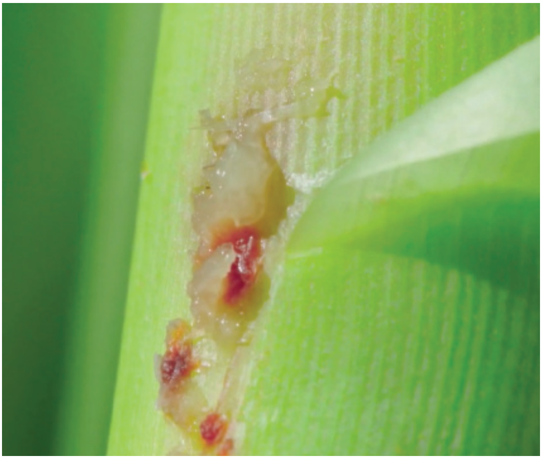
Integrated Pest Management manual for Fall armyworm, stemborers and Striga in Maize



icipe@50 1970–2020 Insects for Life

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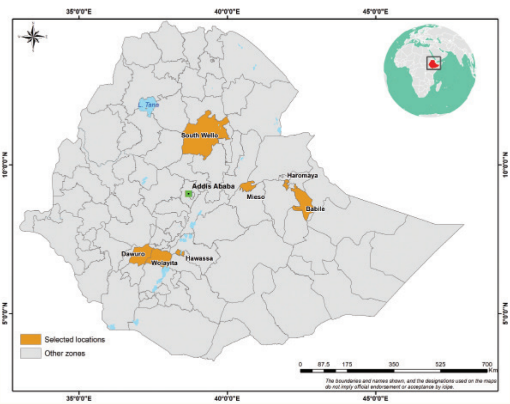
About SCLAMP-EA project

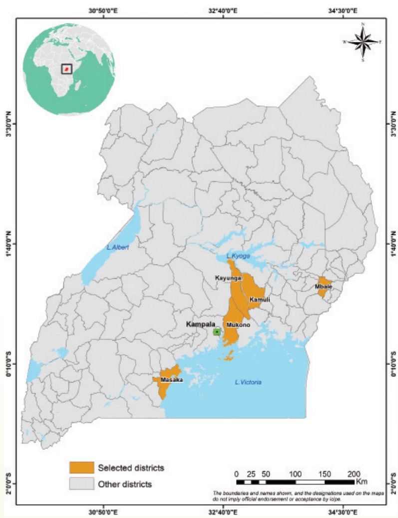
Scaling-up Climate-Smart Pest Management Approaches for Enhanced Maize and Tomato Systems Productivity in Eastern Africa (SCLAMP-EA) is a project funded by GIZ (German Corporation for International Cooperation). It is a 3-year project, running from 2020 to 2022.

The purpose of the project is to facilitate the large-scale adoption of proven and piloted Climate Smart Pest Management (CSPM) technologies and practices by smallholder farmers to improve their food and nutrition security through mitigating yield losses due to key insect pests in maize and tomato.

The projects' target areas are:

- Ethiopia (Southern/SNNPR in Dawuro, Angacha and Shebedino; Northern/Amhara in South Wollo and Western Oromia Region in Sasiga and Diga); and
- Uganda (Central Uganda in Rakai and Kyotera; Eastern Uganda in Kamuli, Namutumba, Mbale and Kween; and Northern Uganda in Amuru, Nwoya, Adjumani and Pakwach/ Southern West Nile).





Map showing project areas in Ethiopia (L) and Uganda (R).

Purpose of manual

To present Integrated Pest Management (IPM) practices that are recommended to be implemented by maize growers. These IPM practices will reduce damage caused by Fall armyworm, maize stemborers and **Striga**, increase maize yield, protect the environment, and safeguard human health – through reduced use of synthetic chemicals.

This manual describes Fall armyworm, maize stemborers and **Striga**, symptoms of damage and available management options.

Objective of manual

To strengthen the practice of IPM for Fall armyworm, maize stemborers and **Striga** in Uganda and Ethiopia. The challenge currently being faced by farmers and extension officers is the lack of adequate information on available IPM practices. Consequently, there is a low adoption rate of IPM practices and over reliance on synthetic chemicals for pest and disease control.

Abbreviations

AEZ	Agro-ecological zone
CABI	Centre for Agriculture and Bioscience International
cm	Centimetre
CSPM	Climate Smart Pest Management
EIL	Economic Injury Level
FAO	Food and Agriculture Organization
FAW	Fall armyworm
g	Gram
GAP	Good Agricultural Practices
GIZ	German Corporation for International Cooperation
icipe	International Centre of Insect Physiology and Ecology
IPM	Integrated Pest Management
kg	Kilogram
PPT	Push-pull Technology
SCLAMP-EA	Scaling-up Climate-Smart Pest Management Approaches for Enhanced Maize and Tomato Systems Productivity in Eastern Africa
ToT	Training of Trainers
USD	United States Dollar

Introduction

Maize is the main staple food crop grown in Africa, and it is estimated that approximately 208 million people on the African continent depend on maize as a staple food. The average maize yield in sub-Saharan Africa is very low, less than 1 ton per hectare, due to many abiotic and biotic constraints. Among the biotic constraints, insect pests and weeds are the most important pests of maize. Stemborers such as *Busseola fusca* (African maize stalkborer), *Sesamia calamistis* (African pink stemborer) and *Chilo partellus* (spotted stemborer) used to be considered the most important pests of maize in Africa. The Fall Armyworm (FAW), *Spodoptera frugiperda*, which invaded Africa in 2016, is now considered as the leading insect pest of maize and a threat to food security.

Striga or 'witchweed' is a parasitic weed that affects cereal crops in most parts of Africa. Stemborers, FAW and **Striga** weed are the three most destructive pests of cereal crops and can reduce yields of maize and sorghum on smallholder farms. These pests can cause yield losses of 30% to 100% if they are uncontrolled. Control of stemborers or FAW by insecticides and control of **Striga** weeds by herbicides is expensive for resource-poor farmers and is also harmful to the environment.

Integrated Pest Management (IPM) is an approach to crop production and protection that combines different management practices to grow healthy crops and minimize the use of synthetic pesticides. IPM emphasizes the growth of a healthy crop with the least possible disruption to the ecosystems. The best way to control both pests and diseases is to keep plants healthy (Table 1).

Table 1: Good agricultural practices

Build healthy soil that provides a home to friendly insects and provide crops with adequate nutrients.
Ensure that soil moisture is adequate to prevent moisture stress.
Use resistant varieties. Plant seeds which are resistant to common pests and diseases.
Use recommended spacing for each crop. Planting crops too close together limits the sunshine and air that reaches the leaves, and allows diseases to thrive. But planting crops farther apart leaves room for weeds, dries the soil and may reduce the harvest.
Plant at the right times. Planting with the first rains can make crops benefit from nitrogen rush, and the crops will be mature enough to resist pests or diseases that come at a certain time.
Ensure **crop diversity** through intercropping, and practise agro-forestry. Large areas with only one kind of plant attract pests.

Fall armyworm

Fall armyworm (*Spodoptera frugiperda*), FAW, is an insect pest of American origin. It is a heavy feeder which derives its name from its feeding habit. Once an 'army' of FAW infests an area, they eat almost everything in the area, before moving to the next available food source.
FAW feeds on more than 80 varieties of crops, including maize, sorghum, rice, millet, wheat, sugarcane and vegetables, but primarily affects maize.

Fall armyworm life cycle

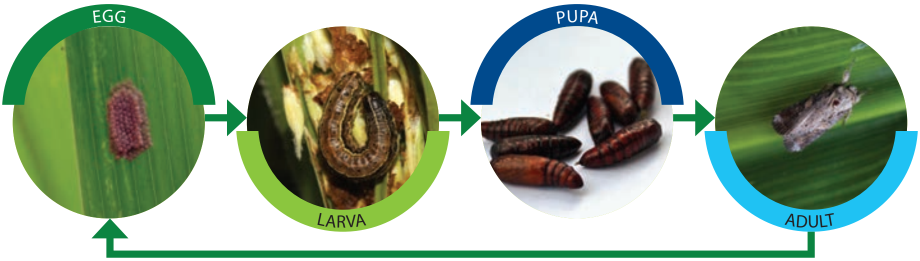


Figure 1: FAW life cycle

Fall armyworm is a fertile insect, laying up to 2,000 eggs in a lifetime. Adult females lay eggs in batches of 100 to 200 on the underside of leaves. The female also deposits a layer of greyish scales between eggs and over egg mass, giving FAW eggs a hairy or mouldy appearance. Eggs hatch into larvae in 3 to 5 days, and after hatching, larvae migrate to the whorl. The destructive larval stage takes 14 to 28 days, after which the pest falls to the soil for pupation. The pupation process takes place in 7 to 14 days. An adult moth emerges from the pupa and begins to lay eggs after 3 to 4 days (Figure 1).

Distribution of FAW

FAW has rapidly spread to and throughout Africa since 2016 (Figure 2).

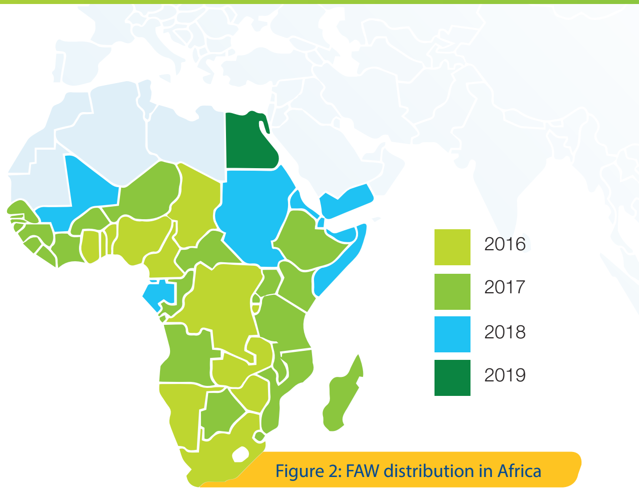


Figure 2: FAW distribution in Africa

Means of dispersal for FAW

Fall armyworm neonates spin a silk thread that they use to balloon away from the egg mass to nearby host plants. Larvae crawl from one host plant to another. Adult moths can fly over 30 to 200 kilometres a day, assisted by the wind.

Damage by FAW

The young larvae feed where eggs were laid; the first two instars feed on young leaves, causing a characteristic skeletonizing or ‘windowing’ effect (Figure 3). Older larval instars feed near the funnel and upper leaves, causing large holes, and leaving sawdust-like excreta (frass). Badly infested fields may look as if they have been hit by a severe hailstorm. In a young crop, FAW feeding can kill the growing point, causing dead heart in maize, which prevents any cobs forming. Fall armyworm can also destroy silks and developing tassels, thereby limiting fertilization of the ear. Maize plants may have the cobs attacked by larvae boring through the cob (Figure 4). Damage to cobs may lead to fungal infection, aflatoxins and loss of grain quality. At high densities, large larvae may act as armyworms and disperse in swarms, but they often remain in the locality on wild grasses, if available.

Figure 3: Windowing on maize leaves

Figure 4: FAW larva on maize cob

Difference between stemborer damage and FAW damage

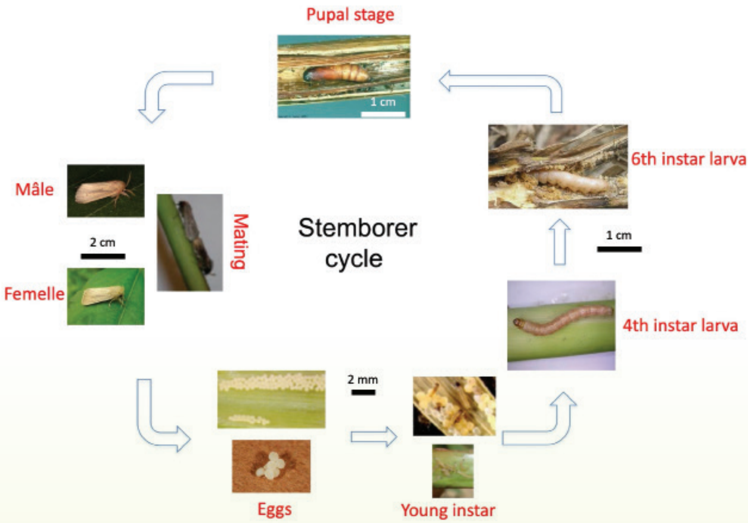
When the stemborer larvae are growing, they start to feed inside the maize stems (A), causing dead-heart (B) if the maize plant is young, or visible holes (C) along the stem on older maize plants, as shown in Figure 5.

Figure 5: Stemborer larva in stem (A), damage caused by stemborer, dead heart (B), and holes on the stem (C)

In contrast, FAW larvae feed only on leaves and not inside the maize stems, causing large ragged holes, as shown in Figure 6.

Figure 6: FAW damage showing large ragged holes and sawdust-like frass

Stemborers



The stemborers' lifecycle (Figure 7) consists of development from eggs to adults, through six larval stages. At early larval stages, the small larvae (or caterpillars) feed on leaves. As the larvae grow, they bore into the stem and feed inside the plant stems, up to the pupal stage. Stemborers pupate in the stem.

Figure 7: General scheme of stemborer's lifecycle

Busseola fusca (Figure 8) takes about 60 days to develop from egg to the adult stage, although this duration varies greatly depending on climatic conditions, which include variations in humidity, temperature and atmospheric pressure.

Figure 8: Developmental stages of *Busseola fusca*: (A) eggs laid between a leaf sheath and stem, (B) larvae, (C) pupa, and (D) male and (E) female adults

Sesamia calamistis (Figure 9) completes its life cycle within 44 to 56 days.

Figure 9: Developmental stages of *Sesamia calamistis*: (A) egg, (B) larva, (C) pupa, and (D) male (above) and female (below) adults

The complete life cycle of *C. partellus* (Figure 10) ranges between 38 and 55 days.

Figure 10: Developmental stages of *Chilo partellus*: (A) eggs laid on leaf surface, (B) larva, (C) pupa, and (D) male (left) and female (right) adults

Distribution of *Busseola fusca*, *Sesamia calamistis* and *Chilo partellus*

Busseola fusca is distributed widely throughout sub-Saharan Africa (Figure 11A). In the continent's eastern and southern parts, *B. fusca* occurs mostly in mid- and high- altitude areas (> 600 m) where it is often the most serious pest of maize. However, *B. fusca* is also found in low-altitude areas mostly feeding on maize as well as cultivated and wild sorghum.

Sesamia calamistis is mainly found in sub-Saharan Africa and some of the Indian Ocean islands commonly occurring in wetter localities at all altitudes (Figure 11B). *Sesamia calamistis* feeds on a wider range of crops than *B. fusca*: maize, sorghum, pearl millet, wheat, rice and sugarcane, and it is considered a critical and economically important maize pest in West Africa.

Chilo partellus is native to Asia where it is a pest on maize and sorghum. It was first reported in Malawi in the 1930s and spread in the 1950s to most East Africa countries. Since then, it has become widespread throughout Eastern and Southern Africa and several West African countries (Figure 11C). *Chilo partellus* is considered to be the most important stemborer species in most low- to medium-elevated areas of Eastern and Southern Africa.

In addition to altitude, other factors play key roles in determining the distribution of stemborers, e.g. crop lifecycle and the presence of host plant.

Maize is widely grown in Uganda, and presently, *B. fusca*, *S. calamistis* and *C. partellus* occur virtually in all maize growing regions.

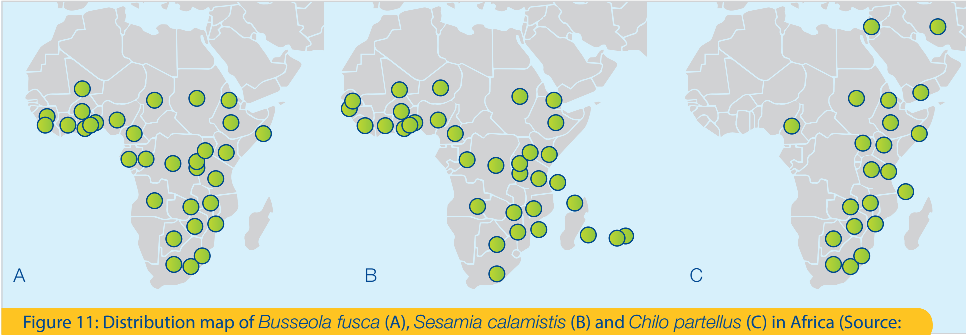


Figure 11: Distribution map of *Busseola fusca* (A), *Sesamia calamistis* (B) and *Chilo partellus* (C) in Africa (Source: CAB international)

Damage by stemborers

Yield losses caused by stemborers vary greatly among regions, depending on the agroecology, density of stemborer population, season, soil fertility status, crop type and phenology during infestation. Accordingly, yield reductions ranging between 15 and 50% have been estimated in East Africa, while in South Africa, losses exceeding 50% have been reported, thus indicating the importance of stemborers as major yield-limiting factor for cereal crops in the region. It has been estimated that stemborers cause yield loss of 15% to 50% in East Africa. Crop losses due to stemborers in Ethiopia ranges from 10% to 50% while in Uganda, the crop losses range from 10% to 30%.

Striga

Striga, commonly known as witchweed, is a parasitic plant that occurs naturally in parts of Africa, Asia, and Australia. In East Africa, there are two common species of the witchweed, *Striga hermonthica* (purple witchweed) and **Striga asiatica** (red witchweed). *Striga hermonthica* is common around the Lake Basin, while **S. asiatica** is mainly found in the coastal areas. The crops most affected are maize, sorghum, rice, finger millet, tef and sugarcane. The parasitic plant grows by attaching itself onto the host plant.

Striga lifecycle

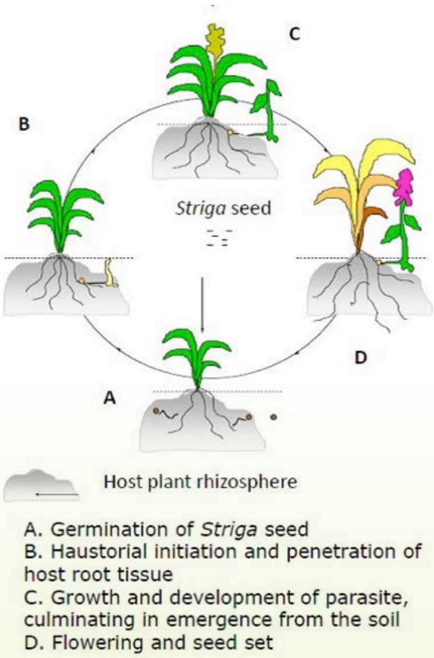


Figure 12: Striga lifecycle

Striga is an annual plant, one **Striga** plant can produce up to 20,000–50,000 seeds, which lie dormant in the soil until a cereal crop is planted. This dormancy can last for over 15 years.

Germination occurs within 24 hours of exposure to a stimulant (usually a cereal plant). In the absence of a host, **Striga** roots will grow to 4 or 5 mm before dying. As **Striga** germinates, its roots grow towards the host crop. They develop an intrusive organ (haustorium) which penetrates host root cells. **Striga** draws nutrients from a host plant, causing severe stunting and yield loss. **Striga** develops underground, where it may spend the next four to seven weeks before emergence when it rapidly flowers and produces seeds (Figure 12).

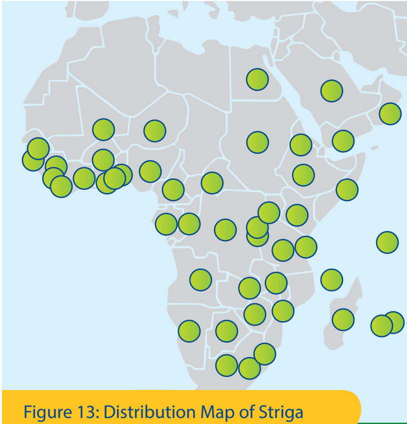


Figure 13: Distribution Map of Striga in Africa (Source: CAB international).

Striga is distributed widely throughout sub-Saharan Africa (Figure 13).

Means of dispersal

Striga seeds are small (0.2 mm long) and are spread by:

- wind
- run-off from heavy rains
- contaminated crop seeds
- animal manure
- farm machinery and tools

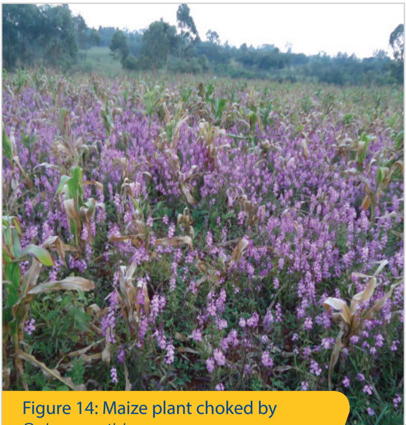


Figure 14: Maize plant choked by *S. hermonthica*.

Damage by Striga weed

Plants affected by **Striga** exhibit stunting, wilting and chlorosis (Figure 14). If both stemborers and **Striga** weed attack maize plants, the yield loss is often 100%. **Striga** weed causes most of the damage to the maize by the time it emerges.

Integrated pest management

Integrated Pest Management (IPM) is an approach designed to manage pests and diseases with as little damage as possible to people and the environment. The focus is on long-term prevention or suppression of pest problems. Different techniques are used within IPM, including scouting and monitoring, as well as preventive cultural, mechanical, and biological control in a compatible manner. Corrective chemical control measures are used as a last resort.

The emphasis of IPM is on control, not eradication. Wiping out a whole pest population is often impossible, expensive and environmentally unsafe. IPM programmes work to create acceptable pest levels.

Economic Injury Level (EIL) is the point where a pest begins to cause enough damage to justify the time and expense of control measures. Below the EIL, it is not cost-effective to control the pest population because the cost of treatment exceeds the amount of damage. Above the EIL, the benefit of treatment is greater than the cost of treatment. The EIL of stemborers is 1 larva per plant, and EIL of **Striga** is 1 weed. One larva can cause considerable yield loss, mainly on maize due to the inability to compensate for stem damage by the formation of tillers.

By allowing a pest population to survive, selection pressure is reduced, and this lowers the chance of pests developing resistance to chemicals. By not killing all the pests, with chemicals, numbers of pests unresistant to chemicals should remain, which will then dilute the prevalence of any chemical-resistant genes that might appear.

Integrated pest management methods for FAW, stemborers and Striga weed

IPM is as a knowledge-intensive system that has a continuous improvement cycle. With each cycle (crop or season), more emphasis is placed on preventive strategies and gaining knowledge not only about maize pests and their behaviour but also about what conditions are favourable or unfavourable to their development. This is illustrated in Figure 15.

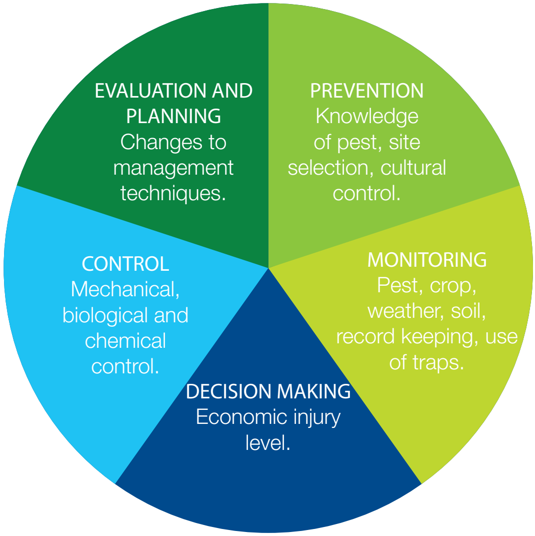


Figure 15: Five components of IPM

Scouting

Scouting is a crucial tool in IPM. It entails field observation made during the crop production cycle for pests, diseases, weeds and crop health (nutrition and water needs). Proper field observations provide information about the status of the crop and enable decision making on appropriate interventions to be taken, for example fertilizer application, irrigation or pest and disease control. Scouting should be done regularly, at least once a week and more often after an infestation is detected. Scouting is achieved by picking and inspecting plants at random from sampling sites and recording the observations. Different sampling sites should be chosen each time the crop is inspected.

- For effective control, start scouting every 3 to 4 days as soon as your maize has emerged, early in the morning or late in the evening.
- Upon arrival at the field, quickly do a visual assessment and scan for "hot spots" while moving through the field.
- Walk through your maize farm in a W pattern (Figure 16). Stop five times.
- At each stop, examine 10 to 20 plants. Focus on the newest two to three leaves emerging from the whorl, as this is where the FAW likes to feed and where FAW moths lay eggs.
- Observe the general health of the maize plants (leaf colour, soil moisture, and presence of weeds, e.g. Striga).
- Look out for the physical signs of pest (egg masses, larvae, pupae and moths) or disease symptoms.
- Look out for signs of FAW, stemborer or Striga damage such as deadheart, windowing, frass, ragged and torn leaves, silk, tassel, ear damage, stunting and chlorosis.
- Record the number of seedlings that are infested and calculate the percentage (%) infestation for this scouting location.
- Now move to the next spot. Examine 10 to 20 plants. Record the data. Repeat the process a total of five times.
- After scouting the five locations in the field, calculate the total percentage (%) infestation across the field.

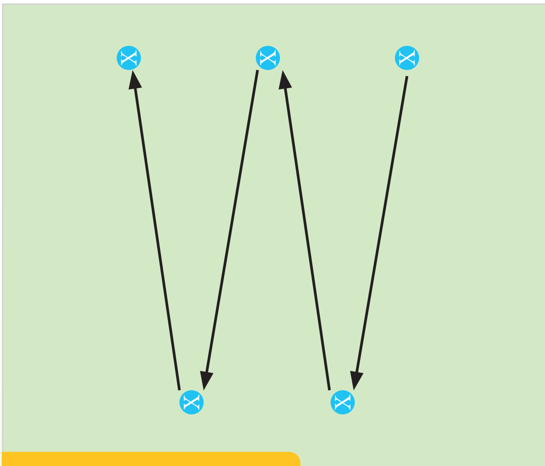


Figure 16: Scouting pattern

Monitoring

Regional FAW and stemborer monitoring is intended to actively track the presence, population, and movement of pests within a specified geography. This is conducted by trained technical personnel at sites throughout a country or region, but can also be conducted at the village and field levels by both smallholder farmers and village-level progressive farmers. In both cases, monitoring relies on pheromone traps erected near fields to trap adult male moths. Trapped moths are identified, counted, and recorded. The data collected is used to inform appropriate action (reporting the data to appropriate authorities and conducting more intensive, targeted field scouting to inform crop management recommendations and decision making).

The data collection tool app, called FAW Monitoring Early Warning System (FAMEWS), can be used to collect the scouting and pheromone trap data.

Mechanical control

Mechanical control is the management of pests by using physical means or hands-on methods such as:

- Post harvest tillage: Tillage reduces stemborer populations by burying them deeply into the soil, or by breaking the stems and exposing the larvae to adverse weather conditions, as well as birds, rodents, ants, spiders and other natural enemies.
- Crushing egg masses and hand-picking larvae: Farmers can mechanically kill FAW eggs and young larvae. This method should be done as soon as possible, beginning a week after planting. Eggs are laid in a mass, and can be easily found on maize leaves. They can be immediately crushed. Young larvae can be picked off the leaves, before they penetrate deep into the whorl. Handpicked larvae can be used as chicken feed. Crushing egg masses and hand-picking larvae is very effective in small areas, but is very labour intensive.
- Pour sand or ash into the leaf whorl: Sand and ash irritate the soft-skinned FAW larvae, forcing them out of the whorl or directly killing them through suffocation.
- Uproot Striga weed when they start to flower, but before they set seed, and burn them. Note that **Striga** can still grow again from seeds already in the soil.
- Mass trapping using pheromone traps: Pheromones traps t can be used for both monitoring and control. If sufficient male moths can be captured, there will be a reduction in the number of fertilized eggs. One male can mate with several females, therefore a high proportion of males needs to be trapped for this approach to be effective.

Cultural control is the modification of the crop environment in order (i) to avoid the meeting of crop susceptible stage with pest highest density, or (ii) to improve the crop growing condition, or (iii) to make the environment unfavorable for the pest. Cultural control methods include:

- Intercropping: Plant rows of other crops between the maize. Intercropping is effective when non-host plants are used. Maize can be intercropped with legumes (e.g. pigeon pea, cow pea, velvet beans, lablab beans) or with other crops (e.g. cassava, sweet potatoes, pumpkins). Intercrops reduce pest damage by: (i) improving soil health and promoting vigorous plant growth through nitrogen fixation, (ii) inhibiting movement of larvae among plants, (iii) preventing female moths from laying eggs, through visual or chemical disruption, and (iv) providing habitat for natural enemies. Crop rotation will reduce pest populations, but FAW can quickly build up.
- Habitat management using push-pull strategy: Plant Desmodium in between maize rows to repel stemborers from the maize. Plant Napier grass along the borders of the maize plot as a trap crop to pull stemborers away from the maize (Figure 17). Other benefits of push-pull are increased crop yields, increased fodder production, increased nitrogen fixation and reduced soil erosion.
- Field sanitation: Remove volunteer plants or alternative host plants. This helps in limiting the initial establishment of stemborers that would infest the next crop. Weed regularly, starting two weeks after germination, and then weed again after six to eight weeks. Weeding reduces competition for nutrients by weeds, some of which are alternate hosts of stemborers.
- Crop residue management: Slash maize stubble immediately after harvest and laying it out (horizontally) on the ground for 4-8 weeks. The sun's heat will destroy stemborer larvae and pupae in the stem. Residue can also be used to feed cattle or to make compost.
- Mulching: Spreading of plant materials such as straw, leaves, crop residues, green manure crops, or saw-dust on the soil surface. Mulching enhances soil biological activity, increases soil organic carbon, and thus supports improved plant growth. Mulch also provides habitat for natural enemies. To reduce the possibility of crop residues harbouring pests and disease, maize stubble should be slashed and laid out on the ground for 4-8 weeks.
- Fertilization: Use legume crops, well-composted organic manure and inorganic fertilizers to provide adequate and balanced plant nutrition. Fertilization increases levels of soil organic carbon, soil biological activities and increases pest resistance. Unbalanced plant nutrition through the use of inorganic fertilizers on poor soils can lead to increased pest damage. For example, the use of high levels of nitrogen fertilizer leads to increased leaf damage.
- Early planting: Plant maize after the first effective rains. This provides good growing conditions for maize and ensures that the crop will be established while pest population is low. Avoid late planting because stemborers and FAW populations build up later in the crop season. Farmers can also plant early maturing maize varieties.
- Crop rotation: Plant non-host crops after maize. Rotate maize with cassava or with legumes such as groundnuts, soybeans or cowpea for minimum 3 years. The roots of these legumes will induce suicidal germination of Striga seeds residing in the soil and improve soil fertility

through nitrogen fixation. Crop rotation increases the abundance of natural enemies and reduces pest and weed build up.

- Attract predators and parasitoids: Ants are important natural predators of FAW larvae. They crawl up the plants, into the whorls, and eat FAW larvae. Farmers have found that they can attract ants to their maize fields by putting fish soup in their maize fields. These substances attract ants to their maize fields, and then they stay, and find and eat FAW larvae. Spraying of maize leaves with 10-20% sugar solution attracts wasps that eat or parasitize FAW.

In addition, farmers can prevent the spread Striga by the following actions:

- Avoid grazing animals in crops infested by **Striga** because the animals will spread **Striga** seeds.
- Wash mud off farm machinery, tools, shoes or feet after working in infested fields.
- Avoid dropping cobs on the soil or threshing them in fields infested with **Striga**.

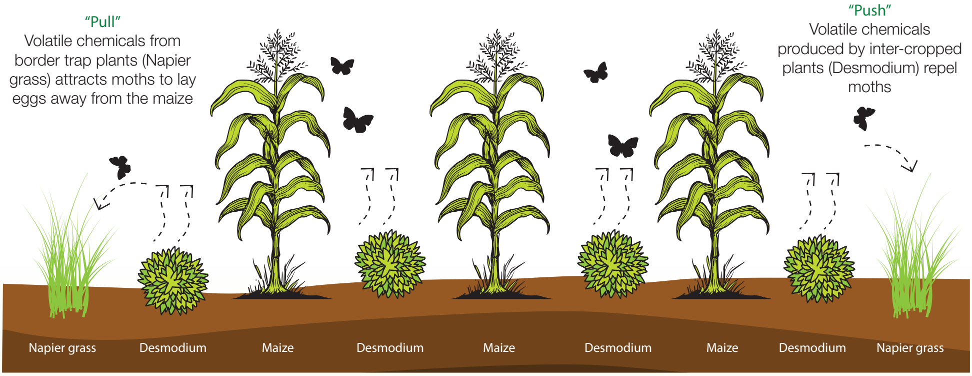


Figure 17: Push-pull technology

Control of Stemborers, Fall Armyworm and Striga weed using push-pull strategy

There are two options of the Push–pull strategy as outlined below:

1. Conventional push–pull: a cropping strategy, where farmers use Napier grass as a border crop and Desmodium legume (silverleaf and greenleaf Desmodium) as an intercrop. Recommended for areas with reliable rainfall.
2. Climate-smart push–pull: a cropping strategy, where farmers use **Brachiaria spp.** (a drought-tolerant grass) as a border crop and Desmodium legume (drought-tolerant greenleaf Desmodium) as an intercrop. Recommended for hot, dry conditions.

Biological control

Biological control is the use of living organisms to suppress the population density, or impact of a specific pest organism, making it less abundant or less damaging than it would otherwise be. These organisms are also known as "natural enemies". Examples of biological control agents are parasitoids, predators, nematodes, fungi, bacteria, protozoa and viruses.

Biological control is implemented through three methods:

a) Classical biological control (importation of natural enemies), where the natural enemy is introduced in a new environment to achieve control;

b) Augmentative biological control (mass-production of natural enemies), in which a large population of natural enemies already present is regularly released to increase their number for control;

c) Conservation biological control (maintenance of natural enemies), in which measures are taken to maintain natural enemies through adaptation of specific cultural practices.

Biological control agents

Natural enemies of stemborers and FAW are parasitoids, and predators such as ants, beetles, predatory bugs, spiders and earwigs.

Parasitoids are a group of insects that parasitize other insects or arthropods at any host stage. Insects that parasitize eggs are called eggs parasitoids, insects that parasitize larvae are called larval parasitoids, and insects that parasitize pupae are called pupal parasitoids. A parasitoid is only parasitic in its immature stage. The free-living adult parasitoids lay their eggs inside the host or attach them outside the host. The most abundant and widespread parasitoids of maize stemborers in the East African region are the egg parasitoids **Telenomus spp.** and **Trichogramma spp.**, and the larval parasitoid *Cotesia sesamiae*. *Telenomus remus* and **Trichogramma** are the main egg parasitoid wasps of FAW in North and South America. In Kenya, augmentative releases of *T. remus* and **T. chilonis** effectively controlled the damage caused by FAW.

Predators, such as ants, spiders and earwigs can cause high mortality of eggs and young larvae.

Cotesia

These are small wasps whose adults deposit multiple eggs in the body of stemborers or FAW. After about three days, the parasitoid larva emerges; it feeds inside the body tissue of stemborers or FAW. Soon after leaving the host, the parasitoid larvae will weave a cocoon on the leaf and turn into a pupa, which hatches within a week. **Cotesia** are mainly larval endo-parasitoids. In Africa, *Cotesia icipe* is a newly described species that has exhibited up to 65% parasitism of FAW larvae in the laboratory. *C. icipe* was found to be the dominant larval parasitoid in Ethiopia with parasitism ranging from 34% to 45%.

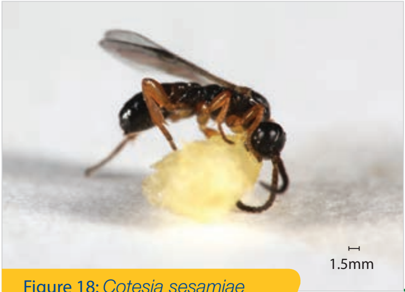


Figure 18: *Cotesia sesamiae*

Cotesia sesamiae

Cotesia sesamiae is an important native parasitoid of stemborers in many sub-Saharan countries. It attacks mid to late instars of the stemborer larvae (Figure 18). *Cotesia sesamiae* attacks several stemborer species including *S. calamistis*, *B. fusca*, *C. partellus* and **C. orichalcociliellus**.

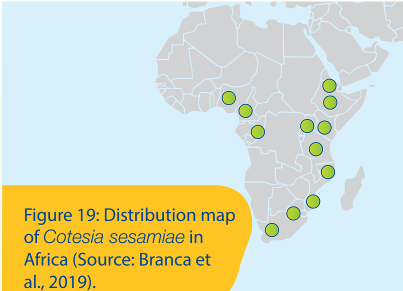


Figure 19: Distribution map of *Cotesia sesamiae* in Africa (Source: Branca et al., 2019).

Distribution of *Cotesia sesamiae* in Africa

Cotesia sesamiae is a common indigenous larval parasitoid that is widespread in various AEZs in Eastern, Southern, Central, and some countries of West Africa (Figure 19).

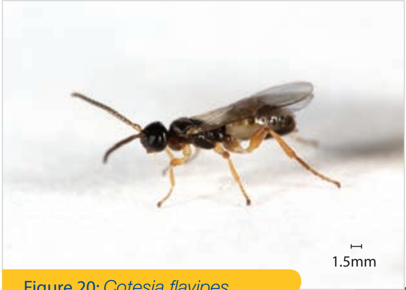


Figure 20: *Cotesia flavipes*

Cotesia flavipes

Cotesia flavipes came from Asia and was introduced into Africa as a classical biological control agent (Figure 20). It was released in 1993 by **icipe** for the control of *C. partellus*, the invasive exotic stemborer of maize and sorghum in Eastern and Southern African lowlands *C. flavipes* complements the activity of *C. sesamiae*.

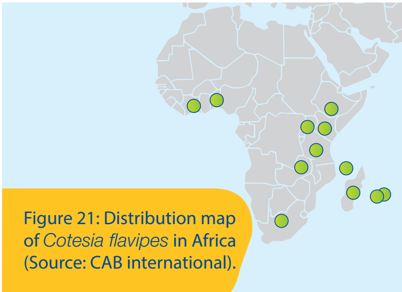


Figure 21: Distribution map of *Cotesia flavipes* in Africa (Source: CAB international).

Distribution of *Cotesia flavipes* in Africa

Since its release in 1993, this species has become well established in East and Southern Africa. It is also present in West Africa (Figure 21).

Advantages of biological control of stemborers in Africa:

- ✓ This is a particular strategy since whichever parasitoid is introduced; it will only control the population of the pest that they are meant to target. For example, *C. sesamiae* specifically controls *B. fusca* on maize, whereas *C. flavipes* specifically parasitizes *C. partellus* and not *B. fusca*.
- ✓ The natural enemies introduced to the environment are capable of sustaining themselves, often by reducing whichever pest population they are supposed to manage. This means that after the initial introduction, very little effort is required by the farmers to keep the system running fluidly. It also means that biological control can be kept in place for a much longer time than other methods of pest control, such as chemical controls.
- ✓ Biological control can be cost-effective and benefits smallholder production systems in Africa in the long run. Although it may be costly at the beginning to introduce a new species to an environment, it is a tactic that only needs to be applied once due to its self-perpetuating nature.
- ✓ Biological control has no environmental side effects since the natural enemies used are environmentally friendly.

Nevertheless, some disadvantages are known:

- × The introduced parasitoids can disappear or simply may not establish in their new environment. Moreover, while they are supposed to manage a specific pest, there is always a possibility or risk that the parasitoids will switch to a different non-target insect.
- × It is a slow process providing no immediate results as pesticides do. It can take a long time for the parasitoids to establish in any environment where they have been released. Nevertheless, the opposite of this is the long-term effect biological control provides.
- × If the farmers are looking to wipe out a pest completely, biological control may not be the right choice as the natural enemies can only survive if their host pest is still present; hence, eliminating the pest population would risk their survival. Therefore, they can only reduce the number of harmful pests.
- × While biological control is cheap in the long run, the process of actually setting up a biological control system is a costly endeavour; a lot of planning and money goes into developing a successful system (e.g. the biological control programme of icipe against *C. partellus* using *C. flavipes*).

Biopesticides

Figure 22: Biopesticide containing spores of *M. anisopliae*.

Biopesticides are naturally occurring beneficial microbes, such as fungi and bacteria, which have been isolated, tested and mass-produced as a crop protection agent. Two biopesticides - Mazao Achieve® (contains ICIPE 78 strain) and Mazao Detain® (contains ICIPE 7 strain) - have been found to be effective against immature stages of FAW. These biopesticides are composed of spores of *Metarhizium anisopliae*, an insect pathogenic fungus. Mazao Achieve and Mazao Tickoff had been commercialized for the control of diverse pests by icipe in partnership with Real IPM Ltd. Real IPM Ltd has embarked on "label-extension" to expand the use of these two biopesticides in the management of FAW in East Africa, and potentially across the continent.

In addition, **icipe** has identified other new and highly potent strains (ICIPE 41, ICIPE 655, and ICIPE 20) that are effective against various life stages of FAW.

Botanicals

Botanicals are plant extracts which are used to control insect pests. Examples of Botanicals are:

- Neem: Put a pinch of ground neem powder into the funnel of young plants. Neem is a feeding deterrent, a growth regulator and a repellent.
- Pepper: Make mixture of 50 grams of hot pepper and 2 kg of ash. Put a pinch of the mixture into the funnel of young plants. Alternatively, spray maize with extracts of black pepper.

Chemical control

The use of synthetic pesticides is highly discouraged for the control of FAW, stemborers and **Striga** because they are ineffective (e.g. FAW larvae are protected inside maize whorl), expensive and toxic to the environment and to human health.

Summary of Maize IPM technologies

Egg crushing and larvae picking

Figure 23: FAW egg mass on maize leaf

Description: Handpick and mechanically kill eggs and young larvae.

How it works: Fall armyworm eggs found on maize leaves are immediately crushed. Young larvae are picked off the leaves, before they penetrate deep into the whorl.

Impact:	Killing one FAW caterpillar prevents immediate crop damage and the appearance of more than 1,500 – 2,000 new caterpillars within less than four weeks.
Where it has been proven:	Africa, America
Cost:	Labour
References:	FAO and PPD, 2020; Harrison et al., 2019.

Sand or ash

Figure 24: Pouring ash into maize whorl

Description: Pour a handful of sand or a bottle top of ash into maize whorl.

How it works: Sand and ash irritate the soft-skinned FAW larvae, forcing them out of the whorl or directly killing them through suffocation.

Impact:	Reduced infestation
Where it has been proven:	Africa
Cost:	Labour
References:	Harrison et al., 2019; FAO, 2018.

Hand-pulling Striga

Figure 25: Farmers uprooting Striga in maize field

Description: Uproot **Striga** weed 2–3 weeks after they start to flower.

How it works: Prevents **Striga** from flowering, setting seed and dispersing seed. Hand-pulling needs to be continued for 3–4 years and is practical on low-infested fields.

Impact:	Reduced infestation
Where it has been proven:	Kenya
Cost:	Labour
References:	Ransom, 1996; Ransom and Odhiambo, 1994; Parker and Riches, 1993.

Mass trapping

Figure 26: Farmers examining FAW moths collected from a pheromone trap

Description: Place 5 pheromone traps per hectare to attract and capture FAW male moths.

How it works: If sufficient male moths can be captured, not all females will be able to find mates, thus reducing the number of fertilized eggs that are laid.

Impact:	Reduced pesticide
Where it has been proven:	Kenya, Uganda, Rwanda, and Burundi.
Cost:	USD 20
References:	Andrade et al., 2000.

Push-pull

Figure 27: Push-pull plot

Description: Desmodium (push crop) in between the rows of maize and plant Brachiaria or Napier grass (pull crop) along the borders of the maize plot.

How it works:	Chemicals produced by the roots of Desmodium suppress *Striga* weed by preventing development of haustoria. Desmodium controls FAW and repels stemborers from the maize while Brachiaria or Napier grass acts as a trap crop to pull stemborers to lay their eggs but does not support larval development. In addition, Desmodium fixes atmospheric nitrogen, adds soil organic matter, conserves soil moisture and enhances soil biodiversity, thereby improving soil fertility, which directly contributes to *Striga* control.
Impact:	Increased yield
Where it has been proven:	Kenya, Uganda, Tanzania, Ethiopia, Rwanda, Burundi, Zambia, Malawi, Togo, Senegal, Burkina Faso, Mozambique, Ghana, and Democratic Republic of Congo
Cost:	USD 120
References:	FAO and PPD, 2020; Harrison et al., 2019; Midega et al., 2018; Hailu et al., 2018; Khan et al., 2002.

Intercropping

Figure 28: Maize intercropped with cassava

Description: Plant rows of non-grass plants between the maize. Maize can be intercropped with legumes (e.g. pigeon pea, cowpea, common beans) or with root crops (e.g. cassava, sweet potatoes).

How it works:	Intercrops can reduce pest damage by (i) improving soil health and promoting vigorous plant growth through nitrogen fixation, (ii) inhibiting movement of larvae among plants, (iii) preventing female FAW moths from laying eggs, through visual or chemical disruption, and (iv) providing habitat for natural enemies.
Impact:	Reduced *S. hermonthica* incidence and increased maize grain yields.
Where it has been proven:	Africa
Cost:	Legume seed
References:	FAO and PPD, 2020; FAO and CABI, 2019; Harrison et al., 2019; Midega et al., 2018; Kanampiu et al., 2018; Hailu et al., 2018.

Food sources for predators

Figure 29: Ants on maize leaves

Description: Spray maize plants with 10–20% sugar solution or place fish soup in maize field, which are food sources for predators.

How it works:	Sugar solution on maize leaves attracts ants, solitary wasps, parasitoids and other natural enemies, while fish soup attracts ants. Ants are important natural predators of FAW larvae (Figure 29). They crawl up the plants, into the whorls, and eat FAW larvae. Wasps parasitize FAW and stemborers. Food sources enhance the activity of predators.

Impact:	35% less FAW leaf damage and 18% lower plant infestation rates
Where it has been proven:	Honduras, Latin America
Cost:	Labour
References:	Harrison et al., 2019; Bortolotto, 2014; Canas and O'Neil, 1998

Fertilization

Figure 30: Farmer examining compost heap

Description: Apply well-composted organic manure and inorganic fertilizers.

How it works:	Organic manure and inorganic fertilizers provide adequate and balanced plant nutrition. Fertilization enables plants to develop well before pest damage occurs. Healthy plants can also invest more in defence thereby increasing the likelihood of escaping serious damage.
Impact:	Yield loss due to stemborer damage decreased with an increase in nitrogen application. Manure application at 10 t ha^{-1} and N rates between 40 - 80 kg N ha^{-1} has increased maize and sorghum grain yield even under **Striga** pressure.
Where it has been proven:	Kenya, Ethiopia
Cost:	Fertilizer, manure and labour cost
References:	FAO and PPD, 2020; Harrison et al., 2019; Altieri and Nicholls, 2003; Esilaba et al., 2000; Ransom and Odhiambo, 1994; Mumera and Below, 1993; Chapin 1991.

Crop rotation

Figure 31: Cowpea plant

Description: Plant non-grass crops in subsequent seasons after the maize crop. Rotate maize with root crops such as cassava or with legumes such as groundnuts, soybeans or cowpea for minimum 3 years (Figure 31).

How it works: (i) The roots of legumes (cowpea, soya bean, pigeon pea, chickpea and groundnut) induce suicidal germination of **Striga** seeds residing in the soil, (ii) improve soil fertility through nitrogen fixation, and (iii) increases abundance of natural enemies and reduces pest and weed build up by interrupting their lifecycles.

Impact: Two-year rotation with non-host crop reduced **Striga** infestation by 50% in Ethiopia. Intercropping and rotation resulted in a lower incidence of *S. hermonthica* and better growth and yield of maize.

Where it has been proven: Africa

Cost: Opportunity cost

References: FAO and PPD, 2020; FAO and CABI, 2019; Harrison et al., 2019; Kanampiu et al., 2018; Hay-Roe et al., 2016; Meagher et al., 2016; De Groote et al., 2010.

Early planting

Figure 32: Well established maize plot

Description: Plant maize after the first effective rains or plant early maturing maize varieties.

How it works: Provides good growing conditions for maize. The crop will be established while the pest population is low, hence escaping important phase of stemborers and FAW impact.

Impact:	Increased yield. Larval population density of *B. fusca* on early-planted maize crop was less than on late-planted crop.
Where it has been proven:	Kenya
Cost:	Labour
References:	FAO and PPD, 2020; Goftishu et al., 2017; Thierfelder et al., 2016.

Field sanitation

Figure 33: Weed maize 3 weeks after planting

Description: Remove volunteer plants or alternative host plants from the field.

How it works: Weeding reduces competition for nutrients by weeds, some of which are alternate hosts of stemborers (provide shelter and food for the pest). It limits the initial establishment of stemborers that would infest the next crop.

Impact:	Reduced infestation
Where it has been proven:	Africa
Cost:	Labour
References:	Harrison et al., 2019.

Crop residue management

Figure 34: Cow feeding on maize stalks.

Description: Promptly cut and spread maize stalks on the soil surface as mulch or plough them into the soil or use as fodder or to make compost.

How it works: The suns' heat and heat generated during composting kills stemborer larvae, which limits the carryover of dipausing stemborer larvae in the next season. Post harvest tillage reduces stemborer populations through mechanical damage, either by burying them deeply into the soil, or by breaking the stems and exposing the larvae to adverse weather conditions as well as birds, rodents, ants, spiders, and other natural enemies. Use of maize stalks as mulch enhances soil biological activity, increases soil organic carbon, and thus supports improved plant growth. Mulch also provides habitat for natural enemies.

Impact: Keeping infested maize stalk in the sun for four weeks effectively reduced the carryover population of *B. fusca* by 95%. Prompt cutting of maize stalk and laying them out in the sun caused 97% mortality of stemborers in maize and 100% mortality in sorghum in Ethiopia.

Where it has been proven: Kenya, Uganda, Tanzania, Ethiopia, Rwanda, Burundi, Zambia, Malawi, Togo, Senegal, Burkina Faso, Mozambique, Ghana, and Democratic Republic of Congo

Cost: Labour

References: Goftishu et al., 2017; Mashwani et al., 2015; Dejen, 2004; Ebenebe et al., 2001; Youm et al., 1993; Ajayi, 1998; Seshu, 1988.

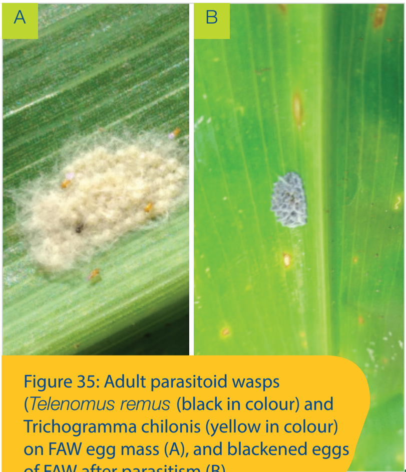


Figure 35: Adult parasitoid wasps (*Telenomus remus* (black in colour) and Trichogramma chilonis (yellow in colour) on FAW egg mass (A), and blackened eggs of FAW after parasitism (B)

Description: Release of larval parasitoids (C. sesamiae and *C. flavipes*) to control stemborers, *C. icipe* to control FAW, and release of egg parasitoids (*T. remus* and T. chilonis) to control FAW.

How it works:	Adult moths of egg parasitoid wasps (Trichogramma or Telenomus) lay their eggs inside the eggs of FAW, which prevents FAW eggs from hatching. Adult moths of larval parasitoid wasps (Cotesia) deposit multiple eggs in the body of stemborers or FAW larvae. After about three days the parasitoid larva emerges; it feeds inside the body tissue of stemborers or FAW. Soon after leaving the host, the parasitoid larvae will weave a cocoon on the leaf and turn into a pupa, which hatches within a week. *Cotesia icipe* attacks mid to late instars of the FAW larvae.
Impact:	Releases of *C. sesamiae* and *C. flavipes* caused a 70% decrease in stemborer densities in Kenya. In Ethiopia, *C. icipe* had over 37% parasitism rate. Releases of *T. remus* in maize fields resulted in 90% parasitism in Venezuela.
Where it has been proven:	Brazil, Ethiopia, Kenya, Malawi, Mozambique, Niger, Somalia, Tanzania, Uganda, Venezuela, Zambia, Zanzibar, and Zimbabwe.
Cost:	Rearing cost
References:	Calatayud et al., 2020; Tefara et al., 2019.

Biopesticide

Figure 36: Biopesticide containing spores of *M. anisopliae*

Description: Spray maize crop with biopesticide containing *M. anisopliae*, an insect killing fungus

How it works: The fungi infects FAW larva through the body and kills it due to destruction of tissues and by production of toxins. Diseased insects stop feeding and eventually die.

Impact:	Reduced infestation of FAW
Where it has been proven:	Kenya, Uganda, and Tanzania.
Cost:	USD 20 per litre
References:	FAO and CABI, 2019.

Botanicals

Figure 37: Neem seed

Description: Use extracts from neem or pepper. Put a pinch of ground neem powder (4 g) per plant into the funnel of young plants, or make a mixture of ground neem seed and sawdust (1:1) and apply as granules at weekly and biweekly intervals (Figure 40). Mix 50 g of hot pepper and 2 kg of ash. Put a pinch of the mixture per funnel when maize is knee-high or spray maize will black pepper extract.

How it works:	Neem has repellent action and deters pest feeding. Chili causes death of larvae.
Impact:	Effectively controlled *B. fusca* in Tanzania. 40% reduced infestation in maize by *C. partellus*. Neem seed powder caused over 70% mortality of FAW larvae in laboratory studies. Black pepper caused over 90% FAW larval mortality.
Where it has been proven:	Cameroon, Ghana, Kenya, Somalia, and Zambia.
Cost:	Labour
References:	Tanyi et al., 2020; FAO and CABI, 2019; Hellpap, C. 1995.

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Glossary

Biopesticide: a type of pesticide derived from natural materials such as fungi, bacteria, viruses, nematodes and plant-derived chemical compounds.

Dead heart: death of young leaves within maize whorl caused by stemborer damage.

Frass: droppings or waste left by feeding insects.

Habitat: natural environment in which a particular species of organism lives. A species habitat is those places where the species can find food, shelter, protection and mates for reproduction.

Instars: Insect form between successive moults.

Larva (plural larvae): immature stages of an insect, often worm-like in appearance.

Natural enemies: living organisms that feed on crop pest.

Necrosis: death of a plant part.

Parasitoid: an organism that gains nutrients and resources from a host and ends up killing or sterilizing the host in the process.

Pathogens: disease-causing organisms, including viruses, bacteria, and fungi that kill or debilitate their hosts. They are usually specific to certain insects.

Pest: any harmful, noxious, or troublesome organism. Pests include weeds, insects, fungi, bacteria, viruses, rodents, other plants or animals.

Pesticide: an agrochemical that is used for crop protection to prevent, destroy, repel or control pests such as insects, diseases and weeds.

Pheromones: chemicals secreted by an organism to attract individuals of the opposite sex of the same species for mating.

Pupa (plural pupae): the stage of development between larva and adult in the life cycle of some insects (for example moths and flies). Pupae usually have hard skin and do not move or feed.

Pupation: process that occurs when larva develops to pupa.

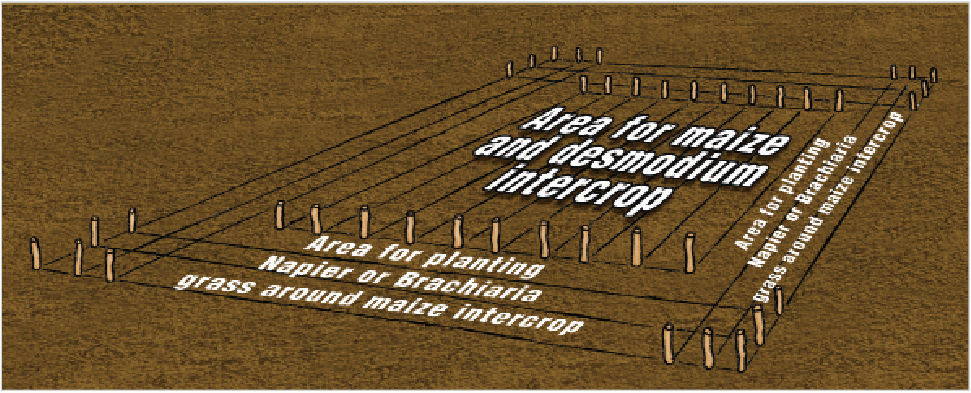
Resistance: a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a pesticide to achieve the expected level of control when used according to the label recommendation for that pest species.

Annexe 1: Farmers' guide on how to establish a Push-pull plot

Push-pull is a cropping system where cereals are intercropped with Desmodium legume and the plot surrounded by a Napier or Brachiaria grass border, to control **Striga** weed, stemborers and Fall armyworm pests. Desmodium planted between the rows of maize repel stemborers (Push) and controls Fall armyworm and parasitic **Striga** weed, while the border grasses attracts (Pull) the stemborer moths to lay their eggs but do not support larval development, hence controlling the pest population naturally.

How to plant Push-pull

> Step 1: Land preparation



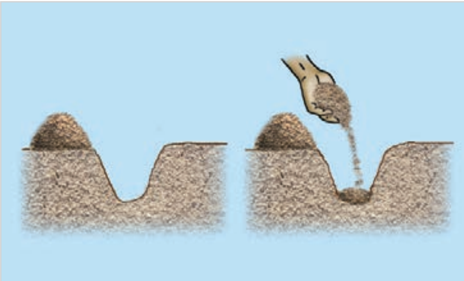
- Clear your land during the dry season.
- Plough and harrow your land to fine soil particles before the onset of the rains. Desmodium has very small seed; therefore, the soil should be carefully prepared.
- Using pegs and strings, measure the first plot 30 m x 30 m. A Push-pull plot can however, be as small as 20 m X 20 m.
- Demarcate the plot by putting pegs at the opposite sides of the field at intervals of 75 cm each.

> Step 2: Planting

2.1. Planting Brachiaria grass or Napier grass

A. Planting Brachiaria grass

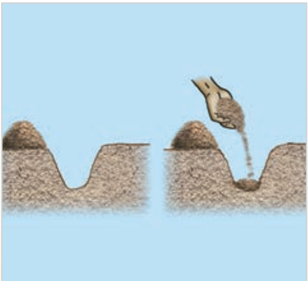
- Plant Brachiaria grass on the border, all-around the maize plot. A minimum of 2 rows of the grass is recommended, although you can plant more rows depending on the size of your land and the number of animals you want to feed from the Push-pull fodder.
- The spacing should be 75 cm between rows and 75 cm between plants within a row. Brachiaria can be planted using root splits or seed.



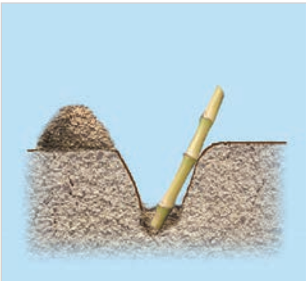
Dig holes along the demarcated lines. Apply two hand-fulls of well-decomposed farmyard manure in each hole.

Place Brachiaria root splits upright into the planting holes and cover with soil.

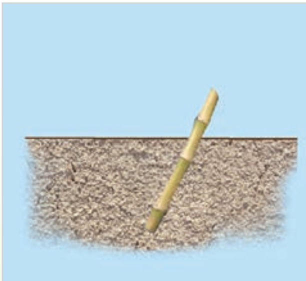
B. Planting Napier grass



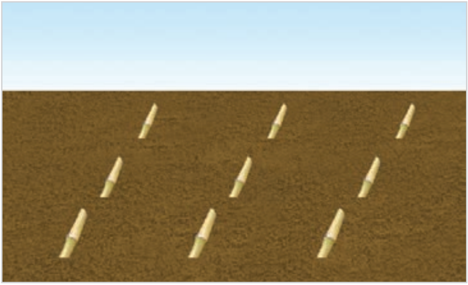
Dig holes along the demarcated lines. Apply one teaspoon of Triple Super Phosphate or 2 hand-fulls of well-decomposed farmyard manure in each hole.



Place a three-node cane into each hole at an angle of 30^{0}C -40^{0}C, all facing one direction.



Cover with soil ensuring that two nodes of the cane are well covered.



Ensure that rows are 75 cm apart and 75 cm between the plants within the rows.

If you are using root splits, place them upright into the planting holes and cover with soil.

2.2. Planting Desmodium

- Desmodium can be planted using root splits or seed.
- Desmodium should be planted in such a way that its rows alternate with maize rows (i.e. they should not be on the same row with maize) so that ploughing of the field in the next season will be easy
- Desmodium is drilled in between maize rows at a 75 cm row-to-row distance
- Using a strong pointed stick, make a furrow 1-2 cm deep in the middle of the rows where maize will be planted.
- Mix the Desmodium seeds with sand at a ratio of 1 part of Desmodium to three parts of fine sand.
- Drill the seeds into the furrows you made and cover with light amount of soil.
- Plant Desmodium on both sides of the outer rows of maize (start with Desmodium on the 1st line and finish with Desmodium on the last line); for maximum germination, plant Desmodium with the rains.
- One kilogram (1 kg) of Desmodium seed is needed for 1 acre of land.

2.3. Planting maize

- Plant your maize in the field already surrounded by Brachiaria or Napier grass.
- Plant maize in between the rows of Desmodium.
- The recommended spacing for maize is 75 cm between rows and 30 cm between hills in a row.
- Apply one teaspoonful of triple superphosphate or two teaspoonfuls of single superphosphate per hole.
- Two handfuls of well-decomposed farmyard manure is recommended where fertilizer is not available.

A well-established Push-pull plot after 5 weeks.

> Step 3: Weeding

Weeding and crop management

- Early weeding is very important for the successful establishment of a Push-pull plot.
- Carry out the first weeding when maize is 3 weeks old or as soon as the weeds emerge. The second weeding should be done when maize is 5 weeks old.
- Hand weeding of Desmodium during its initial stages of growth is recommended. It is important to distinguish between Desmodium and weeds to avoid accidental uprooting of Desmodium seedlings with weeds.

Annexe 2: Technology profile template for Maize IPM

Technology name & Brief description	Owner of the technology	Location where the technology was proven	Number of people used to prove the technology	Results at the test sites of the technology	Success factors obtained from the technology	Cost of the technology	Recommendations	List of value chains suited for the technology application
Push-pull technology (Desmodium [intercrop-push component and Brachiaria or Napier grass border crop pull component] as companion crops with cereal crops such as maize, sorghum and millet.	icipe	Burkina Faso, Ghana, Nigeria, Mozambique, Burundi, Democratic Republic of Congo Kenya, Uganda, Tanzania, Ethiopia, Rwanda, Burundi Senegal, Togo, Zambia, Malawi, Zimbabwe.	241,000	Increased maize yield. Reduced **Striga** and stemborer infestation. Reduced FAW infestation.	Control of maize stem borers, FAW and Striga weed. Increased yields, increased fodder production and enhanced soil fertility.	Direct production costs: land tillage, cereal seeds, Desmodium seeds, Brachiaria seeds and weeding is 120 USD	Need to strengthen supply chains for Desmodium and Brachiaria seeds.	Cereals Vegetable Dairy Pig Rabbit Poultry
Parasitoids (Mass rearing and release of parasitoid wasps such as *C. sesamiae*, *C. flavipes*, *C. icipe*, *T. remus* and **T. chilonis**)	icipe and partners	Ethiopia, Kenya, Malawi, Mozambique, Somalia Tanzania, Uganda, Zambia, Zanzibar, Zimbabwe.		Reduction of stemborer densities. Reduction of FAW damage.	It is specific to target pest.	Cost of establishment of mass-production facilities; rearing parasitoids and rearing hosts.	Conserve parasitoids by habitat management or by avoiding use of synthetic chemicals.	Cereals Legumes Vegetables Fruits Flowers

Technology name & Brief description	Owner of the technology	Location where the technology was proven	Number of people used to prove the technology	Results at the test sites of the technology	Success factors obtained from the technology	Cost of the technology	Recommendations	List of value chains suited for the technology application
Biopesticides (Spray maize crop with biopesticide containing *M. anisopliae*)	icipe and Real IPM	Kenya Tanzania Uganda		Reduction of FAW damage.	Biopesticides are environmentally friendly and easy to apply.	Direct cost is USD 20 per Litre.	Effectiveness of spray depends on the fungal spores coming into contact with the pest.	Cereals Legumes Vegetables Fruits Flowers
Monitoring and mass trapping (Use of pheromone traps to attract and kill moths)		Burundi Kenya Rwanda Uganda		Early detection of pest	Communities are empowered to monitor and report FAW damage.	Direct cost for 5 pheromone traps is USD 20 per Ha per month.	Requires area-wide coordination and implementation.	Cereals Legumes Vegetables Fruits Flowers

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icipe – Working in Africa for Africa…

International Centre of Insect Physiology and Ecology (**icipe**) – was established in 1970 in direct response to the need for alternative and environmentally-friendly pest and vector management strategies. Headquartered in Nairobi, Kenya, **icipe** is mandated to conduct research and develop methods that are effective, selective, non-polluting, non-resistance inducing, and which are affordable to resource-limited rural and urban communities. **icipe**'s mandate further extends to the conservation and utilisation of the rich insect biodiversity found in Africa.

icipe contributes to sustainable food security in Africa through the development of integrated pest management systems for major agricultural and horticultural crops. Such strategies include biological control and use of behaviour-modifying and arthropod-active botanicals. **icipe** puts emphasis on control approaches that have no detrimental impact on the environment. These options are always designed to fit the needs of the farmers and are developed on-farm and with farmers' participation. In addition to fruit flies, other key areas of **icipe**'s research include pests of tomato, brassicas, beans, and staple food crops such as maize and sorghum.

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Internet - Figure 12: **Striga** lifecycle (page 14), Figure 37: Neem seed (page 36)
Charles Muchora (BvAT) - Figure 28: Maize intercropped with cassava (page 30), Figure 30: Farmer examining compost heap (page 31), Figure 31: Cowpea plant (page 32), Figure 32: Well established maize plot (page 33), Figure 34: Cow feeding on maize stalks (page 34)

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