skills and timely and evidence-based decision-making are key to becoming an expert IPM farmer and require field level practice for most farmers and extension staff.

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FFS practical training – not 'with farmers" but 'by farmers"

- IPM skills and concepts are best learned, practiced, and debated in the field. The field is the best teacher.
- Season-long FFS training courses allow all plant, insect, disease, and weed development processes and management to be observed and validated over time. IPM training should be carried out over all crop stages.
- Farmers must be allowed to actively participate and share their experiences during training to achieve maximum interest and effectiveness. Local or indigenous knowledge of the environment, varieties, pests, etc. must play a major role during decision-making.

Observation and reflection should lead to action. For example, some farmers notice that FAW infestation is clumped in certain parts of their fields. They may notice that this part of the field may be lower, and thus more moist. And so the plants grow more quickly there, and attract early oviposition. Or they may notice that along borders where certain weeds or other plants grow, there may be less FAW infestation. This could be because the weeds are "push" plants – the female moths don't like their odour, so stay away. Or farmers may notice that after heavy rains most of the FAW larvae in the whorls are killed.

During their visits they can also take action. It is very easy to scout small areas of maize fields and crush newly-layed FAW egg masses. And they can collect larvae dead from pathogens, to later "recycle" the pathogens, spraying the fungal spores or viroid particles back into infested plants. And they may try simple techniques: applying soil, ash, lime, sand, sawdust, soaps, oils, salt, local botanicals directly into whorls to kill larvae. Or they may put out lard or oil of pieces of fish to attract predatory ants to the fields, who then go on to eat the FAW larvae.

Farmers Become Experts in their fields. This is necessary for a knowledge-intensive agriculture in which farmers are responsible for farm management. Future increases in yields, profits, and sustainability will be the result of farmers making better use of available and new knowledge and technologies and limited resources. More emphasis in all agriculture programs must be placed on the ability of farmers to understand agro-ecosystem processes, make better decisions, increase their own efficiency, and become better managers. The future of food production and food security will depend on how well farmers can innovate and manage systems, especially in the context of climate change inducing more unpredictability and variability. Farming is implemented by farmers, and thus requires an emphasis on farmers' skills and knowledge.

B.2 What do trainers and farmers need to know about the Fall Armyworm

B.2.1 What skills and knowledge are needed to manage the Fall Armyworm?

Understanding the local situation of FAW and farmers' interests. FAW continues to spread on the African continent. Is some areas the pest is already present, and farmers need to develop understanding and skills on how to best manage FAW, using IPM. In some locations FAW might have a first appearance and cause big concerns for farmers (and involved institutions) on how to handle the new pest, and how to avoid crop losses in the short term. After an immediate response, longer-term management strategies need to be put in place. In other locations, farmers might have heard about FAW, but the pest has not yet appeared. Some might worry, and farmers might be interested in gaining some more information on the pest, and emphasis might be put on monitoring and early warning; but farmers' readiness to learn might be limited since the problem is not yet present. When designing training for farmers, it is essential to understand the actual situation of the FAW in the location, to best arrange relevant training modules to improve knowledge and skills of farmers and their communities.

Using FFS for farmer education on FAW. Farmer Field School groups can be a good entry point for farmers to learn about FAW, to test and adapt promising management options and to initiate community action for monitoring and awareness with the larger local population. The actual situation of FAW in the area where an FFS is planned or ongoing will guide the development of a specific curriculum and FFS interventions tailored to the context. If there are no ongoing FFSs or no skilled facilitators in a specific location, then organization of shorter courses which use discovery-learning can be helpful to ensure that farmers have a basic understanding of FAW and options to manage it.

Already trained FFS facilitators are expected to take a lead in integrating FAW into existing FFS, and/or to facilitate short courses for farmers in case no FFSs is ongoing, but demand for improved knowledge is great. FFS facilitators will in most cases need additional training on the FAW, since it is a relatively new problem for most. This kind of refresher courses is mostly provided by experienced FFS master trainers, who will also need new knowledge and skills on FAW.

This section elaborates on knowledge and skills needed with a focus on IPM for FAW, which can be integrated into FFS or used to design short courses in specific circumstances.

It does not elaborate at length on the other technical, facilitation and organizational skills which FFS facilitators and master trainers need to implement a quality FFS on maize! It is assumed that they are known, or that this information can be found in other manuals available (for example on the Global Farmer Field School Platform www.fao.org/farmer-field-school/en, or though Sub-Regional FFS Network, or contacting experienced Master Trainers). The box on the next page summarizes some key skills, as a reminder.

What overall technical knowledge and skills should farmers have gained after a FFS on maize?

- Describe the different crop-development stages
- Know IPM principles and why they are important for good management
- Know how to monitor all elements of the agro-ecosystem, understand relations and interactions between the elements, as a basis for decisions on field management (Agro-Ecosystem Analysis, AESA)
- Describe plant compensation and its importance for leaf-eating pests
- Know ecological function and life cycles of main pests and natural enemies; be able to recognize and distinguish different pests and natural enemies
- Recognize major diseases, the conditions that favour their development, and possible damage they can cause
- Understand toxicity of different pesticides and how to reduce exposure and use
- Describe effects of pesticides on human health, natural enemies, environment
- Know how to collect information for economic analysis comparing farmers' local practice and IPM practice

FFS facilitators and Master Trainers should have at least these technical skills, and preferably a more profound understanding. They also need facilitation skills, and need to be able to organize a FFS, starting with awareness at community level, organizing a group, conducting the FFS and conducting feedback and planning sessions at the end of the FFS. They should also be able to fine-tune a FFS curriculum with FFS participants, reflecting local context and needs and evolving through the growing season based on what is happening in the field and in the group, rather than proposing the same standardized training everywhere.

Master Trainers need to be able to design, fine-tune and organize short Refresher Courses for experienced FFS facilitators, and season-long Training of new Facilitators (TOF).

B.2.2 What do farmers need to know to best manage the Fall Armyworm?

By the end of the FFS, farmers will have the following knowledge and skills specifically related to FAW management.

Biology and ecology of FAW

- Be able to identify and differentiate the FAW (*Spodoptera frugiperda*) from the African Armyworm (*Spodoptera exempta*), *Helicoverpa armigera*, stem borers and other worms
- Recognize the different stages of FAW, and understand the life cycle of FAW
- Know where to find FAW stages on the plant, how the FAW feeds on the plant, and recognizing damage symptoms caused by FAW
- Know other plants of FAW that can serve as a host for FAW
- Know that some plants repel FAW ("push" it away) and others attract FAW ("pull"). The same can be true for natural enemies. Plant diversity is also important as food sources for natural enemies.
- Know which natural enemies of FAW are present, how they attack different stages of FAW and how many pests they can eat, parasitize or infect
- Understand how plants can compensate for leaf damage in different stages of crop development

Management options

- Understand basic IPM principles
- Understand promising management options of FAW, and be able to apply those in their own fields
- Describe pesticides, and effects on health and environment, and on natural enemies
- Be able to monitor all elements of the agro-ecosystem, including FAW, to come to an informed field management decision

Community action for FAW

- Work with interested farmers in the community to monitor FAW, and to share knowledge gained in the FFS

Part A of this guidebook provides detailed information on these various aspects.

B.2.3 What do Farmer Field School facilitators need to know to implement FFS that integrates Integrated Pest Management for the Fall Armyworm?

FFS facilitators will already have basic technical, facilitation and organizational skills to set up and implement FFS on integrated maize production. To integrate topics on FAW, they will need at least the same skills as the farmers will get during the FFS, plus some additional skills.

Biology and ecology of FAW

- Able to identify and differentiate the FAW (*Spodoptera frugiperda*) from the African Armyworm (*Spodoptera exempta*), *Helicoverpa armigera*, stem borers and other worms
- Recognize the different stages of FAW, and understand the life cycle of FAW
- Know where to find FAW stages on the plant, how the FAW feeds on the plant, and recognizing damage symptoms caused by FAW
- Know other plants of FAW that can serve as a host for FAW
- Know that some plants repel FAW ("push" it away) and others attract FAW ("pull"). The same can be true for natural enemies. Plant diversity is also important as food sources for natural enemies.
- Know which natural enemies of FAW are present, how they attack different stages of FAW, and how many pests they can eat, parasitize or infect
- Understand how plants can compensate for leaf damage in different stages of crop development

Management options

- Understand basic IPM principles
- Understand promising management options of FAW, and able to apply those in their own fields

- Describe pesticides, and effects on health and environment, and on natural enemies
- Able to monitor all elements of the agro-ecosystem, including FAW to come to an informed field management decision
- Understand economic threshold level, and how it can be used in AESA

Community action for FAW

- Able to facilitate the development of a community plan on how to monitor FAW, how to share information with other farmers, and how to identify action
- Support interested farmers in the community to monitor FAW, and to share knowledge gained in the FFS

Integrating FAW into the FFS curriculum

- Able to conduct FAW assessment with a starting FFS group, and adapt learning curriculum to reflect gaps and needs for the local context.
- Design most suitable field studies for the FFS, based on local situation assessment and promising management options

In addition to all of the above skills, **Master Trainers** are expected to be able to organize and implement courses for FFS facilitators with emphasis on FAW. In some cases, season-long Training courses of new FFS Facilitators (TOF) will be planned, and FAW might need to be added to the curriculum. In other cases, Refresher courses of a shorter duration need to be organized for already trained FFS facilitators with a focus on FAW, and how to integrate it into FFS activities. Master Trainers also need to be able to design and fine-tune short participatory courses on FAW management for farmers and their communities where no FFS is planned or ongoing, but where there is an acute need for FAW IPM training. They will then work with FFS facilitators to implement such short farmer training courses.

B.3. Building capacity for Fall Armyworm Integrated Pest Management: Farmer Field Schools and short trainings

B.3.1 Some questions to ask to identify the most appropriate training modalities

The previous chapter provides ideas on what knowledge and skills farmers, FFS facilitators and Master Trainers will need on the IPM of FAW. A curriculum for a FFS (or a Refresher course) needs to reflect the specific context. Some reflections can help facilitators and master trainers to best identify the kind of training needed. Below are some questions that can help.

Presence of FAW	Kind of trainings to gain knowledge on FAW IPM	Modalities
FAW is already established in the community, farmers have some basic knowledge and are concerned about management of the pest	FFS useful to deepen knowledge on IPM and to initiate community monitoring and action Short courses for larger number of farmers on FAW IPM	If FFS are planned or ongoing, integrate FAW IPM into curriculum If no FFS are planned, explore possibility of starting FFS Or organize short courses for farmers, using discovery-based learning in the field to better understand FAW and to develop community monitoring. Some handouts on FAW at the end of the session can be useful.
Some FAW present, but new to farmers. Concerns for the new pest	FFS can be useful to learn more about FAW and IPM Short courses might be useful for farmers to get an understanding on FAW and IPM quickly	If FFS are planned or ongoing, integrate FAW IPM into curriculum Or organize short courses for farmers, using discovery-based learning to better understand FAW and to develop community monitoring. Some handouts at the end of the session can be useful. Then explore if FFS can be organized in the future
No FAW present yet, some awareness might exist that a new pest is spreading	Farmers might be curious/anxious about FAW, but they might not want to spend too much time learning about a problem that has not yet occurred FAW IPM can be integrated in ongoing FFS, but in appropriate, more limited way Community awareness raising on FAW	If FFS are planned or ongoing, integrate FAW IPM into curriculum focusing on some basic awareness. If the pest cannot be found, discovery-learning will be challenging Explore if it is possible to visit a nearby area where FAW is present, or whether a farmer from that area with FAW can share experiences with FFS group Organize awareness sessions on FAW in the community, and agree on what needs to happen once FAW is found

B.3.2 Integrating Fall Armyworm Integrated Pest Management into the Farmer Field School curriculum

When integrating FAW IPM into a FFS curriculum on maize, the knowledge and skills that farmers should gain will help define activities during the FFS (see previous section B.2).

A range of tools are used in FFS to enable farmers to learn. The five major activities carried out in the FFS learning process are:

1. field studies
2. special topics

3. Agro-Ecosystem Analysis (AESA)
4. group dynamics and ice-breakers; and
5. monitoring, evaluation and learning.

Field study designs will be fine-tuned with a FFS group to reflect the local FAW situation (and other challenges in growing maize) and to compare different management options. In the technical sections in Part 1, an overview is given of promising management options that can inspire comparisons between local practice and integrated management studies in FFS. For example, setting-up a crop compensation study will be an opportunity to better understand how plants can compensate for damage in different stages of the crop. In section B.4, specific examples of field studies with a focus on FAW are given.

Agro-Ecosystem Analysis (AESA) is a core activity of the FFS. Field observations are done regularly in the different FFS plots. This is a good time to collect different insects, to see where on the plants they can be found, to discuss which insects are found and their functions (pest versus natural enemy). It can also be useful to go to fields with other crops and to natural vegetation to see if the FAW can be found there. During AESA, farmers also collect data for instance on crop development or on costs of production under different management options, to generate comparisons. Section B.5 provides more information on AESA.

Special topics are experiments which facilitators can conduct with farmers. Insect zoo exercises are well suited to learn about functions of insects – pests and natural enemies, about predation and parasitization. Other special topics can contribute to improve understanding of ETLs, or to develop a plan for community monitoring. Section B.6 proposes Special Topics that are relevant for FAW IPM.

Group dynamics and ice breakers do not need to be specific to FAW management. But it is good to select most relevant ones or to select and adapt them to this context. Examples can be found in other numerous FFS documentation available on the Global Farmer Field School Platform and elsewhere.

The Farmer Field School Guidance Document provides suggestions on processes to consider for **monitoring, evaluation and learning**, which can used for FFS which address FAW management.

Keep in mind that the FAW-related activities will come in addition to the plan and curriculum that might already be in place for maize on topics other than FAW (other pests and diseases, plant growth, soil health and plant nutrition, harvest and post-harvest, etc.).

In the FAW curriculum development writeshop in Ghana in July 2017, a matrix summarizing problems and solutions was developed. This was used to define knowledge and skills needed for farmers, facilitators and master trainers. The writeshop also elaborated study designs, and identified key special topics. In Table 1, some main ideas are summarized, on what can be done for FAW IPM in a FFS. Of course, this will need to be adapted to a local context.

Table 5 in Annex 2 provides more detailed information, as developed during the curriculum development writeshop in Ghana.

Table 1: Ideas on how to integrate FAW IPM into FFS curriculum for maize

Timing	Main activities	FAW IPM integration	Learning points for FAW IPM
Preseason, preparation for FFS	• Awareness raising on FFS • Organizing FFS group • Problem analysis with FFS group – fine tuning the curriculum, designing learning plots • Identifying FFS plots	Introduction to the FAW Is FAW present in the community? Field observations with FFS groups to find FAW in fields, surrounding vegetation Integrate FAW focus into learning plots – IPM and Local Practice (LP) plots; compensation studies; fertilization studies, other relevant studies	To create awareness on how to recognize FAW, ensure that FAW is integrated in proper way in problem analysis, discuss study designs for FFS
Pre-season, preparation for FFS	• Land preparation • Layout and prepare study fields for the FFS • Seed selection	Reflect FAW management options in selected study designs Healthy seeds as the start for a healthy crop that can compensate damage Any varieties or crops that are resistant/tolerant for FAW? How to use them in learning plots? Is seed dressing an option for FAW management – test in the field and compare? What is soil health? Healthy soils for healthy crop	How to lay-out fields, how to prepare IPM plots and LP plots, discuss differences, and why Seed quality (germination capacity) How good seed quality can help get a good crop How healthy soils are the basis for a healthy crop
Seeding/planting the field studies	• Seed the study fields • What are IPM principles? – discussion on what and why	FAW reflected in study designs Understand IPM approach, and link to FAW as well as to other pests, diseases in the agroecosystem	How to lay-out field, prepare and seed – IPM compared to LP plots. Differences, why (seeds, lines, distances, seed dressing, etc) IPM principles, relevance of principles better understood
FFS session 1– crop germination	• Introduction to AESA, including observations for FAW • Group dynamics • Special topic	If FAW is present – what stages, what crops, where on the crop and surrounding vegetation	Building understanding of FAW – development stages, life cycle, natural enemies, host plants, where to find FAW on the plants
FFS session 2	• AESA • Group dynamics • Start crop compensation study and fertilization studies • FAW – observations and insect zoo	Compensation study for FAW Insect zoo if FAW is present, life cycle, natural enemies	Not all plant damage leads to yield loss – to be explored in compensation studies How fertilization can influence FAW oviposition and yields
FFS session 3	• AESA • Group dynamics • Community mapping and how to monitor for FAW • Observe insect zoo, crop compensation study, fertilization studies and other studies	Community map that outlines fields with maize and other crops, other vegetation – link to where FAW might be found Discuss action plan for monitoring FAW at community level – visual observations, traps	Importance of monitoring FAW populations in maize and other vegetation. Action plan for community monitoring and action on FAW using IPM
FFS session 4	• AESA • Group dynamics • FAW insect zoo, effects of pesticides on human health • Crop compensation and other studies	Insect zoo continued on FAW, natural enemies Understanding how pesticides can affect human health, implications of pesticide use for FAW. Botanicals vs biopesticides vs synthetic insecticides	Understand effects of pesticides on human health
FFS session 5	• AESA • Group dynamics • FAW insect zoo • Special topic on ETL • Observe compensation and other studies • Community monitoring: feedback	ETL – special topic on ETL, what is it, what are advantages and disadvantages, how to complement with AESA information Follow-up on compensation studies and community monitoring	Strengthen understanding on what information is needed to take good decisions for FAW management, and role of ETL in decision-making Discuss cost of pest management using chemicals

FFS session 6	• AESA • Group dynamics • FAW insect zoo • Effect of pesticides on natural enemies • Compensation and other studies • Community monitoring	Special topic on effects of pesticides on natural enemies	Better understand role of natural enemies and how pesticides can reduce natural enemy populations and how this impacts FAW population development (and other pests as well)
FFS session 7	• AESA • Group dynamics • FAW as needed, follow-up on compensation studies • Other special topics	Compensation studies – how are plants developing in different treatments? What does this mean when an insect like FAW causes damage to leaves in different development stages?	Understand importance of crop compensation
FFS session 8	• AESA • Group dynamics • FAW as needed • Organizing an awareness day on FAW for community	Discuss what community members need to know on FAW, how to share information on FAW, importance of community monitoring	
FFS session 9	• AESA • Group dynamics • FAW as needed • Community monitoring for FAW – status, action		
FFS session 10	• AESA • Group dynamics • FAW food webs	Special topics: foodwebs for FAW (and other insect pests) including life cycle, host plants, natural enemies that feed on pests and their lifecycle. How to increase natural enemy populations. Role of plant diversity.	Understand functions and relations of different elements in the agroecosystem
FFS session 11	• AESA • Group dynamics • FAW, compensation study • Host plants of FAW – field observations, insect zoo. Link to community map and observations	Compensation study – yield cuts, discussion on ability of plants to compensate for damage at different stages of crop development, and what it means for FAW management	
FFS session 12	• AESA • Group dynamics • Preparing for harvest • Where does FAW survive if no maize in the field? How to use this information • Crop compensation and other studies – data collected, implication for FAW management	Harvesting: physiological maturity	To determine the appropriate time for harvesting
FFS session 13	• Field day	Post-harvest handling	To learn about proper methods of post-harvest handling and processing
FFS session 14	• Harvest, Storage	Minimizing losses during storage	Able to minimize losses during storage
FFS session 15	• Economic analysis • Feedback and planning for next season, including FAW action plan	Farm record-keeping and economic analysis of LP versus IPM plots, and other study plot	Know how to analyze records for management decision-making

B.3.3 Short courses using non-formal adult education approaches and discovery-learning

FAW continues to spread to new areas in Africa. When farmers are suddenly confronted with a new pest that seems to be causing damages and losses, urgent action might be needed. Pressure might be high, especially when many farmers are affected. In this case it can be useful to organize short training courses of 1-2 days for farmers to get a basic understanding of FAW and IPM options to manage this. The short training courses can use discovery learning (i.e. a process which facilitates farmers' own learning by direct experience in the field, rather than being told or witnessing a demonstration), as is used in the FFS. If there are ongoing FFS in an area with high presence of FAW, they can include FAW into the curriculum. The farmers trained in short courses can be linked to FFS to define and implement community action plans.

FFS facilitators and master trainers that have participated in refresher courses on FAW IPM would be the best persons to conduct these short courses.

Training should be field-based, taking 1-2 days. Numbers of farmers participating can be higher than in a FFS, as long as there are sufficient FFS facilitators to support farmers splitting into smaller groups during field work in the training.

Key learning points for short courses

The key points that farmers should know about after a short course of 1-2 days include:

- Identify and differentiate the FAW (*Spodoptera frugiperda*) from the African Armyworm (*Spodoptera exempta*), *Helicoverpa armigera*, stem borers and other worms
- Recognize the different stages of FAW, and understand the life cycle of FAW
- Know where to find FAW stages on the plant, how the FAW feeds on the plant, and recognizing damage symptoms caused by FAW
- Know other plants than maize that can serve as a host for FAW
- Know that there are natural enemies of FAW that can help reduce populations and recognize them
- Able to monitor FAW in the field, and engage in discussions on how to monitor at community level
- Have an overview of promising management options of FAW, including the role of plant diversity, the importance of regular field monitoring and crushing of egg masses, how plants can compensate for some level of damage without impacts on yields, the essential role of natural enemies, the use of local controls (like ash, sand, oil, etc.) and the role and risks of different types of pesticides (advantages and disadvantages)
- Know how to link with non-FFSs members community authorities, and monitoring and surveillance systems on FAW if any, and with other FFSs.

Table 2: Some ideas on what the programme for a short course might look like – but this will need to be adapted locally.

Welcome, introduction	Main activity	Process
Recognizing FAW, development stages and lifecycle, functions of different insects and host plants	Field work – collecting pests, natural enemies and samples from damage on the crop (sub-groups of 5-7 farmers) Sorting the insects found by function (pest, natural enemy) including identification of FAW (different stages if found in the field or surrounding vegetation) (groups of 5-7 farmers) Presentations, discussions and summary on FAW stages, differences with other pests, and major natural enemies	Split participants in smaller groups, with 1 facilitator available for 2 to 3 groups during field work. Each subgroup makes observations – some can work in maize, others in other crops, and in surrounding vegetation Subgroups sort insects by function and local names; identify FAW and discuss how it distinguishes from other pests. Also include samples of damage on crops/plants. Discussion on outputs of the subgroups. Facilitators to provide additional information. Some handouts on FAW at the end of the session can be useful
Monitoring FAW in the field and community	Discussion on the following questions: How to monitor for FAW (visual): what stages to look for, where on maize, other plants? The frequency of monitoring for FAW – how often to monitor populations Record keeping at field level Monitoring individual fields – can community share data and discuss for best management?	Discussions can be done in subgroups. Then they report back to the whole group.
Plant compensation	Introduction and discussion in the group or subgroups	If there is some time when preparing this short training, it might be possible to set up a compensation study that the participants could observe and discuss
IPM principles	Introduction of principles followed by discussion	
Pesticides	Start with a small demo on using dye in the spray tank. Discuss effects on health. Discuss advantages and disadvantages of pesticide use.	
Management options – IPM for FAW	Discussion to list most promising management options in the location. Discuss who can be contacted for further support (government services, FFSs groups working on FAW IPM, etc)	Discussion in subgroups on what can be the options. Feedback by the subgroups, listing of potential options. Facilitators to ensure that options reflect experiences from elsewhere

B.3.4 Short refresher courses and season-long Training of Facilitators

In FFS, a Refresher Course is a short course (usually from 1- 2 days to a week) for experienced FFS facilitators who have already followed a season-long Training of Facilitators (TOF) and have facilitated FFS with farmers. Refresher courses are designed to share technical knowledge and tools on new topics, or to go over some competencies or subjects that are already familiar, but where facilitators need strengthening. All FFS projects typically run Refresher Courses, so that facilitators continue improving on their skills.

By contrast, a TOF is the process through which field staff or farmers become new FFS facilitators for the first time. TOF are designed to equip field staff who have never conducted FFS with the technical knowledge and the soft skills to do so. They normally span a period of several months, with sessions timed over the entire crop or animal cycle or issue which is the main focus of the training, "from seed to seed" for crops or "from calf to calf" or "egg to egg" for animals - this is often called "season-long training". A TOF includes a lot of practical field work in TOF plots; some classroom work; and "practice FFS" in which facilitators start facilitating FFS with coaching from their trainers.

Most experienced FFS facilitators will need Refresher Courses on FAW since it is a new pest in Africa that they might not be familiar with. If new Training of Facilitators (TOF) is starting, FAW can be integrated into the curriculum.

Teams of experienced master trainers and facilitators need to design refresher courses or TOFs integrating FAW IPM, to ensure that facilitators have the basic skills to address FAW IPM with confidence and sound knowledge. In some cases refresher courses might have FAW as the main topic, in other cases the refresher course might also include other topics intended to ensure quality FFS.

During the curriculum development writeshop in Ghana in July 2017, FFS trainers and FAW IPM experts elaborated an example of a six-day Refresher Course that can serve as inspiration (Table 3 overleaf). A more detailed version for planning purposes is available at Table 4 in Annex 1.

Planning for and conducting quality Training of Facilitators

For more information on planning for and conducting quality Training of Facilitators, see the Farmer Field School Guidance Document at www.fao.org/3/a-i5296e.pdf; and a wealth of manuals in several languages available on the Global Farmer Field School Platform at www.fao.org/farmer-field-schools/en.

Table 3: Six-day FAW Identification and Management Refresher Training programme for FFS Master Trainers or FFS Facilitators

DAY	TOPIC	LEARNING OBJECTIVE(S)	ACTIVITY
1	Contextualizing the problem	Identify the knowledge gap and bring participants to a common understanding of the problem	• Brainstorming on the existing maize pest complex, existing management practices • Zero down to FAW (history and situation in the country) • Outcomes of the Baseline studies if any, mapping the problem in areas of work of facilitators • FAW management – what is currently happening at farmer level, at government level • Present FAO's Programme of Action on FAW Management, if relevant[8]
	Biology and ecology	Know the FAW life cycle and the preferred development conditions of the pest	• Field work: collect FAW in the field, and in surrounding vegetation; find as many stages as possible • Group work to sort out found insects (FAW and possibly other insects – how to distinguish, different development stages) • Groups to propose insect zoo exercises to learn about life cycle of FAW • Presentations – how to recognize FAW, life cycle and conducive environments • Groups set up insect zoos
	Identification of the pest and damage	To identify/recognize the pest and its behaviour, and differentiate from other pests/armyworms	• Field work – collection of FAW and other pests, and samples of damage on maize and other plants • Group work: describe and draw Signs and symptoms • Discuss feeding behaviour: what stage of FAW feeds on what parts of the plant, why? Where can you find eggs, larvae, pupae, adults? (preference on young soft leaves; if not, will migrate to tassels and cobs), moving, oviposition • What other insects are found? Functions? Which insect zoos are useful? • Differentiate FAW, AAW (Spodoptera exempta), other worms • Set up/observe insect zoos
2	Management of FAW	IPM for FAW	• Introduction of IPPM – IPM principles, and what it means in the context of FAW
	Insect zoos	FAW and other insects	• Reports on insect zoos, discussion
	Monitoring and early warning	To know how to carry out regular field monitoring using AESA	• Tools (pheromone traps…) • Process for scouting • Parameters to observe • Techniques for the sample collection and handling • Preparation for the field
3	Field immersion	To build the capacity of participants on regular field observations and informed decision-making for FAW management.	• AESA (Identification, sampling, collection, decision-making - observe and identify correctly FAW egg masses, young larvae and damage, observe natural enemies (coccinellids, earwigs, lacewing, ants, parasitized eggs, etc.) • Data analysis, presentation and synthesis of the key learning points • Set up new insect zoos, report on earlier insect zoos
	Field work	Plant compensation	• Introduction and discussion on plant compensation. How to set up a study in the FFS • Set up plant compensation study in the learning field, to know how it can be done in FFS
	Pesticide risk reduction	To understand the adverse effects of the use of pesticides	• Two special topics: 1. Effects of pesticide on health (mummy exercise). 2. Effects of pesticides on natural enemies • Discussion • Highlight aspects on loss of ecosystem services, resistance development, toxicity and impact on trade • Linkages to crop production intensification to meet the full elements of sustainability (economic, social and environmental)

8 FAO's Programme of Action on FAW, and up-to-date FAO Guidance on FAW can be found at: www.fao.org/food-chain-crisis/how-we-work/plant-protection/fallarmyworm/en

4	Monitoring the samples of damaged plants	To learn the life cycle or the development stages of the pest.	• Observation of samples collected from the field, report back on insect zoos
	Natural enemies (Farmers friends)	To identify and differentiate natural enemies	• Differentiation of farmers' friends (parasitoids, predators, entomopathogens...) • Special topic – exercise on bacteria (Bt) and modes of action
		To know how to use natural enemies	• Conservation and use of farmers friends Natural enemies (insectaries, landscape management
	Preparation and handling of botanicals	To prepare and make proper use of botanicals or bio pesticides	• Examples of common botanicals • Explain the process of preparation, application • Apply the extracts on some of the target pests for the farmers to appreciate effectiveness • Discuss mode of action (repellent, or insecticidal), explain the possible dangers (toxicity)
5	Management practices (how to minimize build-up of pest population)	To put emphasis on the management options including prevention measures and action to control the FAW	• Varietal diversity, crop diversification and intercropping reduce oviposition and builds natural enemy populations • Stover management • Picking egg masses – why? • Host plants; effects of repellent plants and attractants and mode of action • Seed treatment • Planting dates - avoid staggered planting • Good soil health
	Awareness and communication	To carry out appropriate sensitization to stakeholders	• Community action for FAW – trapping, observing, mapping, action, etc. • Mass extension campaigns • Reporting mechanisms for FAW. Why should farmers report, to whom, how? • Role of farmers in sharing information with the rest of their communities and with other FFS • Information, education and communication materials
	Designing of the possible studies	To define and design field studies from potential priority solutions (prioritized solutions)	• Reviewing of possible potential studies for outreach • Review of any existing protocols that can be adapted to local needs
6.	Action planning	To develop a program that includes the resources needed for a season	• Developing of farmer education programmes around FAW: integration FAW into FFS; and short courses for FAW • Identification of possible facilitators
	Monitoring, Evaluation and Learning	To build and consolidate collaboration among stakeholders and practitioners	• Documentation of practices • How to link with national task forces, research etc. • Linkages with plant health systems and networks
	Closing		• Overall evaluation of the training • Closing remarks

B.4 Farmer Field School field studies for Fall Armyworm management

The facilitator conducts a baseline survey or a participatory rapid appraisal in a given area with community members. Local solutions are recorded, discussed and prioritized based on their potential effectiveness and constraints.

The prioritized suggested solutions or options can be either tested or validated in the FFS though Field Studies (i.e. a kind of experimental plot to compare different management options) in the FFS learning field, or they can be covered as Special Topics (i.e. a short exercise or discovery activity which does not necessarily need to be followed throughout the growing season in an experimental plot). This will help explore solutions to the problems encountered by the community, and help discover important agro-ecosystem processes. Key special topics might be associated with specific field studies, to build the knowledge and skills of FFS members and their capacity in running field studies.

FFS Master Trainers and facilitators are used to conducting such processes with farmers, as this is an essential part of FFS. For information about defining Field Studies and special topics with farmers, you can refer to classic FFS guides, for example "FACILITATING SCIENTIFIC METHOD as follow-up for FFS graduates" (see Bibliography).

Based on the recommendations from resource persons with sound experience on FAW management in the Americas and the suggestions of international and African FFS and IPM practitioners, the following field studies are proposed. They should be adapted to the local context.

B.4.1 Effect of different maize production practices on Fall Armyworm management

Rationale:

The reaction of many farmers when they observe FAW infestation in a maize field from the early growth stage is to spray chemical pesticides repeatedly. This practice tends to reduce the population of natural enemies. Repeated sprays (often using non-authorized or highly hazardous pesticides) are in many cases not cost effective in smallholder maize systems in Africa, and bring too many risks to the environment, animals and human beings.

Proper planting dates, fertilization and soil health and moisture management, and the use of mechanical controls and botanicals from the early growth stage as part of Integrated Production and Pest Management (IPPM) strategy are effective and efficient to manage FAW infestation while protecting natural enemies population. This set of practices are affordable for smallholders. This study will help farmers discover and assess sustainable, integrated management practices to prevent and to control FAW infestation ensuring profitability, and to compare them with their current practices.

Objectives:

- to compare the incidence of FAW infestation under different management practices: Integrated Production and Pest Management (IPPM) versus Local Practice (LP)
- to compare the agronomic and economic benefits of different management practices

Time required:

Season-long

Materials needed:

Land; seed (same variety, local or improved); field tools; stationary; fertilizer (for basic application and side/top dressing); manure/compost; botanicals (for IPPM plot) and other IPPM needs for botanicals preparation and handling (tools and equipment to reduce risks); synthetic pesticides (for use in the "Local Practice" plot, based on farmers requests or pesticides locally distributed by governments)

Methods/procedures:

2 treatments:

1. T1: Local practices (LP): management is based on typical local farmers practice as identified with farmers at beginning of FFS, including planting dates, pesticide use, use of manure/compost.
2. T2: Integrated production and pest management of maize (IPPM): management – see also Table 5 on Curriculum in Annex 2.
    - use of organic manure as per locally recommended dose
    - spacing as per local research recommendation
    - observations and crushing of egg masses twice a week during vegetative stage, especially during periods of heavy infestation
    - if available locally – erect yellow sticky traps @ 25/ha against rising population of sucking pests;
    - install bird perches @25/ha
    - maintain diverse field borders (open flowers, bushes, etc.)
    - spray solution of water and sugar to attract natural enemies (on the whole plot or a 10mx 10m portion)
    - if available (not mandatory), release Trichogramma chilionis / T. pretiosum @ 1 50 000/ha at weekly intervals for six weeks against *Spodoptera frugiperda* (FAW) and Helicoverpa armigera. Each Tricho card consisting in 20 000 parasitized eggs can be cut into ten pieces and distributed in the fields evenly. Using threads, the cards can be hung from the plant near the top but avoiding exposure to direct sunlight
    - apply botanical or biopesticides as per decision from Agro-Ecosystem Analysis (see section B.5.1 on AESA). Sub-plots can be set up where specific botanicals or biopesticides will be tested over time (see chapter on Botanical pesticides and biopesticides)
    - no synthetic insecticides in vegetative stage; use synthetic insecticides only as last resort, choosing less hazardous pesticide (e.g. Spinosad). (see section 4.3.7 on Synthetic pesticides)

- if of interest, include push pull system; or conduct it as a separate Field Study; (see chapter on plant diversity/push pull)

Plot size = same; Planting date = same day, but starting with Farmers Practices' plot.

Agronomic practices common in all the plots.

Record regularly all inputs and outputs for and from each plot.

In case bio-control agents are released in IPPM fields (but they might not be locally available), maintain about 10-metre buffer zone between T1 and T2 plots to limit the influence of bio-control agents onto the LP plot. In other plots 2 m buffer zone can be adopted.

Weekly AESA should be conducted in both treatment plots with the sampling unit of 5 plants per subplot; implement the decision taken in IPM plots only. In LP plot do not follow the decision on the basis of AESA, instead apply pesticides as per the schedule prepared on the basis of baseline survey conducted in FFS villages, or the schedule recommended by the country's government or research.

Layout: Size 25 m x 25 m

Sampling for data collection:

- identify and mark 5 samples (fixed) per plot at random for agronomic data
- select 10 to 20 plants per plot randomly using X or Z pattern, for regular field scouting and evaluation of FAW infestation/natural enemies population build up
- AESA: leading to informed management decision, especially on IPPM plot

Parameters to measure:

- growth and development parameters (plant height, flowering, cobbing, ear, maturity)
- FAW infestation
- damage from FAW or other pests (on leaf, cob or stem)
- natural enemies' population

- presence of pests and diseases including FAW
- soil health
- yield (including grain/cob)
- cost of production

Results (data analysis):

- growth and development
- yield
- FAW and natural enemies
- commercial value
- cost of production

B.4.2 Maize intercropping studies

Rationale:

Sole maize cropping systems offer conducive environment to pests including FAW to spread fast. FAW adult female moths find the preferred conditions to lay egg masses and increase the number of generations within a season, favouring increased levels of infestation. Plant diversity, including intercropping systems and the use of multiple varieties, can reduce the rate of oviposition by confusing the FAW female moth, therefore helping reduce the level of infestation.

In addition, intercropping and other forms of plant diversity (use of trap crops, repellent plants or a combination of both, i.e. 'push-pull' systems) can help build up the population of natural enemies of FAW and keep FAW away from maize.

Objectives:

- to explore how diversity could reduce pest occurrence and pest populations, by reducing FAW oviposition and increasing populations of natural enemies
- to raise farmers awareness on the economic benefits of intercropping

Time required:

Season-long

Materials needed:

Seeds of maize and the intercrop (cassava, pigeon pea, elephant grass, crotalaria or farmers' choice); fertilizer (organic and inorganic); supplies for AESA (including magnifying glasses); field tools.

Methods/procedures:

Two (2) treatments will be applied at the same planting date: one is suggested (cassava, as it is not a FAW host plant, and it is a common food crop in many parts of Africa) and one will be farmers' and facilitators choice.

Sampling for data collection: 10 plants/stations will be randomly selected in each plot.

Spatial arrangements of plants, planting rates, and maturity dates are important in this cropping system.

Consideration for the choice of intercropping:

- use of organic manure as per locally recommended dose
- intercropping with cassava could be good as it is not a host plant for FAW, and is an important food crop in many parts of Africa
- intercropping with elephant grass/crotalaria ("push pull") or pigeon pea or farmers' choice can attract more beneficial insects, and can help repel FAW from field and control striga
- intercropping with cassava or pigeon pea will provide 2 or more different food crops to the farm family

Plot size = same; Planting date = same day, but starting with Farmers Practices' plot.

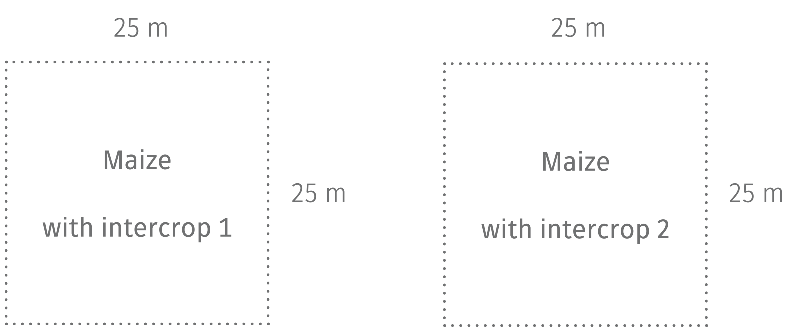
Agronomic practices common in all the plots.

Record regularly all inputs and outputs for and from each plot.

In case bio-control agents are released in IPPM fields (but they might not be locally available), maintain about 10-metre buffer zone between T1 and T2 plots to limit the influence of bio-control agents onto the Local Practice (LP) plot. In other plots 2m buffer zone can be adopted.

Weekly AESA should be conducted in all the treatment plots with the sampling unit of 5 plants per subplot; implement the decision taken in IPM plots only. In LP plot do not follow the decision on the basis of AESA, instead apply pesticides as per the schedule prepared on the basis of baseline survey conducted in FFS villages, or the schedule recommended by the country's government or research.

Layout: Size 25 m x 25 m



Parameters to measure:

- number of infested plants; presence of egg masses and larvae (qualify or quantify)
- time/period and duration of infestation
- presence or absence of natural enemies (in maize or intercrop)
- weed incidence
- soil moisture status
- signs of nutrient deficiency
- yields

Results–discussion:

- compare FAW infestation (oviposition and damages) or population in the different treatments
- compare natural enemies' population
- compare maize yield
- compare the economic benefits
- which intercrop provides better control of pests (including FAW)?
- in which treatment maize has more yield?
- attracts more beneficial insects, especially when flowering crops are included in the cropping system
- minimizes labour cost on the control of weeds (mixture of various crops gives often a better coverage of the soil leaving less space for the development of weeds)
- potential increase for total production and farm profitability
- provides 2 or more different food crops for the farm family in one cropping season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B.4.3 Push-pull intercropping in maize studies

Rationale:

Push-pull is a habitat management strategy which appears to be effective in the management of FAW and other lepidopteran pests (such as stemborers) compared to maize mono cropping systems. In addition, the technology also controls striga weeds, improves soil fertility through nitrogen fixation and offers valuable fodder. Since the technology is pesticide free, push-pull conserves natural enemies thereby increasing their abundance, diversity and activity.

For more information, see the explanations on Push-pull under section A.3.3 Plant diversity.

Objectives:

- to explore if Push-pull intercropping system could reduce FAW occurrence and damage, by reducing oviposition, feeding and increasing populations of natural enemies
- to raise farmers awareness on the economic benefits of push-pull intercropping system

Time required:

Season-long; considering that both border crops (Napier or Bracharia) and Desmodium are perennial, need for at least two seasons

Materials needed:

Seeds of maize and the intercrop (Desmodium seeds, Bracharia seeds and Napier grass splits); fertilizer (organic and inorganic); field tools (ruler tape, tags, hoes, pegs, small buckets, etc. (refer to Push-pull FFS manual, ICIPE 2007).

Methods/procedures:

Three (3) treatments can be applied at the same planting date:

- conventional Push-pull (maize with Desmodium silver leaf and napier grass)
- climate-smart Push-pull (Desmodium Greenleaf and Bracharia)
- maize mono-crop (this can be the FFS “Local Practice” plot set up in the main Field Study, see B.4.1 “Effect of different maize production practices on FAW management”).

Agronomic practices are common in all the plots.

Sampling for data collection: 10 plants/stations will be randomly monitored in each plot.

Spatial arrangements of plants, planting rates, and maturity dates are important in this cropping system.

Use of organic manure as per locally recommended dose.

Consideration for the choice of push-pull:

- Use of organic manure as per locally recommended dose.
- Intercropping with Desmodium as it is not a host plant of FAW, and Napier/Brachiaria which are less is an important food and fodder crop in many parts of Africa.
- Conservation of beneficial insects in Push-pull can help controlling FAW, stemborer and other lepidopteran pests
- In addition to lepidopteran pests, Push-pull also controls striga.
- Desmodium and Napier grass/Bracharia biomass provide excellent fodder and feed for livestock and source of income.

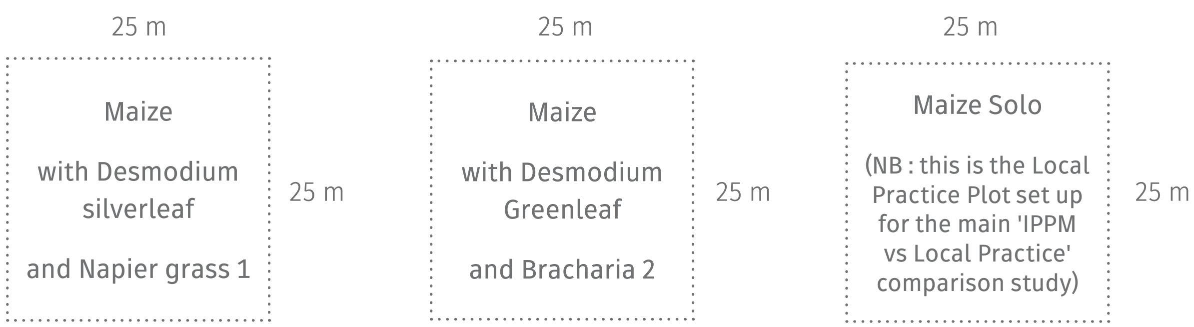
Plot size = same; Planting date = same day along with Local Practice plot.

Record all inputs and outputs regularly for each plot.

Follow instructions as provided in the Push-pull FFS Curriculum (ICIPE, 2007; http://www.push-pull.net/ffspdf.pdf). Desmodium rows need to be well maintained in order to access full benefits of the technology. At the end of the first season, the border crop needs to be trimmed in order to enhance sprouting in the next rainy season.

Weekly AESA should be conducted in all the treatment plots with the sampling unit of 5 plants per subplot; implement the decision taken in push-pull plots only. In control plot (Maize solo) do not follow the decision on the basis of AESA, use farmers cultural practices, e.g. weeding, apply fertilizer or manure, etc.

Layout: Size 25 m x 25 m



Parameters to measure:

- number of infested plants; presence of egg masses and larvae (qualify or quantify) time/period and duration of infestation
- time of first infestation and duration of infestation
- damage on leaves (windowing, shot holes) and cobs (random feeding on the maize kernel, holes in the sheath covering the cobs)

- presence or absence of natural enemies (in maize or intercrop)
- symptoms of nutrient deficiency – www.pioneer.com/home/site/us/agronomy/library/corn-nutrient-deficiency-symptoms
- weed density and diversity in plots
- qualitative soil moisture status
- yield per plot
- estimate cost of cultivation and returns from different plots

Results–discussion:

Discuss overall advantages and disadvantages of Push-pull system versus sole cropping:

- compare FAW infestation (oviposition and damages) or population in the different treatments
- which treatment provides better control of other pests than FAW?
- compare natural enemies' population. Push-pull might attract more beneficial insects, especially when flowering crops are included in the cropping system
- compare maize yield: which treatment has more quantitative and qualitative yield?
- compare the labour costs: Push-pull can minimizes labour cost on the control of weeds (mixture of various crops gives often a better coverage of the soil leaving less space for the development of weeds)
- compare the overall economic benefits (cost of production, gross margins)
- discuss importance of intercropping with Desmodium vs. mono-cropping for household nutrition and animal husbandry
- Push-pull can provides 2 or more different food crops for the farm family in one cropping season
- additional benefits on the use of Push-pull vis a vis access to fodder and yield increase
- discuss any challenges, including access to Desmodium, Bracharia and Napier grass seeds

B.4.4 Effects of planting dates on Fall Armyworm infestation and yield loss

Rationale:

Later-planted maize attracts more oviposition from FAW females, as the populations of adults have built up in the previously-planted maize. We can test this by planting plots of maize every 15 days and measuring oviposition, damage and yield. For more technical information, see section A.3.2 "Crop management".

Objectives:

- understand how staggered planting (i.e. planting close-by maize fields at different dates) and late planting can attract more oviposition, and so increase FAW infestation, and therefore should be avoided

Time required:

Season-long

Materials needed:

Land; seeds (same variety, local or improved); field tools; stationary; fertilizer (for basic application and side/top dressing); manure/compost; botanicals for preparation and handling (tools, and equipment to reduce risks).

Methods/procedures:

Plant plots of at least 25 m x 25 m every 15 days (larger is better). Manage them according to IPPM plot recommendations.

Begin observations 5 days after emergence, carefully looking at 50 plants. The 50 plants should be in five stations of 10 consecutive plants each. Make a "W" through the field, making a station at every turn of the "W". Carefully review each plant and record: presence of egg masses, presence of young larvae (on leaves) and fresh damage in whorl.

For details on how to do this, see section B.5 "Scouting and observations".

Repeat this every week.

Results (data analysis):

- at harvest, measure yield of each plot
- the data can be graphed as percentage of plants with egg masses, percentage of plants with fresh damage over time, comparing planting dates. The yield can be related to the dates

Questions for discussion:

- what did we observe on each plot?
- was there a difference in infestation based on the date? a difference in levels of damage? a difference in yields?
- why?
- did early-planted plots do better than late planted plots? what do we conclude?

B.4.5 Effects of nitrogen fertilization rates and manure on levels of Fall Armyworm infestation and yield loss

Rationale:

Plant nutrition can affect not only plant health and vigour, but also FAW oviposition, compensation of maize plants to foliar damage, percentage of parasitism and ultimately yield. To test this, we can do the following trial. For more technical information, see section A.3.2 on “Crop management”.

Objectives:

- understand the benefits of good plant nutrition on improving yields, maize compensation of damage, and maize quality
- understand the benefits of good plant nutrition on reducing FAW oviposition and percentage of parasitism

Time required:

Season-long

Materials needed:

Land; maize seeds (local or improved); field tools; stationary; fertilizer; botanicals for preparation and handling.

Methods/procedures:

Create 4 plots (25 m x 25 m) of maize with the following treatments:

1. 0 additional fertilizer.
2. The equivalent of one 45 kg sack of urea per ha.
3. The equivalent of two 45 kg sacks of urea per ha.
4. The equivalent of four 45 kg sacks of urea per ha.

Manage them according to IPPM plot recommendations (see field study B.4.1 "Effect of different maize production practices on FAW management”), except for fertilization.

Starting at 5 days after emergence, carefully look at 50 plants. The 50 plants should be in 5 stations of 10 consecutive plants each. Make a “W” through the field, making a station at every turn of the “W”.

Carefully review each plant and note: presence of egg masses; presence of young larvae (on leaves); fresh damage in whorl; and number of larvae found dead from natural enemies.

For details on how to do this, see section B.5 “Scouting and observations”.

Repeat this every week.

Results (data analysis):

- measure infestation levels (i.e. percentage of infested plants)
- at harvest, measure yield of each plot
- assess maize quality
- record production costs and calculate gross margins for each plot

Questions for discussion:

- what did we observe on each plot?
- based on the type of fertilization was there a difference in infestation levels? a difference in levels of damage? a difference in yields? what are possible explanations?
- what was the difference in production costs?
- what do we conclude?

B.5. Scouting and observations

B.5.1. Agro-EcoSystem Analysis in maize with special emphasis on the Fall Armyworm

Rationale:

Agro-EcoSystem Analysis (AESA) is a decision-making tool used to make weekly field observation throughout the crop life cycle to determine plant health and its compensation abilities, population fluctuations of pests and natural enemies, soil conditions, climatic factors, agronomic practices etc. and analysis of situation taking into consideration the inter-relationship among the factors. The analysis leads to taking a quality decision on appropriate management practices.

Objective:

- to build the capacity of farmers to understand their agro-ecosystems, and to make informed decisions for the management of the crop based on thorough observation, discussion and analysis

Time required:

One (1) to two (2) hours

Materials needed:

Polythene bags, notebook, vials/plastic bottles/jars, aspirator, pencil, sketch pen, knives (pen and cutlass), cardboard, flipchart, markers, eraser, camel hair brush, disposable gloves, measuring scale, rubber bands, magnifying glass.

Methods/procedures:

Group work; brainstorming using Q&A and the “What is this” principle; sharing; problem-solving

There are four steps involved:

1. Field observation.
2. Analysis and discussion in small groups.
3. Synthesis and decision-making in small groups, including drawing on a poster.
4. Presentation & discussion in a large group, and conclusion of management practices.

1. Field Observation

Recall and record the climate prevailing in the preceding one week. Record the stage of the crop. A total of 20 plants per field have to be sampled. The plants within one to two meter from the edge should not be included to avoid border effect on samplings. Randomly select 20 plants.

Of these 20 plants, mark 5 plants with permanent labels for recording the plant growth parameters. Record all findings in a table.

- count the flying insects in and around the plant canopy without disturbing the plant
- examine leaves on both sides and stems for egg masses (count number of egg masses per 20 plants); collect egg masses, if any, for rearing and recording the percentage egg parasitism
- next examine leaves for 1-2 instar larvae. Collect 10 to 25 healthy as well as inactive larvae/pupa for rearing and recording the larval parasitism
- examine whorl (funnel) and leaves for three types of damage: windowpane (scratching), pinhole damage (small holes), rugged damage and frass (sawdust-like appearance)
- observe natural enemies
- look for larvae dead from pathogens and count number
- observe growth parameters of plants: stage of growth, age, height, colour, number of leaves, presence of pests and pathogens. To assess the damage to leaves, count the total number of leaves and number of damaged leaves and calculate the percentage defoliation. Leaves with less than 25 percent leaf area damage may be ignored
- observe soil conditions: moisture, weed spectrum (observe around the plant in one square metre area and record the type of weeds, size in relation to maize population density in terms of either number or percentage area affected)
- record weather

For FAW collect the following info (an example):

	Seedling	Early whorl	Late whorl	Cobs	Where to find
Egg masses	X	X	X		Leaves – both sides, stems
1-2 instar larvae	X	X	X		On leaves – presence or absence (they may also be found in the whorl)
3-6 instar larvae	X	X	X	X	In whorls (funnel) – presence or absence
Adult moth	X	X	X	X	Number on plants
Larvae attacked by pathogens		X			
Windowpane damage					Presence or absence
Pinhole damage		X			Presence or absence
Rugged damage – frass			X		Presence or absence

Plants/ samples	Insects					Natural enemies (which)					Number of leaves	Number of damaged leaves/cobs	Plant height
1													
2													
3													
4													
5													
…													
…													
20													
Total													

2. Discussion in small groups

Now the group discusses about the field situation by raising many questions. For this purpose referring the previous weeks charts are essential to note the population fluctuation of pests and defenders as well as the trends in plant infestation levels. Discussion points should include the following:

- plant stages, health and compensation ability
- changes in pest population in comparison to previous weeks
- corresponding changes in natural enemies population
- diseases – presence of inoculum, favourable climate, availability of susceptible varieties
- climatic factors – temperature, rainfall, humidity, wind velocity and their influence on pest, defenders, crop growth etc.
- weeds – susceptible stage of the crop, alternate host for pests
- shelter for defenders etc.
- agronomic practices – irrigation, fertilizer application and inter cultivation, etc.
- after considering all related factors, the group members arrive at a conclusion and recommendations written in the lower part of the chart

3. Synthesis including drawing

- Make the drawing on the manila paper/flipchart paper. Use live specimens as models for drawing. Top two third portion of the sheet is used for drawing and the remaining one-third portion for writing conclusion and recommendations.
- Draw the plant with the correct average number of leaves found.
- For weeds write approximate density and size of weed in relation to the size of the plant. Draw the kind of weeds (broad-leaf or grass type).
- For pest population intensity, draw the pest as found in the field on the right side of the plant. Write the average number (per leaf for sucking pests and per plant for others) and local name next to the insect.
- For defender population abundance, draw the organisms as found in the field on the left-hand side of the plant. Write the average number per plant and their local names next to the drawing.

- Use natural colour for all the organisms. For instance, draw green for healthy plant and draw yellow for diseased plant or deficient plant. Draw pests and natural enemies nearer to the plant where usually they are seen.
- If fertilizer was applied, place a picture of hand throwing N, P, and K depending on the type used.
- If insecticides are used in the field, show sprays with a nozzle and write the type of chemical coming out of the nozzle.
- If the preceding week was mostly sunny, draw a sun, just above the plant. If the week was partially sunny and partially cloudy draw the sun but half covered with dark clouds. If the week was cloudy all day for the most of the week, put just dark clouds.
- Discuss in the small group what should be the decision for the days to come in the IPPM field, and record those, based on AESA. What is the decision in local practice for the days to come?

4. Presentation to the large group

One representative from each group presents their analysis report before the larger group and invites discussions and interactions. The decision on management practices are finalized and implemented in the field.

Key message: On daily basis, AESA refers to the major observation done and the decision made (recommendation) and validated by the whole group to guide the management options/practices for the FAW. A comparison should be made also with the previous AESA in order to evaluate the effectiveness or appropriateness of the management options imposed.

B.5.2 Scouting for the Fall Armyworm

If during the Agro-Ecosystem Analysis conducted during FFS the group finds FAW, you might want to get sub-groups to scout also in farmers' neighbouring fields and surrounding vegetation.

Farmers should know that one of the most important things they can do to manage FAW is to enter their fields at least once a week, more often when there are dynamic changes. This "scouting" will help farmers better understand the biology of the organisms in the field and their interactions (ecology). This observation is the basis for better understanding and knowledge, leading to better decision-making, in turn resulting in greater production, fewer wasted resources, and more sustainability.

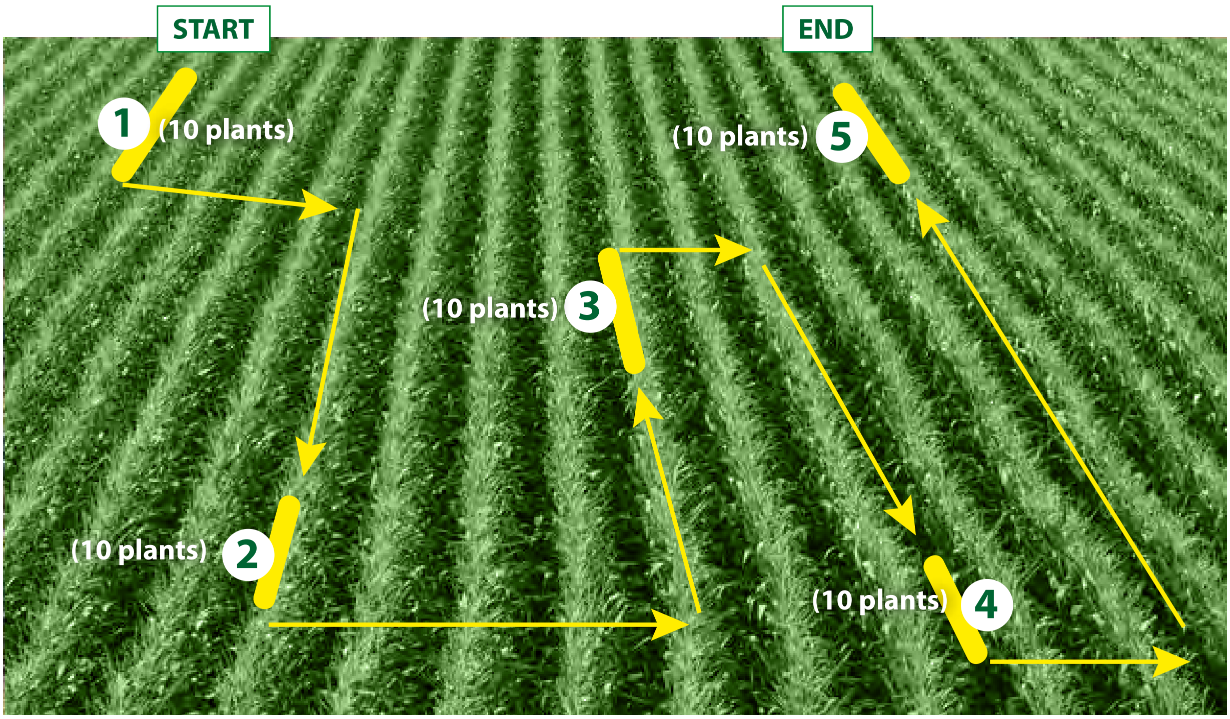
For smallholders (with less than 2 ha), scouting will also help farmers learn the variability of their fields – where the low-lying spots are that are more humid, where the soil types are different, where increased organic matter results in better plant growth, where a certain type of weed is almost always more abundant, etc.

"Scouting" means rapidly and systematically determining overall crop health and estimating presence of certain organisms causing damage and potentially yield reduction.

For FAW, the procedure is quite simple:

Determine the field to be sampled. For a smallholder, this is typically less than 2 ha. If the fields were planted at different times, with different varieties, or with different conditions (intercropping, fertilization, etc.), then each plot should be sampled differently.

In the field, walk a letter "W", covering the entire field:



At the start and at every turn, inspect **10 plants** in a row. These ten plants are called a "station". Look carefully in the whorl of each plant for signs of recent leaf damage or fresh frass in the whorl. These indicate a live larva, probably FAW, in the whorl. Do NOT include plants with some damage to older leaves, but with no clear signs of current damage. **Only currently infested plants need be counted**. Keep track of the number of plants currently infested in this way (in this example FAW infested plants are marked with an "X"):

Station 1		Station 2		Station 3		Station 4		Station 5	
Plant no.	Infested?	Plant no.	Infested?	Plant no.	Infested?	Plant no.	Infested?	Plant no.	Infested?
1	X	1	X	1		1	X	1	X
2		2		2		2		2	
3	X	3		3	X	3	X	3	
4	X	4	X	4	X	4	X	4	X
5		5		5		5		5	X
6	X	6	X	6		6		6	X
7		7		7		7		7	X
8	X	8		8	X	8	X	8	X
9		9		9		9		9	
10	X	10	X	10	X	10	X	10	X
Total number plants infested	6		4		4		5		7

The total number of plants infested in the 50 plants counted is 6 + 4 + 4 + 5 + 7 = 26

So in 100 plants it would be double: 26 X 2 = 52, or 52 percent of the plants infested.

REMEMBER: We are looking for **signs of FAW presence (i.e. fresh leaf damage or frass in whorl)**. So the **sampling doesn't depend on finding the larvae, or how many you find**. This way the sampling is fast, non-destructive and can be done any time of the day.

While scouting for FAW-infested plants, it is also important to make an overall assessment of the fields, the crops, and especially for **natural enemies**. There are many naturally-occurring "farmers' friends" that help control FAW – predators (ants, earwigs, pirate bugs, birds, etc.), parasitoids (wasps that kill eggs and larvae), and pathogens (bacteria, fungi, and virus).

For more information on 'natural enemies':

- Check section on Biological Control under Part I
- See the Special Topics on 'Insect Zoos' and 'Inviting natural enemies to our fields'

Information collected during field scouting should be carefully recorded, ideally in the FAO FAMEWS mobile app (bit.ly/2BZEW8q), so that it can be shared and used for early warning.

When the level of FAW infestation is calculated, along with observations about the general health of the crop, the farmer may want to know: 'Is the FAW infestation level so high that it will significantly reduce my yield?' This is a topic for discussion in the next FAO Guidance Note for sustainable management of FAW.

Farmers should look for :

- uneven darkened eggs (they might be parasitized by natural enemies)
- any larvae killed by parasitoids (white silken cocoons) or pathogens (hard or soft larval cadavers).

As farmers learn about their "friends" and observe their effectiveness in the field, they can begin to appreciate their activity and learn how to favour their populations in the field. Farmers can begin to understand how to create the conditions to favour natural enemies, and even how to increase their populations.

B.6 Special topics

B.6.1 Insect zoos: lifecycle of the Fall Armyworm

Insect zoos are an important special topic in FFS. Participants can set up insect zoo experiments which allow them to follow and observe behaviour of insects that are alive (discovery learning). The insect zoo also helps find out more about functions of an insect in the field, which is very important information when managing insects through IPM. It can help farmers get a better understanding of insects even if they have limited access to information from outside.

Insect zoos also motivate farmers to continue observing and exploring their agro-ecosystem, as they realize that they can make important and useful discoveries by themselves to improve their farm management.

Overall, learning in the insect zoo generates knowledge and information that help to take informed management decisions for the IPM of FAW and other pests.

Purpose of insect zoos:

- study the function of an insect – is it eating plants? Other insects?
- understand more about natural enemies – including rate of predation (for example by putting together a natural enemy with a pests and finding out how much pests a natural enemy can consume during a day); and rearing egg masses or larvae or pupae to observe parasitization
- explore life cycles of insects – setting up experiments to observe the life cycle of an insect, where different stages can be found (on or in the plant, in the surroundings), and how long different stages of the life cycle will last

Rationale:

The Fall Armyworm is an invasive alien pest in Africa which is causing a lot of damage in maize fields across Africa, and is a cause for great concern. Farmers have very limited knowledge on the pest. Hence they need to build their skills to properly identify the pest and understand the behaviour in its environment in order to help them manage FAW sustainably.

Objectives:

- to help farmers understand the biology and life cycle of the FAW and to recognize the various stages, to enhance better decision-making for IPM

Time required:

1.5 hours

Materials needed:

Field plots; hand lenses/magnifiers; vials or plastic bottles for field collection; mosquito nets; small knife; cutlash; sticks.

Methods/procedures:

Two (2) methods can be used:

Method 1: Open field insect zoo.
Method 2: Insect zoo in bottles, jars, or other containers.

1. Method 1: In the planted field. Look for egg masses starting one or two weeks after planting. Look for FAW in nearby fields if not present. Select one or 2 maize plants that will be covered by muslin veil cages. If the plants already have egg masses of FAW, note where to find them. Remove all other insects from the plant. If there are no egg masses, release adults of FAW to lay eggs, if possible. Observe regularly – different stages of development, where they live and feed on the plant, how long it takes to change from one stage to another. Continue this until the life cycle is complete.

2. Method 2: Collect egg masses and preserve them in well aerated plastic bottles, observe them daily until they hatch (most likely, it will take 2-3 days maximum for eggs to hatch). Feed emerging larvae regularly with fresh maize leaves. It might not be easy for the FAW to survive its entire development cycle in simple containers, therefore, collect FAW at different stages of development: egg masses, various instars (i.e. from smaller to larger larvae), pupae, adult moth, and try to observe as each one develops onto their next stage.

N.B. Larvae should be isolated individually in the rearing containers to avoid cannibalism, i.e. larger FAW larvae will eat smaller ones to reduce competition for food.

In addition to the insect zoo, collect FAW life stages during AESA, and ask questions about life cycle on FAW to reinforce learning regularly.

Parameters for observation:

- number of days between the different stages of development
- morphological characteristics of FAW (egg mass, larvae, pupa, moth)
- differentiation from other worms that are locally present, such as African Armyworm (*Spodoptera exempta*), *Spodoptera esigua*, Cotton bollworm (*Helicoverpa Armigera*).
- feeding, moving and pupation behaviour
- damages: scratching on the leaves; holes on the leaves emerging from the whorls (windows); frass from larvae in the whorls; occasional damage on the stems, tassel and on maize ears

Results–discussion:

Map/draw the different stages of development.

Discuss:

- what is the duration of the different stages of development of the pest? what can influence the duration of the different stages?
- what have we learnt about the behaviour of FAW?
- what kind of damage does it produce at various stages? what stages can do most damage? where on the crop are they found? is it easy to manage them when they are in the whorl?
- what is the most vulnerable stage of the crop? can we observe signs of a damaged crop that has recovered?

B.6.2 Insect zoo: the role of natural enemies (farmer friends)

Insect zoos are an important special topic in FFS. Participants can set up insect zoo experiments which allow them to follow and observe behaviour of insects that are alive (discovery learning). The insect zoo also helps find out more about functions of an insect in the field, which is very important information when managing insects through IPM. It can help farmers get a better understanding of insects even if they have limited access to information from outside.

Insect zoos also motivate farmers to continue observing and exploring their agro-ecosystem, as they realize that they can make important and useful discoveries by themselves to improve their farm management.

Overall, learning in the insect zoo generates knowledge and information that help to take informed management decisions for the IPM of FAW and other pests.

Purpose of insect zoos:

- study the function of an insect – is it eating plants? Other insects?
- understand more about natural enemies – including rate of predation (for example by putting together a natural enemy with a pests and finding out how much pests a natural enemy can consume during a day); and rearing egg masses or larvae or pupae to observe parasitization
- explore life cycles of insects – setting up experiments to observe the life cycle of an insect, where different stages can be found (on or in the plant, in the surroundings), and how long different stages of the life cycle will last

Rationale:

Natural enemies provide a natural pest regulation mechanism. There is a wide range of natural enemies (insects–predators, parasitoids; birds; frogs; and micro-organisms – fungi, viruses, bacteria, nematodes) in our fields. Many of them can help manage FAW. Farmers usually are not aware of the presence and the benefit of friends of the farmer (natural enemies) to control pest populations in their field.

Objectives:

To build the capacity of farmers to recognize natural enemies in the maize field and their impact, by:

- getting to know the function of an insect in the field (e.g. what does it eat or do)
- understanding/observing predation and parasitization and pathogen infection
- observing rates of predation and parasitization
- understanding its life cycle through life cycle studies

Time required:

Season-long

Materials needed:

Field plots; hand lenses/magnifiers; vials or plastic bottles for field collection; mosquito nets; small knife; cutlash; sticks.

Procedures and parameters for observation:

- Collect various insects and arachnids (i.e. "spiders") you can find and make direct field observations on what they are doing.
- Set up a simple experiment using empty bottles or jars (make sure the bottle has small aeration holes or cover the lid with veil/net)
- Predation: put a caterpillar and/or egg masses in a bottle with the suspected predator and make observations (approx. 5 min). Observations can be repeated daily, as homework for interested FFS participants to observer predation. Note how many FAW a day are eaten. However, note that the predator might not be able to exhibit his natural behaviour under these circumstances. This may lead to a substantial underestimation of the efficacy. You can also just observe - for example count digger wasps visiting their holes and count the number carrying larvae.
- Egg parasitism: Parasitized eggs are likely to have a darker colour (which can sometimes be confused with eggs close to hatching) – if parasitism is suspected, collect eggs masses with the leaf, put it in a clear, aerated plastic bottle and observe daily and discuss the results. What happens? What are the differences with hatching of non-parasitized egg masses?
- Larvae parasitism and diseases: Look for larvae with abnormal behaviour; collect each such larva into individual transparent bottle or jar with some leaves and make observations.
- Field study monitoring for observation, data collection and analysis for learning and informed decision-making will be done using the AESA process regularly.
- It is possible to do a systematic comparison between IPPM and LP as part of the AESA – by collecting a fixed number of egg masses in each field and observing if there is a difference between the treatments.

Results–discussion:

- diversity and numbers of natural enemies
- function and behaviour of natural enemies; predators vs parasitoids
- diversity of insect pests
- crop growth and vigour
- yield

B.6.3 Inviting local Fall Armyworm natural enemies

Rationale:

General predators, such as ants, or parasitoids, such as wasps, may be very effective to reduce FAW populations. Those predators may not be in farmers' fields, because of habitat destruction or the use of insecticides. Nevertheless, we can take steps to attract those natural enemies to our fields (this is called "conservation biological control"). Besides eating worms, ants and wasps are attracted to sugar.

Objectives:

- find predators that are available around our fields
- understand their potential to reduce FAW
- document cultural practices to increase those natural enemies in our fields

Time required:

One or two months

Materials needed:

Land, maize crop, field tools, stationary, sugar, water, sprayer.

Methods:

You will compare plots of maize as follows:

1. The control plot is the "Local Practice" plot
2. The "sugary plot" is the IPPM plot, or a smaller portion of it (10 m x 10 m)

Once the maize is established, start monitoring for FAW.

As soon as the first larvae appear, in the IPPM plot, apply a solution of water and sugar with the pump over the plants.

For the next week:

- observe if more wasps or ants are attracted to this "sugary plot" than the control
- observe if predators (for instance ants) are eating the FAW
- or if you can observe parasitism, or find egg masses/ larvae parasitized by parasitoids (for instance by wasps).

For the next months, evaluate and compare FAWs damage in both plots.

Invite farmers to observe what other predators eat the FAW, and to be creative on how they can attract natural enemies to their fields (maybe moving wasps nests near their fields, using perches to attract birds, building a refuge for bats...).

For more information on natural enemies of FAW, see section A.3.5 on Biological control.

B.6.4 Community awareness and monitoring for the Fall Armyworm

Rationale:

Many farmers are not familiar with FAW, since it is a new pest in Africa. The FFS can help increase awareness of the pest, help monitor FAW and promote IPM solutions. The FFS group can also link with government services through the FFS facilitator on FAW development, experiences with FAW management and getting additional information.

Mapping out crops and other vegetation is a first step to discuss where FAW populations can be found, and to monitor populations at strategic points. This information can be shared with the community for further action. The sharing event can also be used to raise awareness and knowledge on FAW, for example recognizing FAW's different stages and where to find them, natural enemies, and options for IPM.

Monitoring FAW can be done visually, as used in the AESA in the FFS. Several plants per field or in surrounding vegetation are observed and the numbers of FAW (by stage) and natural enemies are recorded. In some cases pheromone traps are being used. They attract adult FAW, and can provide information on when FAW adults start being present in the larger area. This might then need more intensive monitoring at field level.

Objectives:

- discuss relevance of monitoring FAW at large community level, and raising awareness of other farmers on FAW
- develop an action plan for monitoring and sharing results for community action

Time required:

90 minutes

Materials needed:

Flip charts and markers

Methods:

Ask FFS participants to draw a map of the village on flip charts, indicating main roads, houses, fields (mentioning the specific crops grown) and other vegetation. Discuss where FAW might be found. Scouting of the vegetation surrounding the FFS plot or elsewhere in the village can also be organized as a follow-up exercise by the group (see Special Topic, B.6.5 "Host Plants for FAW").

Questions for discussion:

- Discuss whether it is feasible to monitor FAW at strategic places – in different crops, natural vegetation. And how this can be done: visual observation of plants and/or pheromone traps (see related Special Topics in the highlight box below).
- Are there any volunteers to monitor? Can they report back the results of the monitoring during each FFS session?
- Can the FFS group organize an awareness session, or a field day for other members of the community to learn more about FAW IPM?
- What are the action points, and who will be responsible for the different actions?

For related information and Special Topics see also:

- Section B.5 on Scouting and observations
- Special Topic B.6.5 on Host plants for FAW
- Special Topic B.6.6 on Using traps for FAW monitoring
- FAO's FAW website for regularly updated guidance on scouting, trapping, and the release of FAO's new App 'FAMEWS" for FAW Monitoring and Early Warning: http://www.fao.org/food-chain-crisis/how-we-work/plant-protection/fallarmyworm/en

B.6.5 Host plants for the Fall Armyworm

Rationale:

FAW can infest maize, but also many other plants. There might be around 80 plants that FAW can feed upon. The FFS focuses on maize, a major food crop that is attractive for FAW. However, it is useful to know on which other plants FAW can live, be they crops grown in the field or vegetation around fields and in the community. FAW populations can survive and sustain itself on other plants when there is no longer maize in the fields. Besides FAW, there might also be natural enemies on vegetation around fields, which can be useful when FAW starts to appear in a crop.

Objective:

- understand the range of host plants of FAW
- discuss the need for community monitoring of other crops and surrounding vegetation during the maize cropping season, and after the maize cropping season is over to prevent infestation of future maize crops

Time required:

90 minutes

Materials needed:

Plastic bags or plastic bottles or glass jars, magnifying glass, markers and flipchart, clear tape.

Methods:

Work in subgroups, and assign each subgroup to observe different habitats close to the training site. This can be the maize field, another field crop, vegetation around the field and in other places. Ask each group to look for and collect FAW in different stages, also collect other insect pests and natural enemies.

Each subgroup will separate collected insects (different stages) by function and local names, the plants on which they were found and how many they were. Samples of the insects and plants can be taped to a flip chart, and data can be added in writing.

Ask each group to present their findings from the different habitats and discuss

Questions for discussion:

- On what plants did we find FAW? Are there plants they seem to prefer (high densities)? If there is no maize in the field, where can FAW go?
- Did we find natural enemies in the different habitats? Are they natural enemies of FAW, or of other pests?
- How can we manage vegetation to increase natural enemy populations?
- If there is no maize in the field, what can be done to reduce FAW? What can be done to increase natural enemies populations?

B.6.6 Use of traps for Fall Armyworm monitoring

Rationale:

The presence and build-up of FAW in a particular area can be detected by using pheromone traps. Pheromones are natural compounds that are emitted by female FAW moths to attract male moths for mating. Synthetic compounds that mimic natural FAW pheromones, often referred to as lures, are placed in traps to attract and trap male moths. Moths that are caught are then counted. From these numbers, farmers can know if FAW is present in their fields and if there is a need for increased scouting.

Traps could therefore be a useful monitoring tool for FAW populations. However they are not a management method for FAW; this would not be cost effective, and traps and lures might be difficult to procure locally. FFS can become part of a broader monitoring and surveillance system for FAW. If feedback systems are in place through which farmers can see the use which is made of the data they have provided, this can be very rewarding for farmers, and encourage them to intensify their efforts.

FAO is building an App for field monitoring of FAW through, which will be gradually deployed in countries starting with East Africa.

Objectives:

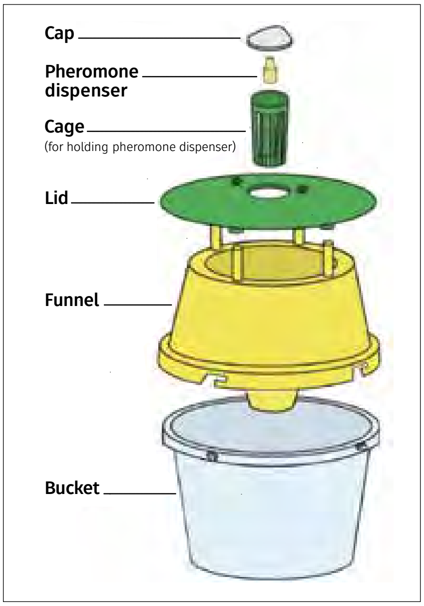
- familiarize farmers with traps as a tool for monitoring of FAW
- detect if FAW is present in the area around the FFS and if there is a need for increased scouting (NB: farmers should not wait for trap results to monitor their fields!)
- establish the FFS as a sentinel site in a government- or community- monitoring/ early warning system for FAW

Time required:

Season-long

Materials needed:

Traps, FAW-specific lures (enough quantity for the whole cropping season, i.e. generally about 5 lures per trap, depending on manufacturer), notebook, flipchart paper, markers.



Funnel or bucket (unitrap, universal trap) is the preferred trap for FAW

- green lid/yellow funnel/white bucket
- male moths are attracted by a pheromone and caught inside a round bucket
- high moth catches, sturdy, reusable, can be deployed for long period
- can fill with water; attracts bees, other insects, spiders and frogs

There may be other similar home-made traps from empty plastic soda bottles.

Methods/procedures:

Place traps in the field just after planting. A suitable location should be selected for positioning a trap. The selected site should be inside or on the edge of a maize field, or an open area nearby.

Hang the trap from a suspended pole or branch about **1.5 m** above the ground. One trap should be used for every **0.5–2 ha.**

Counting should start **after emergence** of the seedling, in order to best detect the first arrival of moths.

The traps should be checked **two times per week** by counting the number of FAW moths inside:

1. Open the bucket trap by an anti-clockwise twisting of the low transparent bucket at the bottom of the trap while holding firmly the yellow funnel on top.
2. Create a clean flat surface and invert the bucket to pour out the moths onto this surface.
3. Remove any non-FAW moths and insects that may have been caught in the trap.
4. Carefully count the number of FAW moths by putting counted ones to one side.
5. If you are in doubt as to whether the moth is FAW, then compare with the photo of male FAW moth.

Information collected when checking pheromone traps should be carefully recorded, so that it can be shared and used for early warning. If the FAO FAMEWS mobile app (bit.ly/2BZEW8q) is available as part of a FAW monitoring system, that is even better to use.

Location: 0°3'51" N / 32°26'49" E						
Date checked	FAW confirmed	FAW suspected	Other species	Trap replaced	Lure replaced	Lure name
15/11/2017	2	4	10	n	n	
18/11/2017	4	0	5	y	y	

The pheromone lure usually needs to be replaced **every 3–6 weeks** to achieve optimum results, depending on temperature, pheromone components and release characteristics. This means about **five lures will be required per trap for one maize growing season.**

Unopened pheromone dispensers should be stored within an air-tight bags, tightly sealed glass containers or foil pouches, preferably inside a refrigerator or freezer to achieve up to two years shelf life. Pheromones degrade rapidly if exposed to bright light or high temperatures. Therefore, dispensers should be kept inside their sealed packaging until ready to use.

Not all commercially-available lures are the same. Different companies use different number, combinations and percentages of the different identified key components of the FAW pheromone. This affects the capture of male FAW and other moths, and therefore makes lure standardization and moth identification so important.

A trap should never have more than one lure at a time. To activate the bucket trap, put the lure into the red rubber septum and then put the septum in the green coloured receptacle. The receptacle is then plugged into a hole on top of the green cap, which provides the roof of the bucket trap. The receptacle is then covered by a white lid. During lure replacement, the receptacle cap is simply removed and the rubber septa inserted into it. To activate the delta trap, place the lure on its side in the centre of the sticky insert or hang the lure from the top in the centre of the trap using a lure basket.

NB: for FAW, traps can be used **only for monitoring purposes. They are not a management option** (i.e. trying to trap all the males to control the infestation). It would be expensive and ineffective.

Key special topics/discussions related to the study:

- How many individuals did we find?
- Is the population increasing? decreasing? how does that compare with the number of infested plants we see in the field in AESA?
- Should we check our fields more frequently?
- How do FAW move about? How much can they fly? What factors can favour increased infestation? What factors can decrease it?
- How can we use trap as part of a community or government monitoring system? What role can our FFS play?

B.6.7 Compensation experiment on maize attack by the Fall Armyworm

Rationale:

Farmers first reaction when seeing maize defoliation due to Fall Armyworm infestation can be to spray chemicals in order to avoid yield losses. However, maize plants have a significant capacity to compensate damage to the leaves (called foliar damage) caused by pests at the early stages of growth and development. In other words, defoliation observed in the field may not necessarily translate into yield loss! The time period the infestation occurs in relation to the growth stages and the duration of infestation will affect the level of compensation and the yield. For more information, see section A.3.2 "Crop Management".

Objectives:

- to allow farmers to understand that the maize plant can compensate leaf damage caused by FAW at the early seedling or vegetative stage; this can support farmers to make better decisions on how to manage FAW or other pests that can cause leaf damage
- to help farmers discover that spraying chemicals is not a must when early defoliation is observed in the field

Time required:

Season-long

Materials needed:

Maize plants; scissors.

Methods/procedures:

This kind of study does not require a separate study plot, it can be set-up in the IPPM plot by marking plants/areas where plants are cut.

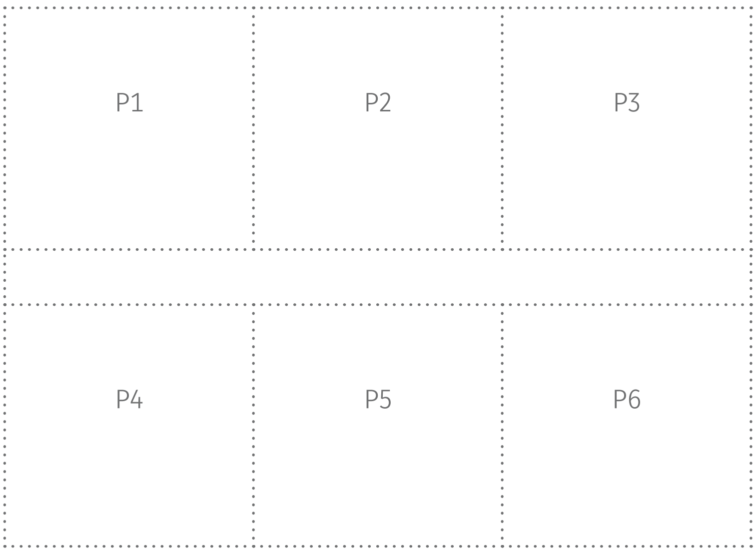
There are 6 treatments about 1 m x 1 m each, plus the control plot with no defoliation (this is the rest of the IPPM plot):

- Treatment 1: 25 percent defoliation at seedling stage (4 to 6 leaves): 7–15 days after planting (DAP)
- Treatment 2: 50 percent defoliation at seedling stage (4 to 6 leaves): 7–15 DAP
- Treatment 3: 25 percent defoliation at seedling to vegetative stages (knee-height to 1 m height): approx. 30 DAP
- Treatment 4: 50 percent defoliation at seedling to vegetative stages (knee-height to 1 m height): approx. 30 DAP
- Treatment 5: 25 percent defoliation at late vegetative stage (more than 1 m height): approx. 45 DAP
- Treatment 6: 50 percent defoliation at late vegetative stage (more than 1 m height): approx. 45 DAP
- Control: no defoliation at all (this is the rest of the IPPM plot)

Sampling: Select five plants per treatment at random; or mark 1 m^2 to assess yield cuts later on.

- Before proceeding with defoliation, observe the field and destroy all egg masses and FAW larvae present on the plants.
- Divide leaf surface into ten parts.
- Cut off the leaf part(s) in relation to the defined treatment percentage **without damaging the main vein (rib).**
- Observe weekly to evaluate plant growth rate in relation to the stages.
- Set up small groups of FFS members to scout and crush egg masses every two days.

Layout:



Treatments will be randomly assigned to the 6 plots + the control plot (which is the rest of the IPPM plot).

Parameters to measure:

- number of new leaves in all treatments
- plant height in all treatments
- number of egg masses/treatment
- number of larvae count/treatment
- number of ears with hidden larvae

Results:

- growth (regeneration) rate
- yield per treatment
- comparison of the yield losses
- gross margin

Guiding questions for discussion:

- what happened in a given treatment after two weeks? after 4 weeks? at the end of the season?
- how do plants recover from defoliation? how do the different treatments compare with the control plants after 2 and 4 weeks? do they have the same number of leaves, the same height?
- what differences do you find between treatments (25 percent and 50 percent) at the same growth stage? and what about early and later defoliation? in what stage can the plant compensate? when is it more difficult for the plant to compensate? why?
- in what treatment the yield was not different from the control? why?
- in what treatment the yield was different from the control? why?
- what does it mean for IPM if the plant can compensate? if you have some leaves damaged in an early stage of the maize crop can the crop compensate? what if you would spray a pesticide, are the costs justified? and what would happen to natural enemies?

B.6.8 Use of local controls (ash, soil, sand, lime, soaps, salt, oil)

Rationale:

Many farmers try their own remedies. Sometimes because they don't have anything else, other times because they know something about the materials they try. For example, sand is very abrasive and can scar insect larvae. Ash too. Ash is also very alkaline. So is lime. Soaps can be too. Soil can harbour pathogens that can kill FAW larvae. So most of these homemade remedies probably have a biological or chemical basis to their functionality. Even more important, they often seem to work, especially when applied directly into the whorls of infested plants. For more information, see section A.3.4 "Mechanical control and local controls".

Objectives:

- to test local remedies to see if they can kill FAW larvae in maize whorls

Time required:

30' + 5h wait + 20'+ time to spray

Materials needed:

Local materials to test (ash, soil, sand, lime, soaps, salt, oil...); mixing bowls; pesticide sprayer; soap.

Methods/procedures:

Collect materials to be tested. About 500 mg of each should be enough and much less for soap or salt. Randomly select small plots (the number of plots needed will depend on the number of materials tested) and leave one plot as a control plot – where nothing is applied.

Use at least three blocks – which contain one plot of each treatment.

- at 14 days after germination, measure the percentage of plants infested with FAW in each plot and record
- at 15 days after germination, apply the material directly in the whorl of each plant in the plot. Apply a small "pinch" of material transported by the thumb and two fingers. Use thin neoprene gloves or a plastic bag to cover your fingers to avoid over-exposure to any of the substances
- at 20 days after germination, measure again the percent of plants infested with the FAW
- at 39 days after planting, measure the levels of infestation again
- repeat the applications at 40 days after planting
- at 45 days after germination, measure levels of FAW infestation. Note presence of natural enemies and dead FAW larvae
- at harvest, measure yield from each plot separately and record results

Results–discussion:

- which treatment provides better control of pests including FAW? graph results
- compare natural enemies' population
- compare maize yield, which treatment maize has more quantitative and qualitative yield?
- compare the costs economic benefits
- overall importance advantages and disadvantages of using botanical
- option of combining them with other IPM strategies

B.6.9 Recycling FAW pathogens

Rationale:

Pathogens (especially fungi, bacteria and virus) commonly kill FAW larvae in the field. These pathogens are often naturally present in the environment and when FAW larvae come in contact with them or ingest them, they are killed. Smallholder farmers in the Americas often "recycle" these pathogens, by collecting dead larvae killed by the pathogens, extracting the infective particles, and spraying them back out into maize whorls. For more information, see section A.3.5 on Biological control "Entomopathogens".

Objectives:

- to demonstrate that dead larvae killed by pathogens contain living particles that can be sprayed out again onto living larvae to kill them

Time required:

30' + 5 hrs wait + 20' + time to spray

Materials needed:

Dead larvae killed by pathogens collected from the field; small blender or mortar and pestle; material to filter; pesticide sprayer; soap.

Methods/procedures:

Go to field, collect larvae killed from fungi or virus.

- crush them very well with a mortar and pestle or put them in a blender with a litre of water and blend thoroughly
- filter out the body-part pieces
- use what is strained through to re-apply in the field: mix with water in a backpack sprayer (which was not used for fungicide before) and spray mixture directly into the whorls of only those plants which are currently infested with the FAW (fresh damage and/or fresh frass)

Parameters to measure (during AESA):

- number of infested plants; presence of egg masses and larvae (qualify or quantify)
- presence of newly-killed larvae
- presence or absence of natural enemies (in maize or intercrop)
- yield per plot
- estimate cost, benefits and contraints (collection in the wild, preparation time, ...) of botanical pesticides vs. synthetic pesticides
- estimate cost of cultivation, and returns from different plots

Results–discussion:

- which treatment provides better control of pests including FAW?
- compare natural enemies’ population
- compare maize yield, which treatment maize has more quantitative and qualitative yield?
- compare the costs economic benefits
- overall importance advantages and disadvantages of using botanical
- option of combining them with other IPM strategies

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B.6.10 Preparation of some botanical pesticides

Rationale:

Botanical pesticides can constitute a real arsenal in the management of the FAW for African smallholders as part of an IPM approach. Farmers can learn to test local plant that might be effective against the FAW. For more information, see section A.3.6 on Botanical pesticides.

Objectives:

- learn to prepare and to test efficacy of local plants with pesticidal effect

Time required:

30' + 5 hrs wait + 20' + time to spray

Materials needed:

Mature fruit or leaves with pesticidal properties; mortar and pestle; or small blender/crusher; material to filter; pesticide sprayer; soap

Methods/procedures:

Collect mature fruits of neem (*Azadirachta indica*), remove the flesh and dehusk the seeds OR collect leaves of plant materials (e.g. Neem leaves; Pyrethrum extract...see ideas in section A.3.6 on Botanical pesticides)

- grind 500g of neem seed kernel in a mill or pound; or 1kg of plant material
- mix the crushed neem seed with 10 lit of water or more
- allow the extract to stand for at least for 5 hours in a shady area
- filter the mixture to obtain the extract
- add soap or detergent as surfactant/emulsifying agents
- spray the neem extract on maize or other cereal crops.

Indicatively, 6 to 8 Kgs for Neem kernel's might be required to treat one hectare of maize crop.

Neem extract can be retained for at least 3 to 6 days.

You can also dilute into different simple solutions (75 percent, 50 percent, 25 percent and 0 percent).

FFS experiments can be done with farmers to assess efficacy of botanical pesticides against FAW, and evaluate benefits and farm income, by using botanicals in combination with other IPPM measures in the IPPM Plot, comparing them with the Local Practice Plot through AESA.

Parameters to measure (during AESA on the IPPM plot vs. Local Practice plot):

- number of infested plants; presence of egg masses and larvae (qualify or quantify)
- time of first infestation and duration of infestation
- damage on leaves (windowing, shot holes) and cobs (random feeding on the maize kernel, holes in the sheath covering the cobs)
- presence or absence of natural enemies (in maize or intercrop)
- yield per plot
- estimate cost, benefits and constraints (collection in the wild, preparation time, …) of botanical pesticides versus synthetic pesticides
- estimate cost of cultivation, and returns from different plots

Results–discussion:

- which treatment provides better control of pests including FAW?
- compare natural enemies' population
- compare maize yield, which treatment maize has more quantitative and qualitative yield?
- compare the costs economic benefits
- overall importance advantages and disadvantages of using botanical
- option of combining them with other IPM strategies

B.6.11 Spraying pesticides: pesticide hazards and pesticide risk reduction

Very often in FFS or other farmer trainings, a special topic on pesticides is done by a “formal” presentation by the facilitator, giving lectures on types of pesticides and what they kill, details of the absorption of pesticides by different parts of the body, discussion of "safe-use" of pesticides, and calculations on pesticide dosage.

While all of this may be interesting to know, it is good to note that the central message about this topic that we want to get across is the HAZARD. We cannot spray without getting contaminated and most chemical pesticides are poisonous because that is what they were designed for.

Rather than lecturing, or discussing about this, the exercises in B.6.11 and B.6.12 are good examples of how this message can be delivered through an experiential approach.

For more information, see section A.3.6 on Botanical pesticides and A.3.7 on Synthetic pesticides.

Rationale:

Spraying pesticides is hazardous. The compounds used for spraying are in a concentrated form which makes them even more dangerous than usual exposure. Concentrated liquids directly from the bottle, and exposure to sprays in the field during application can cause numerous symptoms such as skin rashes, dizziness, nausea, and headaches. The usual recommendation for gloves, boots, rain clothes, and masks are often impossible to implement for most farmers because of the costs, and hot climatic conditions. While some farmers use “protective” clothing they do not fully understand how pesticides enter the body and how so-called “protective” clothing does NOT guarantee that contamination will not occur.

There are many other precautions to take to reduce exposure to pesticides when spraying. For example, consider the direction and velocity of the wind. If the wind is blowing hard, farmers should not spray. The chemical will never reach most of the plant. Never walk into the wind when spraying, but spray to the side downwind, so you don’t walk into the spray or the newly sprayed crop. This exercise will help participants understand that there is really no "safe application” of pesticides.

When discussing precautions, FFS facilitators and farmers better avoid using terms of "safe use", and rather speak of "pesticide risk reduction" and "reducing risks from pesticides".

Objectives:

- to discuss that protective clothing is NO guarantee against exposure to pesticides
- to discuss whether there is really a “safe application” of pesticides in smallholder farming contexts

Time required:

120 minutes

Materials needed:

Sprayer, Bucket, Red dye, White pants, Shirt, Gloves, Mask, Cigarette, Snacks to be eaten with the hands, Cup of water for drinking, paper and markers.

Methods/procedures:

The facilitator should mention that in real life, participants/farmers should observe precautionary measures to reduce exposure to pesticides. These include the preparation of the equipment, the preparation of the pesticide, wearing "protective" clothing, using correct spraying techniques, etc. However, in this exercise, participants should be able to observe farmers' common practices in spraying, also if they are incorrect. These will be the basis for later discussions. Stress that the exercise is intended to initiate discussions on whether or not there is really a "safe application" of pesticides.

- All participants go to the field. One person in the group will play the role of a "farmer". This person should put on the white pants, shirt, gloves, and mask – to make it easier to see the red dye ("pesticide") stains*. The "farmer" will show common practices, MOSTLY INCORRECT, practices in spraying. The "farmer" may exaggerate for emphasis.
- The "farmer" should fill the tank with water and add red dye. Add a lot so that the water is very red. Close the tank and shake the tank to mix the water and the dye. (Farmers often mix pesticides with their bare hands.)
- The "farmer" will spray 500 m2 of the field with the tank of water and dye using 2-3 tanks (as per farmers practice) and take a break between spraying to smoke, eat with hands and drink from a cup (without washing hands). The "farmer" sprays without checking the direction or velocity of the wind.
- The other members of the group should make notes on what the "farmer" is doing. They should measure the time required and observe the spraying technique. They should also note how the "farmer" could have reduced his/her exposure to the spray liquid.
- After finishing spraying, the "farmer" empties the excess mixture from the tank – farmers normally empty tanks into irrigation canals.
- Now observe the sprayer. Is the red dye on the skin or clothing of the person who sprayed? Using a sheet of flipchart or other paper, ask each group to draw the points of contamination. Use red colour to show pesticide contamination.

* Some FFS groups use white crepe or tissue paper to cover the "farmer" in from head to foot (including the face, hands, and feet, leaving a small space to breath and see through!). This is called the **mummified** spraying exercise.

Results-discussion:

- elicit observations from farmers on the role play/demonstration. More incorrect practices demonstrated and observed will lead to more discussions on what can be done to reduce exposure to poisons. Use the following table as an example:

What the “farmer” did	What the "farmer" should have done
The “farmer” did not clean the sprayer.	If the sprayer has been used before, wash it thoroughly with detergent. Use gloves when washing the sprayer.
The “farmer” used his mouth (blew) to clear the clogged hose.	Check to see if the sprayer is working properly by pumping and spraying water. This will also clean the hose and nozzle of the sprayer. If necessary, use a fine stick or wire to clean the hose and clear the holes of the sprayer.
	Take note of the size and type of the nozzle to see if this suits your requirements. (Farmers may not have very much choice about sizes and types as they might only have one nozzle!)
The “farmer” used his bare hands for mixing the “chemical”.	Use a long disposable stirrer to mix the pesticide and properly dispose of the stirrer.
The “farmer” had red dye all over his back – the sprayer was leaking.	Check for leaks by carrying the tank and spraying with water.
The “farmer” sprayed against the wind.	Check for the direction and velocity of the wind. If the wind is blowing hard, do not spray. Never walk into the wind when spraying. Always walk at 90 degrees angle to the wind.
The “farmer” was smoking while spraying.	Do not smoke while spraying; use a mask while spraying
The “farmer” ate without washing his hands.	Wash hands thoroughly with soap and water after handling pesticides and especially before eating
The “farmer” emptied his tank into the irrigation canal.	Calculate your needs and use all the pesticides in the field.
Etc.	Etc.

- what signs and symptoms of poisoning can be caused by pesticides?
- what are the experiences of the groups with spraying pesticides?
- discuss the easiest ways for pesticides to enter the body (SKIN, WET CLOTHES) and increase the risk of pesticide poisoning
- discuss that the MOST important time when contamination leading to poisoning occurs, is during mixing the pesticide concentrates...which is WORSE than when using a pre-mixed pesticide cocktail!
- discuss that protective clothing is NO guarantee that contamination will not occur, but ask what low cost practical measures can be taken to reduce skin contamination.
- present the following situation: A farmer sprays for two hours. He only changes clothes and takes a bath four hours after spraying. (Note: The farmer’s skin is not exposed just two hours but six hours because his skin has continued contact with pesticides for the extra four hours between finishing spraying and taking his bath.) Ask for ideas of everyone in the group. Discuss importance of bathing with SOAP immediately after spraying and always using freshly washed clothing for spraying.
- how can farmers reduce the exposure to pesticides?
- discuss "is there really a 'safe application' of pesticides?"

Key special topics/discussions related to the study:

- what effect does this pesticide contamination have on our health in the long term? (are there any local experiences?)

– who else is at risk of being contaminated by the pesticide when you spray the fields?
– do any of the women in this area spray when they are pregnant? What effect could this have on the baby that she is carrying?
– what other ways can we think of that pesticides might be contaminating people or animals? (drinking water, drifting sprays etc.)
– what effects do pesticides have on pigs, chickens and other warm blooded animals? (it may be appropriate to discuss the labelling of pesticides here – how can you recognize the ones that are most dangerous to warm blooded animals and humans)
– what effects do pesticides have on other animals that we would like to conserve? (fish, birds, etc. and beneficials like bumble bees, other natural enemies........this leads into the insect experiment to discover the effects of pesticides on natural enemies)

B.6.12 Effects of pesticides on natural enemies and beneficials

Rationale:

When pesticides are applied in the field, they also spread into the environment. In this experiment, participants can discover that pesticides kill natural enemies of the FAW, which might worsen the problem

Objectives:

- evaluate the effect of pesticides on natural enemies and beneficials

Time required:

3 hours of an FFS meeting + 5 minutes observation daily until the next meeting

Background information:

Generally, pesticides reach the soil either through application on the soil or through run-off. Gaseous chemicals may escape into the air. In the soil, pesticides can bind to soil particles and/or move into groundwater. When a pesticide is highly persistent in the environment, undesirable biological effects may be caused, such as negative effects on soil-flora and -fauna, on aquatic life, on ecological diversity and air quality (pollution).

From the crop management viewpoint, there are some additional, serious disadvantages of the use of chemical pesticides. In addition to the target pest, pesticides may kill beneficials such as natural enemies, bumble bees, and antagonistic fungi.

Pesticides also have a cost, and they might not be the most cost-effective way of managing the pest.

In this experiment, participants can discover that pesticides kill beneficials. It is recommended to include a fungicide in the experiment, to allow farmers (and some facilitators!) to discover that fungicides can also kill insect natural enemies. It will also help remember that fungicides will kill helpful fungi too.

Please do this experiment outside in an open place with plenty of air movement – to prevent the group from getting headaches as they are poisoned by the fumes of the pesticides!

Materials needed:

Natural enemies of FAW; four jars with lids; four pieces of thin cloth and rubber bands; two closed jars; labels; fine-hair paintbrushes; aspirators, if available; tissue paper; scissors; forceps; long disposable stirrers for mixing pesticides; masks; chemical-resistant neoprene gloves; paper; pen; four small hand sprayers (0.5 litre); small amounts of insecticides; clean clothes for the spraying teams to change into after spraying.

Collect insects in preparation for the experiment!

- Collect insects for the insect experiment during the weekly observation of the FFS learning-field.
- Each group needs to collect 15 individuals of 1 kind of natural enemy. Arrange it so that each group collects a different kind of natural enemy.
- Be gentle when collecting insects! Use aspirators for small delicate insects like parasites and fine hair paint-brushes for handling small soft insects like caterpillars and hoverfly larvae. For crawling insects like ladybeetles, the best way to collect is to knock them gently from the plant into a container.
- Don’t forget to provide some food for the insects: sugar solution for parasite adults, prey for the predators and fresh leaves for the plant feeders. Keep the insects in a cool place whilst you prepare the other things for the experiment, or they will all be dying by the time you start the experiment!

Methods/procedures:

Participants prepare four hand sprayers before setting up the exercise. If the sprayers have been used before, wash them thoroughly with detergent. Use gloves when washing the sprayers. Check to see if the sprayers are working properly by pumping and spraying water. This will also clean the hose of the sprayer. If necessary, use a fine stick or wire to clean the hose and clear the holes of the sprayer.

Participants should carefully read the instructions on how to use the product printed on the label. Following the recommended dose at field rate concentrations (this differs from product to product!), participants should prepare the different pesticides. The members of the group handling the pesticides should put on masks and chemical-resistant neoprene gloves. Use a long disposable stirrer for each kind of product that will be used to prepare the solution and properly dispose of the stirrer.

Each group should prepare three hand sprayers with commonly used insecticides for example: pyrethroid, carbamate (chemical insecticides), NPV or Bt (biopesticide) and one hand sprayer with water (control). That means that each group will carry out four treatments (three with chemical/biological insecticides and one control).

Members of the group who will set up the treatments should also use masks and gloves.

- Select four plants in the field: one plant per spray treatment. Using hand sprayers spray the chemical insecticides on the individual plants and label treatments (plants) accordingly. Spray the chemical on the upper side of leaves moving from the top towards the bottom portion of the plant. Then spray the chemical on the underside of leaves moving from the bottom towards the top portion of the plant. Make sure that both sides of the leaves are drenched with the solution. Spray following the direction of the wind. Wash hands thoroughly with soap and water, and change clothes after spraying.

- Let the leaves dry on the plant.
- Pick one or several leaves from each treatment and transfer to glass jars (use gloves!). Label the jars. Each group should have one jar of each spray treatment (four jars in total). Try to get the leaf to lie flat on the inside surface of the jar.
- Get the group to design a simple table in which they can note for each jar:
  - what kind of insect was put in the pot? (not yet done?)
  - how many insects?
  - what they were sprayed with?
  - how long after spraying the insects are being observed?
  - how many are alive and healthy?
  - how many are alive but look sick?
  - how many are dead?
  - also see guiding questions below!
- Collect several predators from the field from the natural enemies you have collected earlier and transfer them to the jars (see previous section!). Put five individuals of the natural enemy species into each jar. Use the same predator species in all treatments. Close the jar with the lid, and place a piece of tissue paper between the jar and the lid to avoid condensation inside the jar.
- Check and record the condition of the predators after eight hours and after 24 hours. Count the number of dead insects. It may be necessary to touch the insect with a pen or pencil to determine if it is dead. If it does not walk off in a normal manner, then record it as dead.

Remember: Dispose properly of empty pesticide containers to prevent pollution of the environment and any possible contamination. If you need to store unused pesticides keep them in a cool place that is safe for people (especially children) and animals. Wash hands thoroughly with soap and water after doing the exercise and each time you handle pesticides!

Trainers should call attention of participants to the need to handle, use, dispose, and store pesticide products properly and with caution. These are poisons!

Guiding questions for discussion:

- what happened to the beneficial insects in the different jars? Why?
- why did we look at the effect of the water spray as well as the chemical sprays? (to check that it is really the chemical that had the effect, rather than the way we handled the insects, or the effect of the water spray)
- what happens in the field when a farmer sprays against a certain pest?

- what will happen in a field 1, 2, 3 weeks after spraying?
- why are some pests alive after spraying and some are dead (phenomena of resistance)?
- why in spite of using heavy spraying, can the pest re-occur later in the season, or next season?
- which pesticides have good quality? What factors make you decide the quality is good?
- do the pesticides kill pests only, or they are biocide (i.e. they can kill other living things too)?

B.6.13 Economic threshold levels and relation with Agro-EcoSystem Analysis

Rationale:

The Economic Threshold Level (ETL) is an attempt to improve decision making, when deciding whether a pesticide should be sprayed. In this activity we will discuss what the ETL is, and how useful it is given many different scenarios of costs of treatment and price variability for the commodity.

Objectives:

- to define ETL
- to discuss the variability of each factor of the ETL
- to discuss how AESA gives additional information to ETLs for good decision making

Time required:

120 minutes

Materials needed:

Paper and markers.

Background information:

The ETL states that a certain pest density (for example number of infested plants) will lead to a yield loss. This yield loss that will occur at the end of the season has a cost (kg/ ha multiplied by the price per kg) which equals costs of treatment.

The ETL is computed usually based on three parameters using the following equation:

$$\text{ETL} = \frac{\text{management costs } \textit{(USD/ha or cost in local currency/ha)}}{\text{commodity price } \textit{(local currency/kg)} \text{ X damage coefficient } \textit{(the expected yield loss at the ETL pest density) (kg/ha/\#pest/ha)}}$$

What is the use of the ETL? Traditionally, when the ETL was surpassed (field populations are sampled and found to be higher than the ETL) the farmer was advised to spray.

IPM now includes a larger analysis of the ecosystem (like the IPM being taught in FFS). Other factors which farmers should take into account include the presence of natural enemies, plant health and its ability to compensate for damage, other investment opportunities, personal health, weather, the local price of maize... The ETL is still a useful part of the analysis, but the ETL is not the only analysis.

In addition, the price of maize can vary considerably depending on the location and the time of the year. But most of the time, farmers don't even know what reference price for maize was used when calculating the ETLs which are given to them as recommendations! So it is hard for them to be sure whether those ETL apply to their situation.

Methods/procedures (for a larger group):

1. Ask whether participants heard about ETL, and what they think it is. Take note, and present the equation for ETL:

$$\text{ETL} = \frac{\text{management costs } \textit{(local currency/ha)}}{\text{commodity price } \textit{(local currency/kg)} \text{ X damage coefficient } \textit{(kg/ha/\#pest/ha)}}$$

2. Go through each factor. Ask participants to explain what they know about each factor.

Note:

Management costs: depend on the type of management used (cheap, such as crushing eggs and larvae or using home-made botanicals; or expensive, for instance buying a costly synthetic insecticide), access to tools (owned or rented), labour costs (own or hired; time of the year), differences between provinces (near cities or far from cities), other conditions.

Commodity price: they may change during the year, and change from place to place depending on markets, etc.

Damage coefficient: varies according to the variety, water availability, natural enemy populations, weediness of the field, nutrient levels, weather, farmer skillfulness in growing the crop, disease infection, stage of the plant, plant spacing, etc. Not all damage leads to yield loss (see Special Topic B.6.7 on Compensation).

Questions for discussion:

- what is the ETL for FAW? Is the ETL fixed for the whole season?
- if a farmer has higher management costs, what happens to the ETL?
- if the maize price is low, what happens to the ETL? is it still worth using pesticides?
- what if the ETL is reached and there are many natural enemies? does it make sense to spray?
- what about the crop stage and ETL? can the crop compensate for some leaf damage?
- what additional information do you collect in AESA beside the number of pests per plant? why is this useful? do you need the additional information to make a good decision?

B.6.14 Record-keeping for economic analysis and decision-making

Rationale:

Farmers rarely write down how much money they spend and how much money they earn. This is due to a lack of knowledge that good record can help them make better choice as far as management decisions for their farms and business is concerned. It is difficult to keep in mind all the information needed to make decisions.

Suggested technologies or options can give very good agronomic results from the learning field, but might not be accessible to small holders because they are not cost effective.

Objectives:

- to allow farmers to know how much money they spend and gain, for better and informed decision-making in a given enterprise
- to facilitate comparisons between the different management practices and treatments in the field studies of the FFS

Time required:

Two (2) hours at the beginning of the FFS; 10 minutes in each FFS session; and 20 minutes at the end of each month.

Materials needed:

Flip chart paper; markers; masking tape; notebook; pens (blue and red); ruler; calculator.

Methods/procedures:

- brainstorming
- practical (exercise)

Prepare a notebook or flipchart sheet as below, for each treatment in the FFS[9]

Record-keeping should be done on a daily basis whenever an activity is done in a field school (or on the farmer's farm) starting from inputs sourcing to selling, except AESA.

See a sample exercise on the following page.

9 Exercise adapted from FAO, *Horticultural Marketing*, Marketing Extension Guide 5 at www.fao.org/docrep/008/a0185e/a0185e00.htm#Contents

Location: _______________ FFS Name: ____________________ Crop:___________________

Year: __________________ Name/description of treatment: __________________________

		Date			Remarks
Income	Income		**(a) Marketed yield per acre 6 000 kg**		
			(b) Price at $0.25 per kg		
			Gross income (a ×b) = $1 500		
				$	
Production costs	Input costs		Seed, 1.5 kg at $22 per kg	33	
			Fertilizer ZZ, 2 × 50 kg at $6 per bag	12	
			Organic manure, 15 tonnes at $5 per tonne	75	
			Spray 1: approx. $11 per acre	11	
			Mechanized soil cultivation $40 per acre	40	
			…		
			…		
			Subtotal inputs	171	
	Labour costs		Manual land preparation, 2 days at $2 per day	4	
			Sowing, 3 days at $2 per day	6	
			Irrigation, 10 days at $2 per day	20	
			Hoeing, 12 days at $2 per day	24	
			Harvesting, 90 days at $2 per day	180	
			…		
			Subtotal labour	234	
			Subtotal production costs	**305**	
Marketing costs			Transport at 1.5 cents per kg × 6 000 kg	90	
			Packaging, 20-kg crates at $1 per crate	300	
			Subtotal marketing	390	
			(c)Total production and marketing costs	**795**	

Gross margin/net return per acre [income – total production and marketing costs] = $...

Break-even price per kg [total production and marketing cost ÷ number of kgs of marketed yield per acre] = ... $ cents per kg

Note on labour and marketing costs: A farmer will need to keep track of his/her labour costs. But in FFS the group can decide <u>not</u> to register these costs to keep things simple as this is only a learning field. However, FFS members should keep track and discuss how labour-intensive various treatments are. Likewise, the FFS group might decide <u>not</u> to record marketing costs to keep things simple, as the marketing costs will be the same regardless of the treatment, so this is not useful when comparing production methods. However, farmers should eventually learn to calculate these costs to make better production and marketing decisions.

Content:

- what to record for/from the field study or a farm?
- how to record the information in a notebook?
- how to evaluate the inputs and the outputs for a given period for different treatment?
- how to compare the cost effectiveness of different treatments from the learning field?
- how to calculate whether you are making a profit or a loss?

Key message:

Record-keeping of inputs and outputs will be done on daily/weekly basis from the onset. It will allow farmers to evaluate and compare technologies or options under experimentation in the FFS, and to make an informed management decision at the end of the season on cost effectiveness of various methods for future planning.

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ANNEX 1

Example of a Fall Armyworm refresher training programme for Farmer Field School trainers and facilitators

Table 4. Six-day FAW Identification and Management Refresher Training programme for FFS Master Trainers or FFS Facilitators

DAY	TOPIC	LEARNING OBJECTIVE(S)	• ACTIVITY	TIMING	METHODS	MATERIALS	RESP. PERSON
1	Contextualizing the problem	Identify the knowledge gaps and bring participants to a common understanding of the problem	• Brainstorming on the existing maize pest complex and existing management practices • Zero down on FAW (history and situation in the country…) • Outcomes of the Baseline studies if any • Present FAO FAW Management framework in brief [10]	2.00 hrs	Brainstorming, Sharing of experience, Presentation, Discussion	Flip chart, markers, masking tape, note books, pens (from here on*)	Master trainers, FAO
	FAW biology and ecology	Know the FAW life cycle and the preferred development conditions of the pest	• Description of the life cycle and conducive environments	2.15 hrs	Brainstorming, Presentation, Discussion Insect zoo	(*) + Samples (live or posters), lenses	IPM specialist/ Entomologist
	Identification of the pest and damage	To identify/recognize the pest and its behaviour, and differentiate from other pests/armyworms	• Signs and symptoms • Behaviour for feeding, moving, oviposition, etc • Differentiate FAW, AAW (Spodoptera exempta), other worms	3.00 hrs	Brainstorming, Presentation, Discussion, Demonstration	(*) + Samples (live or posters), lenses	IPM specialist/ Entomologist
2	Management of FAW	To contextualize the management of FAW	• Introduction of IPPM and what it means in the context of FAW	4.00 hrs	Brainstorming, Presentation, Discussion	(*)	IPM specialist
	Monitoring and early warning	To know how to carry out regular field monitoring using AESA	• Tools (pheromone traps…) • Process for scouting • Parameters to observe • Techniques for the sample collection and handling • Preparation for the field	3.00 hrs	Brainstorming, Presentation, Discussion, Problem solving	Traps (see sections on Monitoring and scouting) Smart phones/tablets with FAO FAW App (if deployed in the country) (*)	

10 The FAO FAW Management Framework, and up-to-date FAO Guidance on FAW can be found at: http://www.fao.org/food-chain-crisis/how-we-work/plant-protection/fallarmyworm/en/

3	Field immersion	To build the capacity of participants on regular field observations and informed decision-making for FAW management.	• AESA (Identification, sampling, collection, decision-making - observe and identify correctly FAW egg masses, young larvae and damage, observe natural enemies (coccinellids, earwigs, lacewing, ants, parasitized eggs, etc.)	4.00 hrs	Brainstorming, group discussions; field practical; "what is this?" principle; demonstration	FAW infested field and neighbouring landscape for field practice; samples for regular monitoring; material for insect zoo (see Special Topics on Insect zoos) + (*)	Senior MTs & Entomologists
			• Data analysis, presentation and synthesis of the key learning points	1h	Group work, presentations and discussion	(*)	Senior MTs & entomologists
	Pesticide risk reduction	To understand the adverse effects of the use of pesticides	• Highlight aspects of cost of treatments, resistance development, toxicity of different pesticides, impact on natural enemies, trade… • Linkages to crop production intensification to meet all elements of sustainability (economic, social and environmental)	3.00 hrs	Brainstorming, Discussion	(*) + Samples of botanicals, bio pesticides, containers of chemical pesticides	IPM specialist, Entomologist
4	Monitoring the samples of damaged plants	To learn the life cycle or development stages of the pest.	• Observation of samples collected from the field	30 min	Brainstorming, Discussion, Demonstration	(*) + Samples collected from the field, insect zoo, lenses	Entomologist & IPM specialist
	Natural enemies (Farmers friends)	To identify and differentiate natural enemies	• Differentiation of farmers' friends (parasitoids, predators, viruses (ex: NPV, EPF) bacteria (ex: Bt), fungi) and modes of action	1.45 hr	Brainstorming, Discussion, Demonstration	(*) + Samples (live or posters), insect zoo	IPM specialist, Entomologist
		To know the role of natural enemies	• Conservation and use of farmers friends i.e. natural enemies (insectaries, landscape management…)	1.15 hr	Brainstorming, Discussion, Demonstration		
	Preparation and handling of botanicals	To prepare and make proper use of botanicals or bio pesticides	• Examples of common botanicals • Demonstrate the process of preparation, application • Apply the extracts on some of the target pests for participants and farmers to appreciate effectiveness • Explain the possible hazards (toxicity)	4.00 hrs	Brainstorming, Sharing of experience, Discussion, Problem-solving, Demonstration	(*) + Samples of botanicals leaves/ seed, scale, mortar, bucket, water, soap bar, knap sack, mask, boots, gloves	IPM specialist

5	Management practices (how to minimize build-up of pest population)	To put emphasis on the management options including prevention measures and action to control the FAW	• Varietal diversity, crop diversification and intercropping to reduce oviposition and build natural enemy populations • Maintaining trees and diverse borders for natural enemies • Crushing egg masses (why?) • Host plants; effects of repellent plants and attractants and mode of action • Seed treatment • Planting dates (avoiding staggered planting) • Good soil health	2.00 hrs	Brainstorming, Discussion, Group work Demonstration & Field visit if time allows for practical	(*) + FAW infested field, Samples of egg masses, host plants, treated seed	Entomologist, & IPM specialist
	Awareness and communication	To carry out appropriate sensitization to stakeholders	• Community action for FAW – trapping, observing, mapping, action, etc. • Mass extension campaigns • Reporting mechanisms for FAW. Why should farmers report, to whom, how? • Role of farmers in sharing information with their communities and with other FFS • IEC materials	1.00 hr	Brainstorming, Presentation, Discussion	(*) +	Communication specialist, & Club Dimitra officers or resource person
	Designing of the possible studies	To define and design field studies from potential priority solutions (prioritized solutions)	• Reviewing of possible potential studies for outreach • Review of any existing protocols that can be adapted to local needs	4.30 hrs	Brainstorming, Presentation, Group work, Discussion	(*) + Template	Senior MTs
6.	Action planning	To develop a program that includes the resources needed for a season	• Developing of season-long learning programme • Identification of possible facilitators	2.00 hrs	Brainstorming, Presentation, Group work, Discussion	(*)	MTs & Resource person
	Monitoring, Evaluation and Learning	To build and consolidate collaboration among stakeholders and practitioners	• Documentation of practices • How to link with national task forces, research etc. • Linkages with plant health systems and networks	2.00 hrs	Brainstorming, Discussion, Demonstration	(*)	Resource person or M&E specialist
	Closing		• Overall evaluation of the training • Closing remarks	30 min		(*)	MTs

(*) Flip chart, markers, masking tape, note books and pens are used in the meeting room

N.B. 1. Q&A will be used throughout as method of facilitation.

2. Ideally the courses should be undertaken in a period in which FAW will be observable in the field.
3. In case the FAW is present in the field during training, the preparation of the botanicals should be done on Day 2 in order to spray on Day 4 and monitor the effectiveness before leaving the training centre.

Table 4 presents an example of a training programme for refresher courses of rural advisors, FFS facilitators and Master Trainers. It should be adapted according to local specificities and trainees' interests and needs.

ANNEX 2

Example of maize curriculum including the ecological management of the Fall Armyworm

The results of problems and solutions matrix analysis – what the FFS Master Trainers need to know, the Training of Trainers (ToT) schedule and the field studies and special topics developed – have been summarized in Table 5 overleaf, noting the most important steps to follow from the beginning to the end of a maize cropping season in order to carry out an integrated and sustainable management for FAW, through learning in the farmer field schools.

The curriculum table comprises details on the stages, as follows: the period (related to the cropping calendar), the operation or the activities, the learning objectives (for a given topic), the content, the methods to use in order to facilitate the topic, the material needed, the timeframe or duration to cover the topic, the responsible person, and the evaluation indicators to ensure that the objectives are achieved. One should agree that pre-planting is a phase rather than a growth stage.

It is necessary to highlight here, the importance of training on "Introduction to FAW" is a must at the beginning of the process, to help farmers recognize the pest, its host plants, the natural enemies and the prevention measures which should be taken until planting. The first "Introduction to FAW training" should focus on the pest identification and the prevention measures. The trainer should be well prepared for practicals preferably in an infested field, otherwise using posters. The second step will revisit the identification of FAW but will emphasize the different actions or priority options to be taken to manage it.

Record-keeping for economic analysis is the first topic to be covered in the FFS after the first training. From the onset, all detail on input sourcing, mainly the cost, will be recorded throughout the growing season. Pre-planting, a phase rather than a stage, is critical for prevention measures.

Regular field scouting & monitoring using the Agro-EcoSystem Analysis (AESA) will start from the seedling emergence stage till the maturity stages to help farmers make informed management decision. In addition to the weekly FFS meeting day, two more days field scouting should be implemented from the seedling to the early vegetative stages. In fact, it takes two to three days for the FAW egg mass to hatch and little time for the neonate larvae to move inside the maize whorl, where their management will become more difficult.

Pest and disease management is linked to regular field scouting as far as decision-making is concerned. During vegetative stage, farmers should monitor fields at least once a week, better twice; and in later stages, at least every 15 days.

Table 5. Example of FFS curriculum for integrated management of the Fall Armyworm on maize

WEEK N°	STAGES	ACTIVITIES	TOPIC	LEARNING OBJECTIVE	CONTENT	METHODS	MATERIALS	TIME	RESPON-SIBLE PERSON	EVALUATION INDICATORS
1	Pre-planting	Introductory training on the FAW		To create awareness on how to recognize FAW and implement prevention measures	FAW identification, life cycle (biology) and ecology; Prevention, scouting and actions to manage the FAW; Biological control and cultural control; If already present, collect FAW specimen at different stages (egg masses, larval instars, adult male and female moth), damaged plants, natural enemies, potential local botanical plants, weeds etc for observation and discussion; Collect existing green list of botanicals available and develop simple factsheets on each and their preparation; Integrate indigenous practices into the reviewed existing lists of pesticides and develop a green list for each site/ country.	Brainstorming, discussion, whenever possible: visit infested fields/ vegetation, group work, practical demonstration	Flip-chart, markers, masking tape, knife, plastic bottles/ jars; veil to seal them; magnifier, nets to collect adult moth	4hrs x 2 days	Facilitator/ Resource person	Feedback on how to recognize, and to manage FAW
2	Pre-planting	Farm record-keeping Economic analysis	Farm record-keeping and economic analysis	Know how to keep and analyze field records for planning, management and decision-making	Importance of record-keeping; Types of records, and their use; Inputs and sales records; Costs of production and calculation of gross margins.. Cost effectiveness of treatments for FAW management.	Brainstorming, discussion, Problem solving exercise	Flip-chart, markers, masking tape	2hrs	Facilitator	Feedback to know how the analysis of records leads to management decision-making and planning
3	Pre-planting	Key studies to conduct in FFS		Identifying and selecting possible studies to be conducted in FFS						

	Pre-planting	Discus input procurement and sourcing		To know the characteristics of desirable varieties and seed sources, fertilizers or manures, botanical and biological pesticides	Use and procurement of various inputs in relation to prevention measures for FAW management Difference between seed and grains. Varieties of maize. Suitable variety. FAW resistant inbred lines Types of fertilizer / manure. Information on seed/ fertilizer package and label: raise awareness on seed sources where available Seed, fertilizer rates to source the needed quantity. Germination tests Alternatives to chemicals (indigenous technical knowledge, IPM) Sourcing botanicals and biopesticides Traps and pheromone lures.	Brainstorming, observations and discussions	Samples of seeds, fertilizers and pesticides (chemicals) flip-charts, markers and masking tape, botanicals, authorized pesticides, traps, pheromones lures	1-1.5 hrs	Facilitator	Feedback Able to list characteristics of good seed, fertilizers, biopesticides/ botanicals
4	Pre-planting	Site selection	Site identification (In relation to Prevention measures for FAW management)	Able to identify and select suitable land for maize production and to prevent infestations including FAW	Criteria for selecting land: Awareness on site selection criteria and any differences when setting-up FFS studies to avoid bias; Characteristics of land suitable for maize production; Rainfall pattern; History of the site; Awareness on land use; Rotation and fallow land; Companion cropping, associations, trees, hedges, flowers to enhance habitat for natural enemies. Avoid late and staggered planting to prevent FAW	Brainstorming, Field observations and practice on site identification, and discussions	fields, water, hoe, flip-charts, markers and masking tape	1-2.5 hrs	Facilitator	Feedback Able to list characteristics of good site / land/plant diversity for maize with less risk of early FAW infestation
5	Pre-planting	Land preparation	Land preparation for cultivation (In relation to Prevention measures for FAW management)	To know the importance of good land preparation and how to do this	Types of equipment for soil type and gradient; Role and method of land preparation – different views.	Brainstorming, discussions, field visits, and demonstration	Flip-chart, markers, masking tape, field for field visit	2.0 hrs	Facilitator	Feedback Able to list methods of land clearing and land preparation

6	Pre-planting	Seed testing and seed dressing	Determining seed viability and seed dressing	Able to determine the viability of seed and to dress the seeds.	Reasons for carrying out seed germination tests; Methods of testing seed germination and interpretation of the results; Reasons for dressing seeds; Methods of seed dressing; Safety precautions.	Discussion, practice and observations	Seeds, tissue, water, saucer, seed dressing chemicals, container, flip-charts, markers	1.0 hrs	Facilitator	Feedback Able to test germination and to dress seeds
7		Planting operations (planting, gap filling and thinning)	Planting	To know how to improve maize planting	Time of planting Methods of planting: spacing, depth of planting, seed rate Companion cropping to enhance habitat for natural enemies; Plant and preserve host plants for natural enemies (Crotalaria, flowering plants, Tithonia diversifolia, Tephrosia vogelii, Pigeon pea….); Staggered planting to be avoided as a strategy to limit continuous FAW population build up;. Plant diversity through varietal mix and intercropping to disrupt the oviposition and maintain natural enemies; Importance and method of thinning (with compensation) and gap filling.	Brainstorming, discussions and field visits	Flip-chart, markers, masking tape, field for field visit	1.5 hrs	Facilitator	Feedback Know how to plant, thin and gap fill.
8	Seedling	Specific training	Introduction to the FAW (ctd) (In relation to the management action to control the FAW)	To create awareness on how to recognize and to take management action to control the FAW	FAW identification, life cycle (biology) and ecology; Prevention, scouting and action; Bio control and cultural (mechanical) control; Collection of existing green list of botanicals available and development of simple factsheets on each; Integration indigenous practices into existing lists of pesticides and development of a green list for each country; Brainstorming with farmers or risk and costs of synthetic pesticides.	Brainstorming, discussion, whenever possible: Field visit, group work, practical demonstration	Flip-chart, markers, masking tape	4.0 hrs x 2 days	Facilitator / Resource person	Feedback on how to recognize, and to manage FAW

9	Seedling to Maturity	Regular field scouting / monitoring (from seedling to maturity stages)	Crop & FAW management requirements (Management action for FAW)	To identify pests / natural enemies, any emerging problems for immediate action; To assess effectiveness of the management options undertaken, records To identify problems in the field/crop, evaluate previous management decision made	Agro-EcoSystem Analysis (AESA); Stage of growth/ development; Pest, weeds and disease infections, pest infestations, natural enemies and host plants identification; Identify/collect FAW and natural enemies specimen at different stages, damaged plants, potential local botanical plants, weeds etc for observation and discussion; Infestation evaluation: incidence & severity; Evaluation and comparison of the effectiveness of treatments applied; FAW population monitoring; Weather effects; Soil/water/plant conditions: Soil structure, drainage and organic matter.	Brainstorming, group discussions and field practical	Flip-chart, markers, masking tape, field for field practice, knife, plastic bottles/jars, nets, vials magnifiers…	2-3 hrs /session	Facilitator	Feedback Know how to manage the main pests and diseases.
10	Seedling - Vegetative to Flowering	Pest and diseases management	FAW and other pest and disease management	Understanding the appropriate methods and timing of managing FAW and other pest and disease	Importance of managing pest and diseases and FAW in the context of the farmers' traditional systems and in the context of sustainable soil and water management practices (especially CA); Types, damage signs and characteristics of the different pests and diseases in maize Methods of managing pests and diseases – IPM - Use of ITK Farmer practices; Biocontrol and cultural (physical) control; Physical hand picking and crashing egg masses and larvae; Testing the use of sand and ash to control the early instars; Use biopesticides/ botanicals, botanicals preparation and handling; Risks; /...	Brainstorming, group discussions and field practical	Flip-chart, markers, masking tape, field for field practice, (bio) pesticides application equipment	2-3 hrs /session (multiple times)	Facilitator	Feedback Know how to manage the main pest and diseases.

10 cont.					.../cont. Collecting dead larvae, making a home-made biopesticide by blending, straining and diluting the larvae dead from pathogens; Action thresholds and cultural practices; Moisture control practices; Termite control (cultural practices including use of neem extract - leaves/ seed).					.
11	Seedling to vegetative	Soil health and Fertilizer application	Soil fertility and moisture management	Understand soil health Able to correctly apply basal fertilizer	Concept of soil health Soil characteristics: composition, texture, structure, water holding capacity, etc; Importance of organic matter; Composting, manure; Types of organic and in-organic fertilizers and their characteristics; Sources of fertilizers; Methods, rates and timing of application; Basal and top dressing; Organic and inorganic fertilizers; Suitable rate for nitrogen fertilizer.	Brainstorming, discussions and field practical	Flip-chart, markers, masking tape, field for field practice, material for soil health exercises	3.0 hrs /session (multi-ple times)	Facilitator	Feedback Know how to manage soil fertility.
12	Vegetative	Weeding	Weed Management	Able to manage weeds	Importance of weeding; Methods and timing of weeding (weeding before reproductive stage); Characteristics of different weeds; Safety precautions	Brainstorming, discussions and field practical	Flip-chart, markers, masking tape, field for field practice	1.5 hrs	Facilitator	Feedback Know how to control weeds.
13	Cobbing & Maturity	See N° 9 & N° 10 Regular field monitoring		To monitor, identify and solve problems in the field/crop						
14		Harvesting	Harvesting: physiological maturity	To determine the appropriate time for harvesting	Signs and characteristics of maturity; When and how to harvest; Reducing harvesting losses; Good crop residues management (destroy egg masses); Identify and discard infected ears.	Group discussion and practical	Field with mature crop	1.0 hr	Facilitator	Feedback Know when and how to harvest

15		Post harvesting / processing	Post-harvest handling	To learn about proper methods of post-harvest handling and processing	Minimize post-harvest losses (quality and quantity); Dehusking/drying; Shelling/drying/ Winnowing Sorting/grading/bagging, when/if needed.	Presentation, group discussion and practical	Flip-chart, markets, masking tape, grains, examples processing tools / equipment	1.5 hrs	Facilitator	Feedback Know about proper methods of post-harvest handling and processing.
16		Storage	Minimizing losses during storage	Able to minimize losses during storage	Importance of good storage; Determine proper moisture content of grains; Storage methods; Seed storage methods; Causes of losses; Storage pests and diseases and their management; Fumigation chemicals.	Presentation, group discussion and practical	Flip-chart, markets, masking tape, grains in store, examples of chemicals	2.0 hrs	Facilitator	Feedback Know how to store their grains and to manage storage pests.
17		Economic analysis	Farm record-keeping and economic analysis	Know how to analyze records for management decision-making	Importance of record-keeping; Cost benefit analysis; Economic benefit of the treatments – comparisons; Cost of production and gross margins.	Brainstorming, discussion	Flip-chart, markets, masking tape	1.5 hrs	Facilitator	Feedback Know how to keep and use farm records.

N.B. N° 10 is carried out according to the decision made (N°9).

Bibliography and resources

Farmer Field School material:

Many Farmer Field Schools documents, including the documents below, can be found on the website of FAO's Global Farmer Field School Platform: www.fao.org/farmer-field-schools/en

The Platform has a page dedicated to FFS on FAW: www.fao.org/farmer-field-schools/overview/fall-armyworm/en

Useful specific documents (including maize production):

FAO. 2005. *Horticultural Marketing* by Grahame Dixie. Marketing Extension Guide 5. www.fao.org/docrep/008/a0185e/a0185e00.htm#Contents

FAO. 2017. *Discovery-based learning on land and water management: A practical guide for farmer field schools.* Rome. 348 pp. This guide focuses largely on maize production systems, so can be very helpful for facilitators dealing with FAW.

FAO. 2016. *Farmer Field School guidance document – planning for quality programmes*. Rome. 112p

FAO. 2001. *Facilitating Scientific Method as follow-up for FFS graduates.* Peradeniya. 14p. FAO Programme for Community IPM in Asia.

ICIPE. 2007. *Push-pull Curriculum for Farmer Field Schools.* International Centre of Insect Physiology and Ecology, Nairobi, Kenya. ISBN 92 9064188 6. www.push-pull.net/ffspdf.pdf

Up-to-date information on FAW:

FAO's website on FAW provides FAO's latest documents and Guidance Notes: www.fao.org/food-chain-crisis/how-we-work/plant-protection/fallarmyworm/en (or google "FAO Fall Armyworm"). The website is very regularly updated with new information.

FAMEWS mobile app and training kit in English/French (bit.ly/2BZEW8q)

Scientific articles on FAW:

Bardner, R., & Fletcher, K. E. 1974. Insect infestations and their effects on the growth and yield of field crops: a review. *Bulletin of Entomological Research*, 64(1), 141-160.

Bode, W. M., & Calvin, D. D. 1990. Yield-loss relationships and economic injury levels for European corn borer (Lepidoptera: Pyralidae) populations infesting Pennsylvania field corn. *Journal of Economic Entomology*, 83(4), 1595-1603.

Buntin, G.D. 1986. A review of plant response to fall armyworm, *Spodoptera frugiperda* (J.E. Smith), injury in selected field and forage crops. Florida Entomologist. 63(9):549-559.

Cruz, I., & Turpin, F. T. 1983. Yield impact of larval infestations of the fall armyworm (Lepidoptera: Noctuidae) to midwhorl growth stage of corn. *Journal of Economic Entomology*, 76(5), 1052-1054.

Cruz, I., Figueiredo, M. L. C., Oliveira, A. C., & Vasconcelos, C. A. 1999. Damage of Spodoptera frugiperda (Smith) in different maize genotypes cultivated in soil under three levels of aluminium saturation. *International Journal of Pest Management*, 45(4), 293-296.

Evans, D.C. and P.A. Stansly. 1990. Weekly economic injury levels for fall armyworm (Lepidoptera: Noctuidae) infestation of corn in lowland Ecuador. J. Econ. Entomol. 83:2452-2454.

Gross, Jr., H.R., J.R.Young, & B.R. Wiseman. 1982. Relative susceptibility of a summer-planted dent and tropical flint corn variety to whorl stage damage by the fall armyworm (Lepidoptera: Noctuidae). J. Econ. Entomol. 75:1153-1156.

Hruska, A. J. & Gladstone, S. M. 1988. Effect of period and level of infestation of the fall armyworm, Spodoptera frugiperda, on irrigated maize yield. ***Florida Entomologist**,* 249-254.

Hruska, A. J. & Gould, F. 1997. Fall armyworm (Lepidoptera: Noctuidae) and Diatraea lineolata (Lepidoptera: Pyralidae): Impact of larval population level and temporal occurrence on maize yield in Nicaragua. ***Journal of Economic Entomology***, **90**(2), 611-622.

Khan, Z.R., Midega, C.A.O., Bruce, T.J.A., Hooper, A.M. and Pickett, J.A. 2010. Exploiting phytochemicals for developing a 'push–pull' crop protection strategy for cereal farmers in Africa**.** ***Journal of Experimental Botany**,* 61: 4185–4196

Lauer, J.G., Roth, G. W. & Bertram, M. G. 2004. Impact of Defoliation on Corn Forage Yield. 2004. Agron. J. 96:1459–1463.

Midega, C.A.O., Pittchar, J., Pickett, J.A., Hailu, G. & Khan, Z.R. 2018. A climate-adapted push-pull system effectively controls fall armyworm, ***Spodoptera frugiperda*** (J E Smith), in maize in East Africa. ***Crop Protection***, 105: 10-15.

Morrill, W. & Greene, G. L. 1974. Survival of fall armyworm larvae and yields of field corn after artificial infestations. J. Econ. Entomol. 67(1): 119-123.

NCIS. 2017. What is crop insurance? (https://cropinsuranceinamerica.org/what-is-crop-insurance, 04 December 2017).

Pedigo, L. P., Hutchins, S. H. & Higley, L. G. 1986. Economic injury levels in theory and practice. ***Annual review of entomology***, **31**(1), 341-368.

Perfecto, I. 1991. Ants (Hymenoptera: Formicidae) as natural control agents of pests in irrigated maize in Nicaragua. *Journal of Economic Entomology*, 84(1): 65-70.

Perfecto, I. 1980. Indirect and direct effects in a tropical agroecosystem: the maize-pest-ant system in Nicaragua. *Ecology* 7(6): 2125-2134.

Reddy, K. S. & Sum, K. O. S. 1992. Yield-infestation relationship and determination of economic injury level of the stem-borer, Chilo partellus (Swinhoe) in three varieties of maize, Zea mays L. ***Maydica***, **37**(4), 371-376.

Thomison, P.R., Nafziger, E.D., Coulter, J.A., Zarnstorff, M.E., Geyer, A.B. & Lindsey, A.J. 2016. Response of Corn to Multiple Defoliation Events. Poster presented at the Annual Meeting of the American Society of Agronomy. November 2016. (https://scisoc.confex.com/scisoc/2016am/webprogram/Paper99910.html).

United States Department of Agriculture (USDA) Risk Management Agency. 2013. Corn Loss Adjustment Standards Handbook. FCIC 25080. 98 pp.

Varella, A.C., Menezes-Netto, A.C., Alonso, J.D.dS., Caixeta, D.F., Peterson, R.K.D. & Fernandes, O.A. 2015. Mortality Dynamics of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) Immatures in Maize. PLoS ONE10(6): e0130437. https://doi.org/10.1371/journal.pone.0130437

Williams, W.P. & Davis, F.M. 1990. Response of corn to artificial infestation with fall armyworm and southwestern corn borer larvae. Southwestern Entomologist 15:163-166.

Fall Armyworm (*Spodoptera frugiperda*), FAW, a dangerous transboundary pest native to the Americas, has been spreading rapidly to all sub-regions of Africa since 2016, causing significant damage to crops. Farmer education and community action are critical elements in the strategy to best manage FAW populations, using an integrated and ecological pest management approach. Farmer Field School (FFS), a holistic farmer education approach used in over 90 countries, will be a key component of the response effort.

This guide seeks to provide guidance on how to conduct FFS on the integrated and sustainable management of the FAW in Africa, with emphasis on maize as FAW's preferred host plant. It provides information on the biology and ecology of FAW; field studies and exercises for use in season-long Farmer Field Schools; and suggestions on how to build a training programme for rural advisory services/extension on FAW and FFS refresher courses of Master Trainers and facilitators.

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