TRAINING MANUAL ON FALL ARMYWORM

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PREFACE
Sustainable agriculture and natural resources management is of major social and economic importance in the countries of the SADC region. The region has the potential to be food secure and support a vibrant economy based on intra and inter regional trade. However Food security, livelihoods, trade and national economies of these countries continue to be threatened by the emergence of invasive plant pests which constrain. In 2016 the Fall Armyworm was reported for the first time causing damage to crops on the African continent. The pest is known to have devastating effects on crops, particularly maize a staple food crop in Southern Africa, resulting in major yield losses. Following the outbreak of Fall Armyworm, The Food and Agriculture Organization of the United Nations (FAO) has been given the role of coordinating a response to the menace for Southern Africa and the whole of the African continent. A number of technical consultative meetings have been held to address this challenge. Limited knowledge about the pest, poorly developed surveillance and monitoring systems and limited information on management options have been identified as specific gaps in SADC countries. Gaps in relation to data collection tools for field assessments of Fall Armyworm and assessments related to socio-economic impact of the pest have also been identified. In an effort to address these gaps and enhance capacity of national staff to manage the pest, FAO and its partners held a Fall Armyworm Regional Training Workshop for SADC countries in Pretoria, South Africa from 26 to 30 June 2017. This training manual has been compiled from material used during the workshop and includes standard guidelines that have been developed, field tested and adapted for monitoring and assessing impact of the pest in the region.

FAO would like to acknowledge the contribution of partners and resource experts in the production of this manual, and hopes that it shall contribute to a better understanding of Fall Armyworm and enhance capacity of plant protection practitioners in the region to develop comprehensive management strategies.
ACKNOWLEDGEMENTS

We would like to express sincere gratitude to the Food and Agriculture Organization of the United Nations Sub-regional Office for Southern Africa Resilience Hub for southern Africa (FAO SFS REOSA) and the Agricultural Research Council (ARC) of South Africa for organizing and hosting the Regional Fall Armyworm Training of Trainers Workshop. Funding for the workshop and for preparation of this manual was provided by FAO and it is greatly appreciated.

This publication has been compiled from material that was presented during the Training of Trainers workshop held in Pretoria, South Africa from 26 to 30 June, 2017. The support provided by the following organizations is greatly appreciated:

USAID; CIMMYT; CABI; ARC; Crop Watch; The University of Zimbabwe; Crop Life and IRLCO-CSA.

We would like to thank all resource people for their invaluable input and tireless commitment right through the workshop process. The active participation and constructive feedback from workshop participants was commendable and greatly enriched discussions.

The editors of this manual do not claim to be originators of the material used in its compilation. Main sources of information are quoted and all publications contained in them are acknowledged. Where images used are from the published work of other scientists their contributions are gratefully acknowledged.
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<th>Acronym</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AGRRA</td>
<td>Alliance for a Green Revolution in Africa</td>
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<tr>
<td>ARC</td>
<td>Agricultural Research Council</td>
<td></td>
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<tr>
<td>AAW</td>
<td>African Armyworm</td>
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<tr>
<td>BT</td>
<td><em>Bacillus thuringiensis</em></td>
<td></td>
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<tr>
<td>CA</td>
<td>Conservation Agriculture</td>
<td></td>
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<tr>
<td>CABI</td>
<td>Center for Agriculture and Biosciences</td>
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<tr>
<td>CBAMFEW</td>
<td>Community Based Armyworm Monitoring,</td>
<td>Forecasting and Early Warning</td>
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<tr>
<td>CBC</td>
<td>Conservation Biological Control</td>
<td></td>
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<tr>
<td>CIMMYT</td>
<td>International Maize and Wheat Improvement</td>
<td>Center</td>
</tr>
<tr>
<td>Cry</td>
<td>Crystal a-endotoxin</td>
<td></td>
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<tr>
<td>Cyt</td>
<td>Cytolysins</td>
<td></td>
</tr>
<tr>
<td>DBM</td>
<td>Diamond Back Moth</td>
<td></td>
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<tr>
<td>DMU</td>
<td>Disaster Management Unit</td>
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<tr>
<td>DNA</td>
<td>Deoxyribonucleic Acid</td>
<td></td>
</tr>
<tr>
<td>EPs</td>
<td>Entomopathogens</td>
<td></td>
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<tr>
<td>EtOH</td>
<td>Ethanol</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the</td>
<td>United Nations</td>
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<td>FAW</td>
<td>Fall Armyworm</td>
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<tr>
<td>FFS</td>
<td>Farmer Field Schools</td>
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<tr>
<td>GM</td>
<td>Genetically modified</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>GV</td>
<td>Granulovirus</td>
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<tr>
<td>HPR</td>
<td>Host Plant Resistance</td>
<td></td>
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<tr>
<td>IITA</td>
<td>International Institute of Tropical</td>
<td>Agriculture</td>
</tr>
<tr>
<td>IPM</td>
<td>Integrated Pest Management</td>
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<tr>
<td>IPPC</td>
<td>International Plant Protection Convention</td>
<td></td>
</tr>
<tr>
<td>IRLCO-CSA</td>
<td>International Red Locust Control Organization for Central and Southern Africa</td>
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<tr>
<td>LC50</td>
<td>Lethal Concentration 50</td>
<td></td>
</tr>
<tr>
<td>LT50</td>
<td>Lethal Time 50</td>
<td></td>
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<tr>
<td>NARS</td>
<td>National Agriculture Research Systems</td>
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<tr>
<td>NMD</td>
<td>Numerical Medium Diameter</td>
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<tr>
<td>NPPO</td>
<td>National Plant Protection Organization</td>
<td></td>
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<tr>
<td>NPV</td>
<td>Nucleopolyhedroviruses</td>
<td></td>
</tr>
<tr>
<td>OBs</td>
<td>Occlusion bodies</td>
<td></td>
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<tr>
<td>PPDs</td>
<td>Plant Protection Departments</td>
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<tr>
<td>PPE</td>
<td>Personal Protective Equipment</td>
<td></td>
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<tr>
<td>QTL</td>
<td>Quantitative Trait Locus</td>
<td></td>
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<tr>
<td>REOSA</td>
<td>Resilience Hub for Southern Africa</td>
<td></td>
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<tr>
<td>RVF</td>
<td>Rift Valley Fever</td>
<td></td>
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<tr>
<td>SADC</td>
<td>Southern African Development Community</td>
<td></td>
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<tr>
<td>SFS</td>
<td>Sub-regional office for Southern Africa</td>
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<tr>
<td>SSA</td>
<td>Sub-Saharan Africa</td>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
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BACKGROUND

The Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) (Insecta: Lepidoptera: Noctuidae) is a devastating pest of maize that is native to tropical and subtropical regions of the western hemisphere from the United States of America to Argentina. The scientific name is derived from the feeding habits of the larval life stage, *frugiperda* meaning “lost fruit” in Latin, as the pest can cause damage to crops resulting in severe yield loss. Fall Armyworm (FAW) was reported for the first time on the African continent in early 2016. Initial reports were from West Africa: Nigeria, Benin, Togo and Sao Tome’ and Principe (IPPC, 2016; IITA, 2016). By May 2017 the pest had spread to 14 East and Central African countries and 11 out of the 15 countries of the Southern African Development Community (SADC) region. Currently (July 2017) all SADC states with the exception of Lesotho and the Island states have reported presence of the pest. Although FAW shows a definite preference for the Poaceae it displays a wide host range attacking over 80 different plant species including major crops such as cotton, groundnuts, sorghum, wheat, potatoes, soybean and sugarcane. A number of fruit trees, ornamental plants and weed species are also hosts to the pest. Its polyphagous nature presents challenges in management due to the presence of numerous alternative hosts outside the production season of main crops.

*S. frugiperda* is a transboundary pest therefore its appearance in some countries Africa raises the level of threat to other regions of the continent not yet infested and other tropical and subtropical regions of the world. Outbreaks of this pest can have devastating effects on the economies, trade, and food and nutrition security of whole regions. According to a report on the FAW consultative meeting held in Nairobi, Kenya in April 2017 there is anecdotal evidence that Sanitary and Phytosanitary measures may be causing Non-Tariff Barriers in trade with affected countries, which will have negative effects on trade volumes and income earned. Yield losses of over 70% have been recorded (Hruska and Gould, 1997) and in Africa *S. frugiperda* appears to cause more damage to maize in West and Central Africa than most other African Spodoptera species (IITA, 2016). So far losses due to confirmed and suspected infestations of FAW in maize, sorghum, rice and sugarcane in African countries have been estimated at USD13.38
billion (CABI, 2017). Loss of yields of major food crops will have dire consequences on livelihoods of people in affected regions of Africa. There is urgent need for a coordinated regional approach and cross boundary cooperation in surveillance and monitoring, diagnostics, epidemiology, containment and management in order to combat the menace caused by this emergency plant health matter.

The FAO together with its development partners has formulated a multipronged approach to manage FAW in the continent. In February 2017 FAO in collaboration with the Southern Africa Development Community (SADC) and the International Red Locust Control Organization for Central and Southern Africa (IRLCO-CSA) held a consultative meeting in Harare with governments and stakeholders to address pest awareness, emergency preparedness and rapid response to the pest. Following this further meetings have been held to provide an update on the status of the pest on the continent and to foster a coordinated response to the pest including a review of technical guidelines; discussions on ways to improve emergency detection; and technological options for its effective management.

Strategic partners at an all Africa consultative meeting convened in April 2017 by FAO together with the Alliance for a Green Revolution in Africa (AGRA) and the International Maize and Wheat Improvement Center (CIMMYT) decided that FAO should take the leading role in coordination of the response to FAW in Africa. In line with this FAO is formulating a region-wide Integrated FAW Management Program for the sustainable management of the FAW which will address socio-economic aspects and impacts of the pest on livelihoods and regional food security. FAO is also formulating and supporting various actions for monitoring and assessing the impact of FAW in Southern Africa and the African continent at large in
cooperation with CIMMYT and CABI. Together with CABI, FAO have produced technical extension leaflets on FAW management decisions for use by farmers and agricultural extension workers.

With support from FAO the development of surveillance systems to enable early warning and preparedness is ongoing in some countries; protocols for identification of the pest, conducting of surveys and research trials and damage assessments have been reviewed; research on management options including effective use of pheromone lures and efficacy trials for synthetic and bio pesticides is also in progress. Challenges of inadequate human, infrastructure and financial capacities for identification and management of the pest resulting in misidentification of the pest; incorrect use of synthetic pesticides; lack of regular surveillance and robust early warning systems leading to slow reporting of infestations; lack of data on yield losses due to FAW in some countries; and the need for improved information sharing between sectors and among countries in the region were identified during a technical meeting on FAW for Southern Africa that was held in Nairobi in April 2017. Some immediate actions that emerged from discussions at the all Africa consultative meeting in Kenya were

- The need to compile all available information on the efficacy of different FAW management options and package it appropriately for target audiences in sub-regions of Africa.
- The need to establish a Community of Practice for effective and quick communication to facilitate learning and sharing of information between institutions and across borders for the coordinated management of FAW.
- The need to set up a Fall Armyworm Information Portal, similar to the Armyworm Network Information Portal, which will become a one-stop window for information on the status, management options, research findings and publications on the pest.

Against this background FAO in collaboration with the Agricultural Research Council (ARC) of South Africa convened a FAW training workshop for all SADC countries in Pretoria from 26 to 30 June 2017 with the objective to increase knowledge and skills in these critical areas. The workshop fulfilled some specific actions at sub-regional level that were formulated by FAO and its partners in response to the FAW outbreak.

A FAW training manual has been prepared in response to the gaps in information and knowledge capacity that have been identified in previous meetings. The manual which covers the identification of *S. frugiperda*, pest surveillance and monitoring, assessment tools for FAW and available management options has been compiled from material used in the regional Training of Trainers workshop and additional extension material that has been made available by partner organizations. This manual will be of immediate use in informing staff of NPPOs including extension staff and researchers, regulatory staff, people working in DMUs and other stakeholders to better understand the FAW and develop effective strategies to manage the pest. FAO also contracted Crop Watch Africa, a service provider, to train workshop participants in collection and entry of standardized national surveillance data which shall be used to set up an online regional surveillance grid.

References


Report on Stakeholders Consultation Meeting on: Fall Armyworm in Africa: Status and Strategy for Effective Management. Meeting held in Nairobi, Kenya on 27th and 28th April 2017. Report prepared by Rose Njeru, PhD
INTRODUCTION TO THE MANUAL

This training manual provides information on the identification, biology, lifecycle, and management options of the FAW, particular reference being paid to those options that are available for use by countries within the Southern African region. The manual also provides information on surveillance and assessment tools that have been adapted for use by countries in the region. The publication is arranged in four modules which make use of descriptive notes, color photographs and practical exercises to enhance learning. Material contained in the manual is compiled from presentations given at the Regional FAW Training of Trainers Workshop held in Pretoria South Africa from 26 to 30 June 2017. Publications used in the preparation of this manual are listed and provide readers the opportunity to obtain more detailed information about specific topics. Additional resources including pamphlets and technical extension leaflets developed by FAO and its partners are included as annexes to the manual.

The Training Manual on Identification, Surveillance, Assessment and Management of Fall Armyworm has been produced primarily for.

We hope that this manual will be a valuable tool that will provide useful information for staff of National Plant Protection Organizations (NPPO’s), National Agricultural Research Systems (NARS), extension departments and departments for disaster management in Southern Africa. The manual will also be a useful resource for other countries in Africa to which the FAW has spread and to countries at risk.

The information presented in this publication is the sole responsibility of the authors and any views expressed do not necessarily reflect those of the FAO.
TRAINING MODULES
1. IDENTIFICATION OF FALL ARMYWORM

FAW is a new pest in the African continent and correct identification has been a challenge, with the pest being misidentified and confused with other caterpillar species. This module provides a guide to identification of *S. frugiperda* using morphological characteristics and highlights features that can be used to distinguish it from other common caterpillars encountered in Africa. Evidence based primarily on host plant preference indicates the presence of strains of the fall armyworm, with one strain feeding principally on corn and a few other hosts and the other strain feeding principally on rice. The two strains are morphologically identical and can only be reliably distinguished by molecular methods. This guide will enable trainees to make a preliminary morphological identification of the pest pending confirmation through the use of molecular methods. Practical guidance is provided on collection and preservation of samples for onward transmission to experts for confirmation of species identification.

1.1. Morphological Identification

**AIM**

Incorrect identification of the fall armyworm (*Spodoptera frugiperda*), as well as incorrect reporting of feeding on uncommon hosts, are usually due to the lack of good visual reference material. This section aims to address this shortcoming, and it is hoped that the information and visuals contained herein will assist workers in the field to improve their ability to do preliminary identifications, not only of the fall
armyworm, but also identifications of other common caterpillars on crops in South Africa. However, final and conclusive identifications should always be performed by the experts.

Common caterpillars on crops in South Africa

The following caterpillars may be found in most parts of South Africa, and should therefore be considered when scouting various crops for the fall armyworm. See relevant slides for descriptions of stages and feeding locations.

<table>
<thead>
<tr>
<th>Caterpillar pest</th>
<th>Crops attacked or affected</th>
</tr>
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<tbody>
<tr>
<td>1. Fall armyworm</td>
<td>Mostly maize and sorghum</td>
</tr>
<tr>
<td>2. African bollworm</td>
<td>Most crops</td>
</tr>
<tr>
<td>3. Tomato moth caterpillar</td>
<td>Many crops, especially vegetables</td>
</tr>
<tr>
<td>4. Lesser armyworm</td>
<td>Mostly vegetables</td>
</tr>
<tr>
<td>5. African armyworm</td>
<td>Mostly grasses and maize</td>
</tr>
<tr>
<td>6. Semi-loopers</td>
<td>Many crops, especially vegetables</td>
</tr>
<tr>
<td>7. Cutworms</td>
<td>Many crops, mainly a soil pest</td>
</tr>
<tr>
<td>8. False armyworm</td>
<td>Mostly maize and barley</td>
</tr>
<tr>
<td>9. <em>Chilo</em> borer</td>
<td>Mostly maize</td>
</tr>
<tr>
<td>10. African maize stem borer</td>
<td>Mostly maize</td>
</tr>
</tbody>
</table>

Additional caterpillars can be found on various crops, some specific to certain crops. The caterpillars listed above are all approximately the same size. Some of these species may be found on the same crops and on the same plants.

Stages of the fall armyworm that will be illustrated

Moths
Signs of infestation (egg masses)
Signs of infestation (1st instars)
Signs of infestation (larger caterpillars and moths)
Characteristic marks on caterpillars
Small caterpillars
Large caterpillars
Pupae
Fall armyworm moths are active during the evening and hide during the day. They are sometimes found hiding between maize leaves or in whorls. Male moths find females by following pheromones released by the females. Mating takes place and eggs are laid in masses, two or three days later.
FAW: first signs of infestation (a) egg masses

Eggs are laid in masses on leaves, mostly on the underside, but also on the upper side and on stems. Females can deposit eggs in more than one layer before they are covered by anal hairs of the moth. Egg masses without hair covers may also be encountered. Eggs may be cream-coloured, green or brown, but the whitish colour of the hair covers is easily observed on the green leaves. The presence of egg masses plays an important role in the scouting process.

FAW: first signs of infestation (b) first instars

The first signs of infestation is most often feeding marks by first instars. They only feed superficially on one side of the leaf. Young fall armyworm caterpillars use ballooning (spreading by wind on a thread of silk) to spread to new host plants. One fall armyworm egg batch contains too many eggs for one plant, and ballooning nearly always occurs soon after hatching. Ballooning is one of the reasons why infestation levels of a field can reach 100%, and also why unrelated crops nearby can seemingly be attacked – the small airborne caterpillars have no control on what plants or crops they land on.
FAW: signs of infestation at a later stage

Fall armyworm infestations often are only noted at a later stage, when large holes, accompanied by larval droppings (excrement), are noticed in the whorls and on surrounding leaves. When dry, the excrement takes on a very characteristic appearance, that of sawdust. The caterpillars usually hide deep in the whorl while the excrement they produce serves as a protective barrier which also helps to camouflage them from predators from above.

Detection of FAW caterpillars and moths

Caterpillars are usually found in whorls of young maize plants. On mature plants they may infest ears, where they feed on soft tissue like kernels, soft inner leaves, and silk hairs. They rarely feed on older mature leaves. Moths hide in debris or in other secluded places on the ground, as well as in whorls.
FAW: characteristic marks on caterpillars

Larger caterpillars may contain characteristic marks and spots. Marks that are often used for identification include the upside Y mark on the head region and the four larger spots on the second last segment. The most common lines and spots are indicated above. Note: variations from the illustrations above may be encountered, and other non-related caterpillars may show similar marks and spots, although usually not as vividly as in the fall armyworm.

FAW: young larvae – length 6-9 mm

Top view

Small fall armyworm caterpillars are mostly lighter in colour compared to the older or larger individuals. Green and/or yellow colours are common. These lighter colours not only camouflage the larvae on the green leaves, but also may lead to confusion with other pests. The heads may be black or orange, and the spots on the body may not always be equally clear or apparent. Marks on the head may not be easy to observe on small caterpillars.
FAW: young larvae – length 6-9 mm

The lateral bands are not yet clear on small caterpillars, compared to larger individuals. The colour of small individuals may include green, yellow, brown and black, but mostly greenish/yellowish. A pinkish tint is common on the sides of young individuals. The hairs and bumps are more pronounced on small individuals, similar to all stages of the bollworm. Some may walk with an action similar to the semi-loopers (but not as pronounced).

FAW: mature larvae – length 30-36 mm

The colour of fall armyworms in the late stages is mostly brownish, but may include variations of light to dark brown as well as greenish to blackish. Darker individuals appear when overcrowding occurs. The spots on the body are not always equally clear or apparent.
FAW: mature larvae – length 30-36 mm

Side view

The lower lateral sides of the fall armyworm are usually lighter in colour, with a brown or black band just above the light band. The general appearance is brown, although blackish or greenish individuals may be encountered. The head may be black, brown or orange. Larger caterpillars never walk with a looping action.

FAW: pupae, soil cells and cocoons

Pupae of the fall armyworm are usually found in the soil and are therefore not frequently encountered. They do, however, sometimes pupate on the plant, e.g. when feeding in the ears. The mature caterpillar drops to the ground, burrows shallowly into the soil and makes an earthen cell by constructing a flimsy cocoon into which sand particles are incorporated. Pupae are approximately 15 mm in length and the earthen cells 20 to 25 mm.
The following caterpillars will be illustrated

African bollworm
Tomato moth caterpillar
Lesser armyworm
African armyworm
Semi-loopers
Cutworms
False armyworm
_Chilo_ borer
Maize stem borer

The colour of the African bollworm (Helicoverpa armigera) varies considerably. The spots on young individuals are usually more prominent (middle column). Some individuals may have lighter bands on the sides, similar to the fall armyworm. Of all the caterpillars, it is only the bollworm that displays the characteristic “sphinx stance” when disturbed (top right). Moths are pale brown and do not lay eggs in masses. Pupae are formed in earthen cells.
Caterpillars of the tomato moth (*Spodoptera littoralis*) are usually brownish with distinctive black spots (the black spots are sometimes absent). Some may be yellowish, blackish, or may contain yellow lines or spots on a brown body. Moths are brownish with characteristic “scratch-like” patterns on the forewings. Eggs are also covered with anal hairs and pupae are also found in earthen cells.

The lesser armyworm (*Spodoptera exigua*) is usually olive-green in colour, but yellow or darker individuals may be encountered (darker forms appear during overcrowding). A characteristic pink line or spots are found on the sides of some individuals. The moths have characteristic orange spots on the forewings, while eggs are also covered by anal hairs. Pupae are also found in earthen cells (not illustrated).
African armyworm

In the swarming phase, African armyworms (*Spodoptera exempta*) are usually blackish in colour, but brown to green otherwise. Similar to fall armyworm, they also have an inverted Y marking in the head region, as well as similar lateral stripes and bands. They lack the clear spots, however, and only enter the damaging swarming phase once every five to ten years. They are usually found in masses on grasses and do not hide in crops during the daytime like the fall armyworm. Pupae are also found in the soil. The moths look similar to that of the fall armyworm, and also lay eggs in hair-covered masses.

Semi-loopers

Semi-loopers are so-called because they typically bend their bodies in a semi-loop while walking. The larvae are usually greenish in colour, but yellowish individuals may also be found. The body typically tapers (becomes narrower) to the front. The moth of the plusia semi-looper (*Thichoplusia orichalcea*) has a characteristic yellow area on each forewing, while the tomato semi-looper (*Chrysodeixis acuta*) has silvery spots on the wings. Eggs are not laid in masses and the pupae are formed in silken cocoons on plants.
Various cutworm species may be found damaging crops, usually in the soil. The common cutworm, *Agrotis segetum*, is greyish in colour, while the moths are brown with characteristic spots on the wings. They lay eggs singly on plants and the pupae are formed in earthen cells.

False armyworm (*Leucania loreyi*), varies in colour. It is usually pale pinkish with longitudinal stripes and bands, similar to the fall armyworm. They also produce excrement in whorls. Moths are brownish in colour and lay eggs in masses on plants (not covered). Pupae are found in the soil or on plants.

**Stem borers**

*Chilo* borer

At least three stem borers are known to damage maize, of which the *Chilo* borer (*Chilo partellus*) and the maize stem borer (*Busseola fusca*) are the most common. Young caterpillars feed in whorls but older caterpillars bore into stems and ears. The *Chilo* borer moth is elongated, light brown in colour, while the maize stem borer is a stout brownish moth. Eggs of the maize stem borer are laid in egg batches (not covered) behind the leaf sheath (between leaf and stem), and the *Chilo* borer lays egg batches on both the upper and lower surface of leaves. The pupae are formed inside the tunnels, within ears or stems.
Conclusion

The fall armyworm has been reported in most provinces of South Africa, mostly damaging young maize plants. Identification of the caterpillars are sometimes problematic due to the lack of visual reference material and the usual mistaken identity and confusion with other caterpillars that are encountered on crops.

The information and illustrations in this presentation should assist workers in the field to differentiate between the fall armyworm and other common caterpillars. Workers can also use the illustrations to help farmers with preliminary identification of caterpillar pests on other crops, or work through a process of elimination to establish the most probable identity of a collected caterpillar.

For final and conclusive identifications, adult moths should always be submitted to an expert taxonomist who usually compares the microscopic genitalia of male moths with reference material from a collection.

This presentation is an output of the Fall Armyworm Steering Committee of the South African Department of Agriculture, Forestry and Fisheries

Presentation produced by Diedrich Visser, Agricultural Research Council - Vegetable and Ornamental Plants (ARC-VOP), Roodplaat, Pretoria

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For any comments or further additions to the presentation: dvisser@arc.agric.za
For more information, and reports of new sightings of the PAW: Jan Hendrik Venter, Email: jhv@defd.gov.za, Tel. no: 012 3190364
Refer to Plant Protection Research Institute Handbook No. 7 for practical guidelines on “How to collect and Preserve Insects and Arachnids”.

VIDEO ON DISSECTION OF MALE GENITALIA FOR IDENTIFICATION OF FALL ARMYWORM:

http://youtu.be/XbuQIRiPrQY

http://www.youtube.com/watch?v=XbuQIRiPrQY
1.2. Molecular Identification

FROM THE FIELD TO THE LAB

Preserving field-collected samples for molecular analyses

Introduction

• DNA-based analyses have radically influenced nearly all areas of biological research

• Molecular analyses depend on successful extraction of good-quality DNA

• One major difficulty of collecting samples for genetic purposes is keeping DNA from degrading

• Proper DNA storage is critical for studies involving genetic analysis and for molecular diagnostics
Preservation methods

- Different methods to preserve insect samples exist

- Most frequently used method of DNA preservation is immersion of live specimen in **96-100% ethanol**

Ethanol (EtOH)

- Excellent killing agent and preservative

- Drives out water from tissue and cells, thus dehydrates tissue and so preserves DNA

- Percentage (concentration) is critical: **96%-100%**

- Always use laboratory quality **non-methylated EtOH**

- Volume ratio of specimen and EtOH is important = **1:5**

- Samples can be stored at room temperature for short periods of time, however refrigeration is preferred
Capture/storage equipment

- Waterproof plastic jars/bottles
- Vials or microtubes (screw cap with O-ring) – one for each individual sample (2 ml or various sizes)
- Plastic Zip-lock bags (various sizes)

Labelling and recording data

Labelling is of utmost importance when taking biological samples for genetic analysis.

- All individual samples MUST be labeled with following:
  1. Date
  2. Species/possible species
  3. Location (GPS coordinates)
  4. Individual ID (to be linked to additional metadata)
  5. Host plant information
  6. Collectors name
  7. Other observations (sex, behaviour etc.)

- Ensure that handwriting is legible
Package and transport

• Without EtOH - Send via parcel post
• With EtOH - Ship/transport as dangerous goods
• Follow-up with postal and courier services about proper procedure

Final remarks

DNA sequencing is expensive, so correct id and preservation is very important

1. Have a standard collecting procedure in place
2. To avoid delays at Customs – check permits and documentation
3. Prevent spillage – use leak proof tubes/vials, wrap with parafilm.
4. Use a pencil for labelling
5. Caterpillars lose their colour - normal
6. Adult moths loose scales on wings - wet and dry specimens
7. Retain voucher specimens – send us a leg/abdomen
8. Use laboratory quality EtOH
9. Do AVOID sample-to-sample contamination
10. Alcohol discolouration:
    - change EtOH regularly
    - Increase EtOH volume (1: 5)
Acknowledgements

• Robin Lyle and Sma Chiloane (Biosystematics, Arachnology) for providing the molecular collecting kits

• Herbert Bennett (Biosystematics, Entomology) for providing photographs
2. SURVEILLANCE

Robust surveillance and monitoring of FAW and a coordinated regional approach are needed to enable the region to respond effectively and mitigate against effects of the FAW. Governments and other stakeholders need to develop or improve effectiveness of national surveillance systems in order to map affected areas and quickly detect new invasions. This module seeks to provide information that will enable collection of standardized national data that be used for development of a regional surveillance grid. Lessons learned and best practices from African armyworm surveillance and use of data sets for risk modelling are also discussed. Theory and practical guidelines for the use of an online system for data recording and analysis are presented by Crop Watch Africa, a service provider contracted by FAO.


E. S. Zitsanza. IRLCO-CSA

INTRODUCTION

The International Red Locust Control Organization for Central and Southern Africa (IRLCO-CSA) is a regional organization formed, initially to prevent the re-occurrence of locusts plagues in eastern, central and southern Africa. The mandate of IRLCO-CSA has expanded from the formative years to include other migratory pests such as the African Armyworm and Quelea birds. The current members of the organization are Kenya, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe.

The mandate of IRLCO-CSA is to undertake monitoring, surveillance, forecasting and to coordinate control of the Red Locust, African Migratory Locust, Brown Locust, Desert Locust, Tree Locust, African Armyworm, Quelea birds and any other migratory pest within Member States. In addition, IRLCO-CSA is mandated to conduct research aimed at efficient management of locusts and other migratory pests, and to initiate and implement training programs for plant protection staff of member states. IRLCO-CSA also facilitates exchange of information on migratory pests with Member States and provide monthly pest situation and forecast reports.

To a large extent regional cooperation arising from membership to the Organization has considerably minimized the burden of migratory pest prevention in Member countries. By pooling resources and sharing equipment, the cost of managing migratory pest outbreaks and invasions for each Member country is minimized. Moreover, migratory pests do not respect national boundaries and therefore the need for countries to jointly confront the pests is crucial.
AFRICAN ARMYWORM EPIDEMIOLOGY

The first AAW outbreaks originate in areas countries in east Africa which experience two wet seasons a year (Fig 2). The outbreaks from this region initiate the onset and spread of subsequent secondary outbreaks which reach southern Africa (Fig. 3). AAW outbreaks occur when moths which are dispersed and carried downwind, are re-concentrated by wind convergence such as those associated with rainstorms. Flying moths have been shown to descend to the ground when it rains.
Fig. 2. Migration of AAW moths in southern Africa

Migration of Africa Armyworm moths

- Outbreaks start in central Tanzania then adult moths spread to other parts of the country starting new outbreaks.
- The adult moths from these outbreaks move on to other east African countries including Kenya, Ethiopia, Uganda, Sudan Eritrea and Yemen.
- Also may move southward to Malawi, Mozambique, Zambia and South Africa.

Fig. 3. Sequence of AAW outbreaks during 2012/13
Fig.4. AAW damaged maize crops in Lesotho: February 2013

NEED FOR AN EARLY WARNING SYSTEM FOR AAW OUTBREAKS

Usually, farmers recognize the presence of AAW in their fields after the larvae have reached fourth instar or beyond (Fig 5). By this time, it would be too late to mobilize resources and undertake control operations.

Fig.5. Life cycle of the African Armyworm

Therefore, to achieve timely control of AAW outbreaks, it is prerequisite to have in placed an effective monitoring, forecasting and early warning system. An early warning system enables farmers to prepare for pesticides and spray equipment required for the control operations. With a functional early warning system, an alert of imminent outbreak is issued with advice to farmers to check their farms and undertake effective and efficient control operations on time.

The migrant nature of AAW moths and the spread of outbreaks from one country to another necessitate cooperation between countries to enable agricultural departments to take action to reduce losses. Cooperation between countries can be more effectively achieved if regional organizations are
responsible for coordinating exchange of information. Thus, IRLCO-CSA’s role in this regards is to coordinate the exchange of information and make countries aware of the development and spread of armyworm outbreaks.

Pheromone traps which attract male armyworm moths are recommended for forecasting because they are simple to use (Fig. 6). Traps are place on site during the armyworm monitoring period which starts in October for most countries. If high numbers of moths are caught (more than 30 males over 3-5 nights) it is an indication that egg laying is taking place in the area. High numbers of *S. exempta* moths in pheromone traps have been shown to be reliable indicators of the presence large moth populations in areas up to 100km of the trap site and within which outbreaks are likely to occur. This information is used to advise farmers to check their fields for young instars and prepare resources for control. Traps data is used in conjunction with rainfall figures to determine specific areas where outbreaks are likely to occur.

**Fig. 6. Pheromone trap**

**AAW FORECASTING SYSTEMS**

At present, AAW monitoring and forecasting is done at the regional and national level in southern Africa and elsewhere where the pest is a big problem.

**Regional forecasting**

The Regional Forecasting is carried out by regional organizations such as the International Red Locust Control Organization for Central and Southern Africa (IRLCO–CSA) and the Desert Locust Control
Organization for Eastern Africa (DLCO-EA). These regional organizations collect information from member countries and issue out monthly forecasts of AAW regional situation via e-mail (Fig. 7). In the event that outbreaks are imminent, the regional Organization issues additional warnings and alerts.

![Fig. 7. Distribution of Armyworm outbreaks](image)

**National forecasting system**

Most countries have National (Central) level forecasting systems operated by the National Plant Protection Departments (PPDs). Armyworm monitoring and forecasting is based on the readings of the network of pheromone traps set up across the country. The agricultural Extension Agents record moth catches from the pheromone traps on a daily basis during armyworm season. The records are then sent to the national PPDs via either e-mail, phone or radio communication. The PPD analyzes the AAW report and make a forecast. When positive forecast is issued, the warnings are communicated to the district agricultural offices and the data is also shared with IRLCO-CSA. IRLCO-CSA support national forecasting systems in member countries by procuring and issuing pheromone traps prior to the start of the monitoring season (Oct/Nov) (Table 1).
Table 1. AAW Pheromone traps issued to Member Countries

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>TRAPS (2010-2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya</td>
<td>580</td>
</tr>
<tr>
<td>Malawi</td>
<td>500</td>
</tr>
<tr>
<td>Mozambique</td>
<td>500</td>
</tr>
<tr>
<td>Tanzania</td>
<td>600</td>
</tr>
<tr>
<td>Zambia</td>
<td>540</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>500</td>
</tr>
</tbody>
</table>

Price/unit (excluding shipment)

- Trap- $5.00
- Lure- $1.25
- Total- $6.25

While national forecasting system plays an important role in the control of armyworm, it has experienced a number of challenges including:

- Delays in sending information on moth catches to the PPDs; in many cases trap reports are sent at the end of each month;
- Warnings often do not reach farmers or do so late and that forecasts are issued for districts rather than for each village;
- In some countries, there no funds allocated to service traps at the beginning of monitoring season
- Armyworm monitoring and forecasting is not taken as an integral part of the agricultural extension.

COMMUNITY- BASED ARMYWORM FORECASTING

The limitations that are currently encountered in AAW forecasting, are now being addressed with the community - based AAW monitoring, forecasting and early warning initiatives. This system was piloted in Malawi and Zimbabwe from 2007 to 2010 and farmers in both countries embraced the system after realizing the benefits from early detection of armyworm outbreaks. However, the initiative could not be scaled-out due to lack of constant supply of lures which are procured from overseas. IRLCO-CSA is collaborating with development partners to implement Community Based Armyworm Monitoring Forecasting and Early Warning (CBAMFEW) in its member countries.

The major advantages of CBAMFEW are:

- The monitoring and forecasting are done by the farmers and warnings and alerts are issued quickly to the farmers.
- The early warning system could enable farmers to monitor their fields on time and detect AAWs larvae when they are still young.
CBAMFEW effectively prevents crop loss by providing more time for decision-making, preparations, and taking control actions.

CBAMFEW involves tools such as pheromone traps, rain gauges, etc. and structures that can operate at the local level. It encourages more participation of farmers, developing their skills and capacity.

CBAMFEW creates a sense of ownership and responsibility among local communities given that monitoring and early warning are done by farmers.

It will also empower the community to actively participate in the AAW control operations in their respective villages.

CBAMFEW cannot be a replacement for the National forecasting system, but rather can complement it. The centralized forecasting system will still play an important role in issuing forecasts at a national level and to plan the procurement of inputs such as pheromone traps, pesticides and spraying equipment required for control. Centralized forecasting can also provide support and resources to the CBAMFEW.

APPLICATION OF AAW SURVEILLANCE FOR FAW

The FAW share similar behavioral characteristics’ with the AAW, most importantly being that females of both species release a sex pheromone to attract the males for mating. Just like AAW, the moths of FAW can be monitored using pheromone traps. However, the biology of two pests seem to differ and this had important implications on surveillance and control as highlighted below:

- Fall Armyworm appears to more tolerant of cool climates including most countries in southern Africa and several generations can develop in a year unlike AAW (Fig. 8 & Table 2). FAW has probably established permanently in many countries. Therefore, FAW outbreaks will arise from local populations unlike invasion from distant sources as is the case with AAW. Surveillance of FAW is therefore more effective at the local/village level using pheromone traps operated by communities (Community-based approach).

![% maize plants with FAW](image.png)

**Fig.8. Fall Armyworm infestation on irrigated maize at Ndola site**
Table 2. Pheromone trap catches using FAW and AAW lures

<table>
<thead>
<tr>
<th>Date</th>
<th>FAW</th>
<th>AAW</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-12 May</td>
<td>35</td>
<td>37</td>
</tr>
<tr>
<td>13-19 May</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>20-26 May</td>
<td>46</td>
<td>32</td>
</tr>
<tr>
<td>27-2 June</td>
<td>67</td>
<td>49</td>
</tr>
<tr>
<td>3-9 June</td>
<td>26</td>
<td>59</td>
</tr>
<tr>
<td>10-16 June</td>
<td>16</td>
<td>39</td>
</tr>
<tr>
<td>17-23 June</td>
<td>22</td>
<td>32</td>
</tr>
</tbody>
</table>

- African Armyworm forecasting uses pheromone traps records, wind movements and rainfall to determine areas where outbreaks are likely to occur. It appears FAW moths do not form high density concentrations where rains are falling but are spread out over large areas but infestation levels rise as the crop develops. The most effective monitoring method will be pheromone traps to indicate presence of FAW moths in the area together with scouting for early instar larvae on crops.

- African Armyworm moths which emerge from an outbreak area disperse with the wind, re-concentrate elsewhere and cause another outbreak. It is not certain whether or not FAW behaves the same but the observation more than one generation can develop on a crop may indicate infestation arising from a resident population. Assessment of maize crops have shown larvae of different instars, an indication of attack occurring at different periods.

- Surveillance of FAW is likely to be a year round operation unlike AAW where the most critical periods for outbreaks fall in the period from November to March. During the dry season, irrigated areas constitute reservoirs of FAW populations from which migration to dryland crops occur at the beginning of the rain season. Monitoring and controlling the dry season populations could be critical in reducing infestation on summer rain fed crops.
2.2. Online portal and Mobile application

Refer to Biosecurity Africa Training Guide by Crop Watch Africa
2.3. Linking crop data to risk modelling

Overview of the presentation

• **Example: Risk prediction of RVF in South Africa**

• **Fall Armyworm**
  – Key factors to consider with risk modelling
  – Relevant datasets
    • Wind and temperature (station and forecast data)
    • Weather radar
    • Sentinel 2 satellite imagery
Rift Valley Fever

- viral disease of livestock & humans
- transmitted by mosquitoes
- associated with abnormal high rainfall
- effective vaccine control

Inter-epidemic period

5 – 15 years
Components of an Outbreak

- Historic outbreaks
Risk base map

Main vector species

Aedes spp
Infected *Aedes* eggs

Rainfall
Continuous rainfall – soil saturation

High rainfall event - flooding
Hatching of *Aedes* eggs

Rainfall & soil saturation

[Graph showing rainfall and soil saturation with an outbreak marker]
Rainfall & soil saturation

Outbreak

Rainfall & soil saturation

Outbreak
Rainfall & soil saturation

Outbreak

Risk model

Base map

Soil saturation anomaly of LTM

Rainfall anomaly of max LTM

Potential Risk

Low
High
Map
Risk model

Risk map

Publication

Fall Armyworm - Key factors to consider for risk modelling

- May overwinter in certain “pockets” in southern Africa (too early to confirm).
  - Moths migrate South during Dec, Jan, Feb
  - Monitoring and surveillance is critical
- Small window of opportunity to spray
  - 3-5 days after egg laying
  - Can only be effectively controlled while the larvae are small.
  - Larger larvae are usually found deep in the whorl and are protected from insecticide
  - Early detection and proper timing of an insecticide application are critical.
- Young plants are more vulnerable than mature plants
Wind Speed and direction

- Automatic Weather station data
- Forecast data
Pretoria, annual average
Temperature

- Automatic Weather station data
- Forecast data

Sentinel 2 data

- Multi-spectral data with 13 bands
- 5 day revisit period
- Spatial resolution of 10 m, 20 m and 60 m
- Current products by ARC
  - Leaf area index
  - NDVI
  - Crop types
How RADAR Systems work?

Finding relationship between RADAR echo and drop size distribution DSD (for rainfall) and number and volume of objects per volume (density).

Reflectivity data converted to intensity

http://weather.noaa.gov/radar/radinfo/radinfo.html

Same theory applied for insects, swarms, bats and birds observation

Horizontal radar for distribution
Vertical radar for insects rate

Vertical looking radar system for insect monitoring (Smith et al., 2000)

Daily insects numbers
Mini-portable radars can be used after calibration for insects monitoring.
3. ASSESSMENT TOOLS FOR FALL ARMYWORM

The ability to monitor pest infestations; pest densities in affected areas; crop damage and yield loss levels is an essential step in developing an effective management strategy. The transboundary nature of FAW demands a regional approach and requires uniform standards for data collected across countries. This module provides tools that have been designed to assess and understand:

- The economic losses caused by the FAW;
- The impact of the FAW attack on livelihoods;
- The strategy used by farmers to cope with FAW attacks and;
- The farmers’ needs for recovery

3.1. FIELD INFESTATION AND YIELD LOSS ASSESSMENT PROCEDURES TO DETERMINE IMPACT OF FALL ARMYWORM (*Spodoptera frugiperda*) ON MAIZE

1. Background

This document or manual should be read in conjunction with the “Fall Armyworm Technical Brief”. The purpose of this document is to standardize Fall Armyworm (FAW) (*Spodoptera frugiperda*) assessment procedures in maize\(^1\) and to empower extension personnel and others to do rapid assessments of the incidence of FAW damage and larval infestation levels at field level. Data on the incidence of damaged plants per field, or infestation levels, informs the decision made regarding whether or not to apply insecticides to control the FAW infestation. Pest and damage assessment data are needed when:

- the effects of different pest management measures are evaluated,
- surveys are conducted to monitor pest damage and numbers to forecast outbreaks, and
- decisions have to be made whether to control the pest or not.

Accurate data is needed since specific threshold levels are used to guide decision-making regarding the economics of pest control as well as on other aspects of pest management. For decisions to be made about control of FAW in any cropping system, the level of infestation and population density of the pest must be estimated.

The data collected by means of the procedures described in this document answers three basic questions:

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\(^1\) With the exception of yield loss determination, the procedures outline in this document can also be used for FAW assessments in sorghum.
1) What is the FAW infestation level per field?
2) What is the population density of larvae per field?
3) What is the estimated yield loss due to FAW damage per field?

To answer these questions, procedures should be standardized and not depend on the person who does the assessment. Standardization allows for repeat surveys and comparison between regions, countries and years. Populations are estimated from field samples, as described further in this document. If a pest population cannot be measured or estimated, assessment may be done indirectly by measuring or estimating the effect of the pests on the crop, as injury or degree of damage.

The data obtained using the procedures outlined in this document can be adopted as baseline information by researchers who are conducting detailed studies on the biology and ecology of FAW in Africa. However, since there are still too many knowledge gaps on FAW in Africa, this document may be modified as the suggested procedures are tested in the field.

2. Definition of terms and concepts

In order to make it easier for users of the manual to produce reports which will be understood by anyone who would want to make use of the information gathered, several terms which will likely feature in such reports need to be defined first. Since *S. frugiperda* is a transboundary pest whose management requires collaboration among several countries, harmonization of the reporting language also makes it possible to conduct statistical analyses which can enable comparisons of the impact of the pest between and among countries. Below are some terms which need to be defined.

1) **Economic injury level (EIL) or Damage threshold** – the minimum pest density which will cause economic damage or the amount of injury that justifies the cost of artificial control measures.
2) **Economic threshold (ET) or Action threshold** – the pest density at which control measures need to be implemented to prevent an increasing pest population from reaching the EIL. Alternatively, this can be defined as the average pest density at which the cost of control is warranted. Since socioeconomists define the ET differently, the term which will be used for infestation and damage assessment hereinafter in this manual is Action threshold.
3) **Injury** – the harmful effects of insect pest activities (mostly feeding) on host plant physiology (e.g. growth rate, flowering, grain filling, etc.).
4) **Damage** – the measurable loss of crop usefulness, such as yield (in quantitative or qualitative terms) or aesthetic value.
5) **Sampling unit** – One of the indivisible individual units into which an aggregate is divided for the purpose of sampling. In field entomological studies, the sampling unit can be a leaf, plant, an area of field, or a number of plants in a row/defined area. When the sampling unit is defined as an area of field or group of plants in a defined area, it is generally said to be a plot.
6) **Replicate** – number of sampling units over which the mean of the measured parameter is based upon.
7) **Pest infestation level** – the incidence (%) of plants exhibiting symptoms of FAW damage as determined by the sampling unit area in the field.
8) **Pest severity** – the degree of pest infestation as determined visually from some rating scale, e.g. amount or area of leaf damaged/plant, amount of stem or cob damage, etc.
9) **Pest abundance** – the number of pest individuals (eggs, larvae, nymphs, pupae or adults) per plant in a defined sampling unit area of the field.
10) **Yield** – a measure of the weight of dry grain obtained from a unit of cropped area (expressed in kg/ha or tonnes/ha).
11) **Yield loss** – a measure of the difference (in %) in grain yield (dry weight) between FAW-infested and uninfested plots.

### 3. Assessment objectives

There are four main objectives of a fall armyworm assessment:

- to determine occurrence of the pest in a field or defined area;
- to estimate field infestation levels,
- to estimate pest numbers (eggs or larvae) per sampling unit area, and
- to estimate yield loss due to FAW infestation and damage.

### 4. General Assessment Considerations

General assessments such as those described in this document may be influenced by various factors which have to be kept in mind when doing surveys. These factors include spatial distribution of insect pests in the field, correct identification of pest species and damage symptoms, crop growth stage as well as the presence of other pests.

#### 4.1 Spatial dispersion of insect pests in the field

Spatial distribution of different pest species may differ at field level and may therefore influence field sampling exercises and the reliability of the data obtained. This distribution may be **random**, **aggregated** (or clumped) or **regular** (Figure 1).

![Figure 1. Distribution patterns that organisms can have in space](image)

A purely random or uniform distribution is quite rare. Largely due to “ballooning” of early instar FAW larvae from site of egg hatching, distribution of infested plants ends up being clumped. The
sampling strategy outlined in this manual considered a clumped distribution of FAW damaged plants and hence larvae as the most likely to be encountered in maize and sorghum fields.

4.2 Fall armyworm plant damage symptoms

Field assessments of FAW incidence and damage are largely based on observable plant damage symptoms, e.g. pin holes, “window-panes”, ragged and torn leaves, destruction of unfurled leaves in funnels, tassel damage, and ear damage. However, as eggs may just have been laid on a supposedly “uninfested” plant, a complete assessment of FAW field infestation also needs to have data on presence/absence of egg masses.

Care should be taken that damage symptoms are correctly identified in order not to account for damage which was not caused by FAW larval feeding. Plant damage symptoms by lepidopterous stem-borers (foliar and ear damage) and *Helicoverpa armigera* (ear damage) can be easily mistaken for those due to fall armyworm. Destructive sampling is thus needed in some situations in order to confirm pest identity before attributing the infestation to fall armyworm. Simple figures indicating the different types of FAW larval injury to maize leaves are shown in Figure 2.

![Figure 2. Types of lesions caused by FAW larval feeding on leaves. a = pin-hole, b = small circular lesions, c1–3 = small to large elongated lesions, d1–3 = small to large uniform or irregular shaped lesions, e = shot hole, f = leaf sheath. (From Davis et al., 1992).](image)

4.3 Crop growth stages

When assessing FAW infestation level and pest density in a maize field, it is important to consider the growth stage at which the assessment will be done. Assessments are fairly easy as well as fast on young crops compared to crops in the post-tassel stage. Yield depression is highest if maize
crops are infested earlier on in the vegetative stages compared to reproductive-stage crops. Once the crop is in the post-tassel stages, it is pointless to assess for infestation and/or pest abundance in order to schedule insecticide applications. Any new fall armyworm infestations occurring then will be on the ears and larvae will be feeding cryptically within. However, assessments may still need to be conducted at this stage but only for the purpose of determining pest severity. The latter parameter is necessary for yield loss estimation through modelling.

It is important to note that injury to a plant does not necessarily imply that the plant will suffer yield loss. Also, while foliar damage symptoms are permanent indicators of FAW injury this does not imply permanent pest residency in the field! Stem-borers which could not previously feed alongside the cannibalistic FAW larvae inside leaf funnels are usually the ones found when post-tassel plants with severe FAW leaf injury are destructively sampled and stems dissected.

In order to make FAW assessment procedures more practical and useful, plant growth stages of maize and the terminology describing the various stages is briefly outlined in Figure 3.

![Figure 3. Basic description of the growth stages of maize (Adapted from Beckingham, 2007).](image)

**1. Use of Pheromone Trap Catches for Early Warning Purposes**

It must be stressed that in this manual, the value of FAW pheromone trap catch data is essentially as an early warning tool which will prompt farmers within the trap catchment or region to trigger the most important action of SCOUTING for eggs and larvae in their fields. Scouting, in the context of this document, refers to activities to detect pest presence and/plant damage in fields that are still in the pre-tassel stages (see Figure 3). Awareness of an impending problem (i.e. early warning) at regional or field level and empowerment with skills to monitor the unfolding pest
situation will ultimately lead to improved pest management. The presence of male moths in traps indicates the presence of moths in the area and most likely the presence of ovipositing females.

Being a new pest to Africa, we are still to find out what we can prescribe as an early warning trap-based action threshold. Once the crop has moved past tasseling into the reproductive stages, insecticidal control is pointless as larvae then feed inside ears where they are not reached by insecticides. When traps are set up during the “off-season”, the main purpose of the resultant data would be pinpoint “hostspots” where the pest overwintered on off-season irrigated crops such as maize and winter wheat and from which moths will potentially migrate to infest summer-grown crops (unimodal rain fall regions) or crops grown during the short or long rains (bi-modal rainfall regions).

2. Determination of Fall Armyworm Infestation Levels and Pest Abundance

Whether during general surveillance programmes or field experiments, the procedure for collecting FAW infestation level or abundance data in the field should be the same. However, some improvisations or adjustments may obviously become necessary in survey situations. The sampling unit used in the procedures described below is termed a plot (a defined number of plants in a row). Ideally, the minimum number of plants that constitutes a plot needs to be decided on beforehand, usually through preliminary sampling, and depends on the level of precision required. Furthermore, the number of replicates must also be decided upon. For the purpose of FAW sampling, five plots per field should be assessed and infestation and pest abundance will be based on 20 consecutive plants in each plot (Figure 4).

![Figure 4. Diagram of maize field illustrating 5 plots (replicates), each with 20 plants per plot. Dots represent plant stations.](image)

By definition, infestation level is the proportion of infested plants (as a %) in a field. That is,
\[
% \text{FAW infestation} = \frac{\text{no. of infested plants}}{\text{total number of plants}} \times 100
\]

For most arthropod pests, the assessment of % field pest infestation is generally based only on presence/absence of characteristic damage symptoms. However, due to its damaging potential, this manual recommends that FAW infestation be based on presence/absence of characteristic plant damage symptoms as well as egg masses. In other words, a plant with no outward symptoms of damage or feeding by FAW will only be said to be uninfested if it does not have any egg mass on it as well.

### 6.1 Data collection procedure

1) Randomly select 5 plots each comprising 20 consecutive plants in a row (Figure 4). The five plots should be representative of the whole field. Care should be taken not to select only areas where plants are healthy or damaged. Furthermore, data should never be collected at field edges. Further modifications in the method of selecting plants may become necessary when there are no clear rows such as when seed was broadcast. One way around the problem would be to simply pick a distant point at the end of the field and then select the 20 plants as you move towards the point in a straight line.

2) Examine each selected plant within the plot for leaf-feeding damage symptoms and presence of larvae and/or egg masses. It may be necessary to destructively sample the plant in order to access larvae feeding deep inside the whorls.

3) Determine % infestation for each of the five plots and then calculate the mean plot infestation.

4) Separately determine the number of egg masses and larvae/plant. Zeroes should be written down against uninfested plants, i.e. where a plant has neither damage symptoms nor has larvae or egg masses present, that plant should still be part of the plot but with a zero count of larvae or egg masses). Omitting uninfested plants will overstate pest densities.

5) Determine the mean numbers of larvae and egg masses per plant.

One can also come across whorl-feeding stem-borer larvae or *Chilo partellus* egg masses during the assessment. Due to the confounding effects of stem-borer damage on yield losses, it is important that data on their incidence and abundance be recorded as well.

### 6.2 Fall armyworm action thresholds for insecticide applications

The level of damage and consequently yield loss as a result of FAW infestation is dependent on the growth stage at which the crop is attacked and severity of infestation. Based on FAW biology and field observations made so far in Southern Africa, the primary focus of insecticide applications must be to prevent the establishment of larvae inside plant funnels. To reiterate what was previously alluded to in section 5, insecticidal control is pointless on post-tassel maize as any FAW larvae present will be feeding inside ears where they will not come into contact with insecticides.
Plants are selected and examined as already described in 6.1. The upper and lower surfaces of all 20 plants within the plot must be inspected for the presence of egg batches. Action thresholds are strongly influenced by plant growth stage at the time of initial attack by FAW. The general principle is that younger plants are much more susceptible to damage and subsequent yield loss than older ones. As higher dosages are needed to control middle to late instar fall armyworm larvae, it is more sensible to base the action thresholds on egg counts and then use post-spray live larval counts to gauge the effectiveness of the insecticide application. The suggested provisional action thresholds for FAW control on maize are grouped according to the following crop growth stages: seedling stage, early to mid-whorl stage, and late-whorl stage (Table 1).

Table 1. Suggested action thresholds for control of FAW infestation in maize of different growth stages. WAE – weeks after seedling emergence.

<table>
<thead>
<tr>
<th>Crop growth stage and general plant age</th>
<th>Mean % plants per plot with damage</th>
<th>Mean % plants per plot with egg masses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling (0-2 WAE)</td>
<td>1-5</td>
<td>≥ 5</td>
</tr>
<tr>
<td>Early whorl (3-4 WAE)</td>
<td>1-5</td>
<td>≥ 5</td>
</tr>
<tr>
<td>Mid-whorl (5-6 WAE)</td>
<td>6-10</td>
<td>≥ 5</td>
</tr>
<tr>
<td>Late whorl (7 WAE-tasseling)</td>
<td>11-20</td>
<td>≥ 5</td>
</tr>
<tr>
<td>Tasseling and post-tasseling</td>
<td>No insecticide application</td>
<td>No insecticide application</td>
</tr>
</tbody>
</table>

3. **Yield Loss Assessments (Aimed at extension personnel or advisors)**

In crop situations, it is imperative that policymakers be regularly appraised not only of productivity levels but also of the losses being experienced by farmers due to pests and diseases. Such data is normally collected through crop surveys conducted by extension personnel. In the context of the fall armyworm, yield loss surveys generally have four principal objectives:

- to determine yield losses and their distribution in different areas/agogoeconomic regions,
- to evaluate losses with the aim of forecasting national and/or regional crop production figures,
- determine the regional importance of the pest and to plan intervention strategies, and
- to establish regional baseline data which are used to assess the value or need for area-wide control measures (e.g. classical biological control).

Although national statistics on crop productivity are generally given according to political boundaries as defined by district or province, assessments of FAW incidence/damage and consequent yield loss should be done per agro-ecological region rather than district. This is because agro ecological regions (defined mainly according to altitude, temperature and rainfall) rather than political boundaries determine both the spatial and temporal occurrence of the plant hosts of the pest in addition to having direct effects on the biology and ecology of insect itself. This therefore makes it possible to make extrapolations to certain areas not covered by the crop surveys. Also, obtaining yield loss data on the basis of agro ecological regions reduces variation as there are specific maize varieties recommended for growing in particular regions.
Yield loss assessments, as outlined in this manual, are only possible when information is available about crop yield under conditions of no pest attack as well under pest attack within the same field. In other words, yield loss cannot be estimated using the procedures outlined in this manual when FAW field infestation is 100%. This has been observed to be the case for late-planted maize crops. In terms of strategic decision-making, it is also important to have access to long term yield data.

Since yield loss surveys are costly, it is prudent to get loss estimate data from only a few randomly-selected locations within a given agro ecological region. Yield is estimated by sampling small subplots within a field – referred to as the crop cut method. Households or farms within an agro ecological region will be the replicates (1 field per farm). In conformity with the manner in which plots were demarcated in section 6, subplots should constitute consecutive plants within a row. The area of each subplot should be at least 0.5 m$^2$ but not more than 2.5 m$^2$. Due to non-uniformity of smallholder maize fields in terms of both inter-row and intra-row spacings, the width and length of each subplot will have to be determined using a tape measure. The subplot width is measured up to ½ of the distance to each of the two rows flanking the one in which sampling is being conducted while the length will be up to ½ of the distance to the next plant in either direction (Figure 5). Due to the varied inter-row and intra-row spacings already alluded to, the number of plants within each subplot may differ and these may thus not necessarily be in the centre of the subplot.

![Figure 3. Illustration of typical variability of subplot sizes and number of plants within each subplot in smallholder maize fields due to non-standardization of inter- and intra-row spacings](image)

The total harvest area of the plot upon which the yield of the entire field will be based must be large enough to capture the variability within the field. In other words, the number of subplots in each plot category (i.e. damaged and undamaged) must be large enough to “smooth over” variations in plant growth rates and pest severity in various parts of the field. Thus subplots must not be selected from the edges of the field.
Fall armyworm-damaged and undamaged subplots must be demarcated preferably at grain filling stage when foliar damage is still easy to see and can be rated. At this stage, there is also very little likelihood of additional leaf damage occurring due to FAW. If at all moths will continue to oviposit in the same field, they will do so on developing ears. Subplots must be demarcated using a combination of pegs driven into the soil as well as plant tags.

In order not to make the exercise too cumbersome but still produce results which are acceptable when up scaled to agro ecological region level, there must be 10 subplots of damaged or undamaged plants per field and a minimum of 10 farms (replicates) per agro ecological region. The number of farms sampled will depend on the resources and personnel available. However, due to differences in the sizes of agro ecological regions, some form of self-weighting will need to be used so as to arrive on the final number of farms per region. For example, the number of farms to sample in agro ecological region B which is three times the size of region A, must be thrice the number of farms sampled in A. While it is important that the field chosen for the yield loss assessment on a particular farm be under one variety, replication within the agro ecological region need not be according to variety as the final parameter of interest will not be yield but % yield loss.

For the undamaged or damaged plots, the total harvest area of the plot will be a summation of the areas of the individual subplots (in this case 10 subplots). The plot yield will similarly be obtained by summing up the individual subplot yields. Using the plot yield, the yield per hectare is then calculated using simple proportion. For example, for 10 subplots each of mean size 2 m$^2$, the total harvest area of the plot is 20 m$^2$ (i.e. 10 × 2 m$^2$). The yield per hectare is then obtained by multiplying the plot yield by 10,000 and then dividing the result by 20, that is:

$$Yield \text{ (kg/ha)} = \frac{\text{plot yield (kg)}}{20} \times 10,000$$

This yield figure must be in terms of dry weight after taking into account grain moisture content.

### 7.2.1 Data collection procedure

1) Visit pre-selected fields on different farms at grain filling stage to demarcate subplots (fall armyworm-damaged and undamaged).

2) Tag plants in each subplot.

3) Determine the length and width of each subplot.

4) When the crop has dried and is ready for harvest, remove all cobs in each subplot.

5) Randomly select 6-8 additional cobs (damaged/undamaged) from other parts of the field. Use grain from these cobs for moisture content determination.

6) Dehusk the cobs and place them in small labeled bags.

7) Take the cobs to a central place for final drying prior to shelling.

8) Shell the cobs and determine the grain weight for each subplot.
9) Remove all kernels which are discolored as a result of secondary fungal infection. Weigh this grain and place it in labeled khaki pockets. Retain this grain as there may be need to test it for presence of aflatoxins.

10) Re-weigh the remaining sound kernels for each subplot.

11) Using a moisture meter, determine the grain moisture content of the grain mentioned in step 5. Determine the grain moisture content on 4-5 samples and then calculate the mean. Although the most accurate way of determining moisture content is by using the oven-drying method, this may make the yield loss surveys unnecessarily cumbersome.

12) Determine the dry weight of grain (i.e. yield) for each subplot using the following formula:

\[
\text{Dry wt} = \text{Original Wt} \times \frac{100 - \text{mean moisture content}}{100}
\]

13) Add up the individual areas and the dry grain weights for the 10 subplots to come up with total plot harvest area and total plot yield, respectively. Do this separately for the damaged and undamaged plots.

14) Calculate the plot yield per hectare (kg/ha) using simple proportion. A typical data sheet which can be used to record individual plot yields prior to the calculation of % yield loss is shown in Appendix 1.

15) Calculate plot yield loss using the formula below:

\[
Y_L = \frac{Y_U - Y_D}{Y_U} \times 100
\]

Where:

\(Y_L\) = yield loss (as a %)

\(Y_u\) = total yield of undamaged plot (dry weight)

\(Y_D\) = total yield of damaged plot (dry weight)

It is important to note that probably in the majority of farms, the yield losses obtained in the manner outlined above may only be indicative of the losses which farmers are now experiencing since the advent of FAW rather than FAW-induced losses per se. There are obviously the confounding effects of other pests (e.g. stem-borers and earworm) which need to be taken into account as well as differences in farmer management practices. However, this is far more acceptable that using guestimates.

References


---

**Appendix 1. Data sheet for recording individual plot grain yield**

Farm/Farmer’s name: ____________________________ District: __________________________

Agro ecological region: __________________________

Plot category: (damaged/undamaged): ______________ Variety: __________________________

Harvest date: __________________________ Mean moisture content: __________

<table>
<thead>
<tr>
<th>Subplot</th>
<th>Subplot dimensions</th>
<th>Grain wet wt (kg)a</th>
<th>Dry grain wt (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Width (m)</td>
<td>Length (m)</td>
<td>Area (m²)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
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<td>3</td>
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<td>4</td>
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<td></td>
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</tr>
</tbody>
</table>

69
<table>
<thead>
<tr>
<th></th>
<th>Total harvest area (m²)</th>
<th>Total dry grain wt (kg)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Total harvest area (ha)</td>
<td>Yield (kg/ha)</td>
<td></td>
</tr>
</tbody>
</table>

a After removal of discolored kernels  
b Moisture content
3.2. FOCUS GROUP DISCUSSION CHECKLIST ON THE IMPACT OF THE FALL ARMYWORM (FAW)

Please refer to the soft copy of the instruction manual for facilitators, note takers and supervisors that is provided as an annex to this training manual.

N.B. Before starting the interview please make sure the village was affected by the FAW pest.

Each Focus Group Discussion (FGD) should ideally comprise of 6 - 10 persons. Depending on cultural practices the group can be mixed or separated into male and female groups. Prior to starting the discussions introduce the team members and thank the interviewees for their time. Explain the purpose of the assessment and avoid raising expectations as far as possible. Explain that participation is voluntary and that they do not need to reply to any questions that may make them feel uncomfortable.

General information

Country:
Agro-Ecological Zone:
Region:
District:
Village:
Village / Community GPS coordinates:

Name of the Facilitators
Name of the note taker (if any):

Date of the discussion:

Number of men in the FGD:
Number of women in the FGD:

1. Introduction

Q1.1. How many People are living in this community /village?

.................
Q1.2. How many Households (HH) are in this community / village?

………………

Q1.3. Which share / percentage of the households relay on the agricultural sector and its sub-sectors as their MAIN livelihood activity?

(Crop): |___| % / (Livestock): |___| % / (Fishery / Aquaculture): |___| %

Q1.4 What are the main crops grown in this community?

Please list five crops (From the most to the least important)

<table>
<thead>
<tr>
<th>Crop</th>
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</table>

Q1.5. What is the proportion (%) of HH affected by the FAW attack in the community?

Show the picture in Annex 1 to help identifying the pest

|___| %

Q1.6. When did you first see the FAW? (Please indicate the month and year)

<table>
<thead>
<tr>
<th>Month</th>
<th>Year</th>
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</table>

Q1.7 What was the season like during the month you noticed the FAW infestation?

Dry ☐

Wet/rainy ☐

Q1.8a. During the last season, were there any shocks/constraints that negatively impacted your crop production?

Yes ☐

No ☐
Q1.8b. If yes, Please list five crops (From the most to the least important)


2. Impact / Effect on Crops

Q2.1. Which are the main pests and diseases affecting annual crop production in this community / village?

<table>
<thead>
<tr>
<th>Crop affected (list maximum the five most important)</th>
<th>List of pest and disease (specify name)</th>
<th>Recurrence* (see code below)</th>
</tr>
</thead>
<tbody>
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</table>

* Once every two years or more (1), once a year (2), two time a year or more (3), always there (4)

Q2.2. What are the main crops affected by the FAW and to what proportion was the production affected?

<table>
<thead>
<tr>
<th>List up to 5 main crops grown in the village</th>
<th>Share (%) of importance to food security</th>
<th>% of crop production affected*</th>
<th>Planting (Month)</th>
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<tbody>
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</tbody>
</table>

* For each listed crop the proportion of production losses can range from 0 to 100%

Q2.3. What was the growth stage of the crops when the attack was observed?
Q2.4. What proportion of farmers expect agricultural production to decrease in this community / village due to the FAW attack (from 0 – 100%)?

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>%</th>
</tr>
</thead>
</table>

Q2.5. Please indicate the expected decrease in production.

<table>
<thead>
<tr>
<th>List of crop (up to 5 affected crops)</th>
<th>Crop variety</th>
<th>Expected decrease in production (%)*</th>
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<tbody>
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</tbody>
</table>

* For each crop variety affected the proportion of production losses can range from 0 to 100%

Q2.6. Please indicate if the damage was localized or widespread across the affected fields.

<table>
<thead>
<tr>
<th>List of crops (up to 5 affected crops)</th>
<th>Crop variety</th>
<th>Share (%) of fields completely affected*</th>
<th>Share (%) of fields partially affected</th>
<th>Share (%) of fields non affected</th>
</tr>
</thead>
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</table>

Q2.7. What proportion of farmers replanted the agricultural land area that was affected (from 0 – 100%)?

(1) Emergence-

Seedling; (2) Vegetative; (3) Flowering stage; (4) Post flowering.
Q2.8. What proportion of land was replanted?

<table>
<thead>
<tr>
<th>List of crops (up to 5 affected crops)</th>
<th>Crop variety</th>
<th>(% land replanted)</th>
</tr>
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<tbody>
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</tbody>
</table>

Q2.9. If land was replanted, what proportion of farmers have access to new seeds from the following sources in comparison to sources at initial planting?

<table>
<thead>
<tr>
<th>Sources</th>
<th>(% of farmers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used own saved seed</td>
<td></td>
</tr>
<tr>
<td>Bought from local market</td>
<td></td>
</tr>
<tr>
<td>Free from the government</td>
<td></td>
</tr>
<tr>
<td>Free from a NGO / International Organisation</td>
<td></td>
</tr>
<tr>
<td>Borrowed from relatives / neighbour</td>
<td></td>
</tr>
<tr>
<td>Other (specify) ..................................</td>
<td></td>
</tr>
</tbody>
</table>

3. Pesticides

Q3.1. What proportion of farmers have access to pesticides (from 0 – 100 %)?

| [___ ][___ ]% |

Q3.2. What proportion of farmers have received pesticides from the following sources?
<table>
<thead>
<tr>
<th>Sources</th>
<th>(%) of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bought from the market</td>
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</tr>
<tr>
<td>Free from the government</td>
<td></td>
</tr>
<tr>
<td>Free from an international organization</td>
<td></td>
</tr>
<tr>
<td>Other sources (please specify)</td>
<td></td>
</tr>
</tbody>
</table>

Q3.3. To respond to the FAW attack in this village / community, what proportion of farmers have undertaken the following actions?

<table>
<thead>
<tr>
<th>List of actions</th>
<th>(%) of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bought and sprayed pesticide by themselves</td>
<td></td>
</tr>
<tr>
<td>Received support from the government to buy and spray pesticide</td>
<td></td>
</tr>
<tr>
<td>Requested advice from relevant authority (MoA)</td>
<td></td>
</tr>
<tr>
<td>Nothing (they did not know what to do)</td>
<td></td>
</tr>
<tr>
<td>Nothing (they did not have money to buy pesticide)</td>
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<tr>
<td>Nothing, because they did not consider the pest infestation severe</td>
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<tr>
<td>Other (please specify)</td>
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<td>........................................................................</td>
<td></td>
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</tbody>
</table>

Q3.4. If farmers did apply pesticides, please indicate the names of the pesticides and the proportion of farmers who used them.

<table>
<thead>
<tr>
<th>List of crops (up to 5 affected crops)</th>
<th>Crop Variety</th>
<th>Commercial names of pesticides (up to 5)</th>
<th>(%) of farmers</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>
Q3.5. Please indicate the average number of times pesticides were applied by farmers in response to the FAW attack and the number of days between each application?

<table>
<thead>
<tr>
<th>List of crops (up to 5 affected crops)</th>
<th>Crop Variety</th>
<th>When were the pesticides used?*</th>
<th>Number of pesticide applications</th>
<th>N. of days between applications</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

*Numbers of days after the attack was observed

Q3.6. Who sprayed the pesticide in the crop fields affected? If no pesticide was used, skip this question.

<table>
<thead>
<tr>
<th>List of people who applied pesticide</th>
<th>(%) of people*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer (man)</td>
<td></td>
</tr>
<tr>
<td>Farmer (women)</td>
<td></td>
</tr>
<tr>
<td>Hired labourer (man)</td>
<td></td>
</tr>
<tr>
<td>Hired labourer (women)</td>
<td></td>
</tr>
<tr>
<td>Other (specify)</td>
<td></td>
</tr>
</tbody>
</table>

*Total should sum up to 100 %

Q3.7. What methods were used for pesticide application and by which proportion of farmers were they used?

<table>
<thead>
<tr>
<th>Method</th>
<th>Yes/No</th>
<th>(%) of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprayer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pouring</td>
<td></td>
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<tr>
<td>Hand splashing</td>
<td></td>
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<tr>
<td>Other (specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q3.8. Were the farmers wearing protective gear during pesticide application? If yes, fill in the table below. If not, move to next question.

<table>
<thead>
<tr>
<th>Type of protective gear</th>
<th>(%) of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mask</td>
<td></td>
</tr>
<tr>
<td>Gum boots</td>
<td></td>
</tr>
<tr>
<td>Gloves</td>
<td></td>
</tr>
<tr>
<td>Other (specify)</td>
<td></td>
</tr>
</tbody>
</table>

Q3.9. Please indicate the proportion of farmers who know how to use pesticides (from 0 – 100%)?

[___] %

Q3.10. Please indicate how farmers learned to use pesticides?

<table>
<thead>
<tr>
<th>Source</th>
<th>(%) of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read in the product instructions</td>
<td></td>
</tr>
<tr>
<td>Through advice from extension service provider</td>
<td></td>
</tr>
<tr>
<td>Using their own knowledge</td>
<td></td>
</tr>
<tr>
<td>Other (specify)</td>
<td></td>
</tr>
</tbody>
</table>

Q3.11. How effective was the pesticides applied against the FAW?

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Crop</th>
<th>Crop variety</th>
<th>Effectiveness of the Pesticides applied*</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>
4. Impact on Livestock

Q4.1. What proportion of farmers have experienced a reduction in pasture availability for livestock due to FAW attack?

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
</tr>
</tbody>
</table>

5. Impact/effect on livelihoods

Q5.1. What proportion of farmers has engaged in any of the following actions during the past 30 days to respond to the FAW attack?

<table>
<thead>
<tr>
<th>List of coping mechanisms</th>
<th>(%) of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sold household assets/goods (radio, furniture, refrigerator, television, jewellery, etc.)</td>
<td></td>
</tr>
<tr>
<td>Reduced non-food expenditures on health (including drugs) and education</td>
<td></td>
</tr>
<tr>
<td>Sold productive assets or means of transport (sewing machine, wheelbarrow, bicycle, car, etc.)</td>
<td></td>
</tr>
<tr>
<td>Spent savings</td>
<td></td>
</tr>
<tr>
<td>Borrowed money/food from a formal lender/bank</td>
<td></td>
</tr>
<tr>
<td>Sold house or land</td>
<td></td>
</tr>
<tr>
<td>Withdrew children from school</td>
<td></td>
</tr>
</tbody>
</table>
6. Recovery Needs

Q6.1. What type of support is needed most to resume / enhance the crop production affected by FAW?

<table>
<thead>
<tr>
<th>Importance</th>
<th>Off season / minor season</th>
<th>Next main growing season</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td></td>
<td></td>
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<tr>
<td>Second</td>
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<td>Third</td>
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<td>Fourth</td>
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<tr>
<td>Fifth</td>
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</tr>
</tbody>
</table>

7. Additional Information

Q7.1. What else would you like to tell us about the FAW?

[Blank lines for additional information]
3.3. KEY INFORMANT INTERVIEW ON THE IMPACT OF THE FALL ARMY WORM ON SMALL-HOLDER FARMERS

Please refer to the soft copy of the instruction manual for interviewers and supervisors that is provided as an annex to this training manual.

INTERVIEWS (KIIs): To be held with extension workers.

NOTE: Throughout the conversation, the options provided in this form are not to be read to Key Informant participants. They are to be used only by the enumerator to ensure all issues are discussed and recorded.

General information

<table>
<thead>
<tr>
<th>Name of the Key Informant</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Official title / profession</td>
<td></td>
</tr>
<tr>
<td>Organisation/employer</td>
<td></td>
</tr>
<tr>
<td>Years of work experience in the area</td>
<td></td>
</tr>
<tr>
<td>Education level</td>
<td></td>
</tr>
<tr>
<td>Area of specialization</td>
<td></td>
</tr>
<tr>
<td>Cell phone number</td>
<td></td>
</tr>
<tr>
<td>email address</td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td></td>
</tr>
<tr>
<td>Agro-Ecological Zone</td>
<td></td>
</tr>
<tr>
<td>Province</td>
<td></td>
</tr>
<tr>
<td>District</td>
<td></td>
</tr>
<tr>
<td>Agricultural Camp/Ward</td>
<td></td>
</tr>
<tr>
<td>Village / Community name</td>
<td></td>
</tr>
<tr>
<td>Village / Community GPS coordinates</td>
<td></td>
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<tr>
<td>------------------------------------</td>
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<tr>
<td>Date of interview</td>
<td></td>
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<tr>
<td>Place of interview</td>
<td></td>
</tr>
<tr>
<td>Name of interviewer</td>
<td></td>
</tr>
<tr>
<td>Interviewer phone number</td>
<td></td>
</tr>
<tr>
<td>Gender of the Interviewer</td>
<td></td>
</tr>
<tr>
<td>Email address of the interviewer</td>
<td></td>
</tr>
</tbody>
</table>
1. Impact on Crops

Q1.1. What proportion of households rely on the following categories as their main source of livelihoods?

<table>
<thead>
<tr>
<th>Crop production (%)</th>
<th>Livestock production (%)</th>
<th>Fishery and aquaculture production (%)</th>
<th>Agricultural labour (%)</th>
<th>Trade of agricultural products (%)</th>
<th>Other agricultural livelihoods (i.e. forestry) (specify) (%)</th>
<th>Non-agricultural livelihoods (%)</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

Q1.2. For each of the main five crops grown in the area, can you please indicate the proportion of land area affected by FAW, the production losses and the average price?

Show the picture in Annex 1 to help identifying the pest

<table>
<thead>
<tr>
<th>List of up to five most affected crops</th>
<th>Crop Variety</th>
<th>Proportion of land area affected (%)</th>
<th>Proportion of yield loss (%)</th>
<th>Expected yield in the area (kg/ha)</th>
<th>Farm-gate price per kg</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Q1.3. What was the growth stage of the crops when the FAW attack was observed?

<table>
<thead>
<tr>
<th>List of the five most affected crops</th>
<th>Crop Variety</th>
<th>Growth stage*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

* (1) Emergence-Seedling; (2) Vegetative; (3) Flowering stage; (4) Post flowering.

Q1.4. Please indicate if the FAW infestation was localized or widespread across the fields.
Q1.5a) Were crops replanted following the FAW attack?

Yes ☐

No ☐

Q1.5b) If yes, what proportion of the affected land was replanted?

(Please list the five most affected crops only)

<table>
<thead>
<tr>
<th>List of the five most affected crops</th>
<th>(%) of affected land replanted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Q1.5c) What have the farmers done with the affected crops?

<table>
<thead>
<tr>
<th>List of crops</th>
<th>Use (i.e. animal feed, burnt, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Q1.5d) If crops were not replanted, could you please indicate the reasons?

(Rate the most important reason 1= less important, 5 =most important)

<table>
<thead>
<tr>
<th>Reason</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>It was too late to replant</td>
<td></td>
</tr>
<tr>
<td>The damage was insignificant</td>
<td></td>
</tr>
<tr>
<td>Farmers did not have additional seeds</td>
<td></td>
</tr>
</tbody>
</table>
Q1.6a. Did the extension officer get any information and/or training on how to deal with the FAW?

<table>
<thead>
<tr>
<th>Information</th>
<th>Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>Yes/No</td>
</tr>
</tbody>
</table>

Q1.6b. If yes, who/which institution provided the information/training and what type of information/training were given?

<table>
<thead>
<tr>
<th>Adviser/Trainer (i.e. FAO, academia, etc.)</th>
<th>Type of advice/Training</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Q1.7. What have you been recommending to farmers to manage/control FAW?

<p>| | |</p>
<table>
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</table>

Q1.8. Can you please state the main practices adopted/used by farmers to reduce the impact of the FAW attack?

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</tbody>
</table>

Farmers did not have additional fertilizers
Farmers were afraid to lose their production again
Other (please specify) .........................
Q.1. 9. Have you seen any effective and not effective cultural practices used by farmers to cope with FAW? *(If yes, please explain)*

<table>
<thead>
<tr>
<th>Effective practices</th>
<th>Not effective practices</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Q1.10. How useful were the pesticides applied to combat FAW?

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Crop affected</th>
<th>Crop variety affected</th>
<th>Effectiveness of the Pesticides applied*</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

* Rank in order of effectiveness 1=Very useful  5= Less useful
Q1.11. What is the proportion of farmers that used pesticides before the FAW attack and what is the proportion of farmers using them during the attack? (Please list maximum the 5 most common pesticide)

<table>
<thead>
<tr>
<th>Active Ingredients</th>
<th>Crops</th>
<th>Man</th>
<th>Woman</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before (%)</td>
<td>During (%)</td>
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</tbody>
</table>

Q1.12. Please indicate the main sources and prices of the pesticides used to combat FAW infestation. Please use the following options:

1= Bought from the local market; 2= Received for free from the government; 3= Received for free from an organization; 4= Own formulation; 5= Obtained from friends and / or relatives; 6= Commercial suppliers.

Note: Multiple answers are allowed

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Source (specify)</th>
<th>Price per Unit</th>
<th>Unit (liter, kg, etc.)</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

Q1.13. What are the three main sources of seed used by farmers in the area? (Rank in order of importance 1=Least important, 2=important, 3= Most important)
<table>
<thead>
<tr>
<th>Name of the five most common planted crops</th>
<th>Sources of seed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bought from local market</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

Q1.14. What are the three main challenges in accessing seeds for the farmers in the area? (Order of importance 1=Least important, 2=moderately important, 3= Most important)

<table>
<thead>
<tr>
<th>Name of the five most common planted crops</th>
<th>Challenge</th>
<th>Rank</th>
<th>Challenge</th>
<th>Rank</th>
<th>Challenge</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

2. **Impact on labour**

Q2.1. Did farmers rely on agricultural casual workers to spray or mix pesticides before and during the FAW attack? (If yes, indicate how many people (male, female, children), for how long and what the wage was per day)

Before the FAW attack
<table>
<thead>
<tr>
<th>Casual labour activities</th>
<th>Men (%)</th>
<th>Women (%)</th>
<th>Children (%)</th>
<th>Duration (Days)</th>
<th>Daily wage- (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide application</td>
<td></td>
<td></td>
<td></td>
<td>(Man) (Woman)</td>
<td>(Children) (adult) (Children)</td>
</tr>
<tr>
<td>Mixing pesticide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**During the attack or soon after**

<table>
<thead>
<tr>
<th>Casual labour activities</th>
<th>Men (%)</th>
<th>Women (%)</th>
<th>Children (%)</th>
<th>Duration (Days)</th>
<th>Daily wage- (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide application</td>
<td></td>
<td></td>
<td></td>
<td>(Man) (Woman)</td>
<td>(Children) (adult) (Children)</td>
</tr>
<tr>
<td>Mixing pesticide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Impact/effect on livestock**

Q3.1 Has livestock been affected by the FAW?

- Yes ☐
- No ☐

Q3.2. If yes, please indicate the effects of the FAW on livestock.

1
2
3

4. **Impact / effect on livelihoods**

Q4.1. How did the community cope with the effect of the FAW?

<table>
<thead>
<tr>
<th>List of coping mechanisms</th>
<th>Credit</th>
<th>Cash</th>
<th>(% of farmers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buy food on credit</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Borrowed money to purchase food
Reduce number of meals a day
Selling productive assets (e.g. livestock)
Other (specify)

Q4.2. What is the proportion of farmers affected by FAW infestation in the area?

|___|___| %

5. Recovery Needs

Q5.1. What type of support would farmers need most to mitigate the effects of the FAW?

<table>
<thead>
<tr>
<th>Importance</th>
<th>Off season / minor season</th>
<th>Next main growing season</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td></td>
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<tr>
<td>Second</td>
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<tr>
<td>Third</td>
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<tr>
<td>Fourth</td>
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<tr>
<td>Fifth</td>
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</tbody>
</table>

6. Other Hazards affecting the community

Q6.1. What are the main hazards affecting the community besides the outbreak of the FAW?

(Consider the list is not to be read. It is just for your support)

<table>
<thead>
<tr>
<th>List of hazards</th>
<th>Yes/No*</th>
<th>Recurrence (see code below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pest and disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hail</td>
<td></td>
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<tr>
<td>Flood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drought</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt water intrusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
*If yes, choose the recurrence code: once every two years or less (1), once a year (2), two time a year or more (3)

7. **Additional Info/Note:**

Q7.1. What else would you like to tell us about the FAW?
Key Informant Interview (commercial farmers) on the impact of the Fall Armyworm

INTERVIEWS (KIIs): To be held with owners of commercial farms.

Start the interview with the usual greetings and explain the purpose of the interview. Indicate that similar interviews were conducted with local extension officers and small-holder farmers but that at the same time we would like to collect additional specific information that can help us get the most accurate picture of the Fall Armyworm infestation.

NOTE: Throughout the conversation, the options provided in this form are not to be read to Key Informant participants. They are to be used only by the enumerator to ensure all issues are discussed and recorded.

General information

<table>
<thead>
<tr>
<th>Name of the Key Informant</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Official title / profession</td>
<td></td>
</tr>
<tr>
<td>Year of birth</td>
<td></td>
</tr>
<tr>
<td>Education level and field</td>
<td></td>
</tr>
<tr>
<td>Cell phone number</td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td></td>
</tr>
<tr>
<td>Agro-Ecological Zone</td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td></td>
</tr>
<tr>
<td>District</td>
<td></td>
</tr>
<tr>
<td>Village</td>
<td></td>
</tr>
<tr>
<td>Village / Community GPS coordinates</td>
<td></td>
</tr>
<tr>
<td>Date of interview</td>
<td></td>
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<tr>
<td>Place of interview</td>
<td></td>
</tr>
<tr>
<td>Name of interviewer</td>
<td></td>
</tr>
<tr>
<td>Interviewer phone number</td>
<td></td>
</tr>
</tbody>
</table>

Impact on Crops

Q1.1 Was your farm and agricultural production attacked by the Fall Armyworm pest?
Show the picture in Annex 1 to help identifying the pest

Yes □
1.2 If yes, can you please list the crops affected by the pest and indicate the proportion of land affected, the proportion of plants affected (in the same area) as well as the equivalent loss of production recorded?

<table>
<thead>
<tr>
<th>List of the five most affected crops</th>
<th>Crop Variety</th>
<th>Growth stage*</th>
<th>Area harvested</th>
<th>Proportion of cultivated land area affected (%)</th>
<th>Proportion of plants affected (%)</th>
<th>Estimated production losses at harvest (Kg/Ha)</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

*(1) Emergence-Seedling; (2) Vegetative; (3) Flowering stage; (4) Post flowering.

Q1.3a) Did you replant agricultural land following the FAW attack?

Yes ☐
No ☐

Q1.3b) If yes, what proportion of the affected land was replanted?

<table>
<thead>
<tr>
<th>List of the five most affected crops</th>
<th>(%) of affected land replanted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q1.3c) What use have you made with the affected/destroyed crops?

<table>
<thead>
<tr>
<th>List of affected/destroyed crops</th>
<th>Use (i.e. animal feed, burned, sold, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q1.3d) If you did not replant at all, can you please indicate the reason?

(Rate the most important reason 1 = less important, 5 = most important)

<table>
<thead>
<tr>
<th>Reason</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>It was too late to replant</td>
<td></td>
</tr>
<tr>
<td>The extent of damage did not justify replanting</td>
<td></td>
</tr>
<tr>
<td>I did not have additional seeds</td>
<td></td>
</tr>
<tr>
<td>I did not have additional fertilizers</td>
<td></td>
</tr>
<tr>
<td>I was afraid to lose my production again</td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
</tr>
</tbody>
</table>

Q1.4 How much maize (ton/Ha) have you harvested after the FAW attack and how much do you think you would have harvested if the attack had not occurred?

Harvest after FAW = .......... (Ton/Ha)

Potential harvest without FAW attack = ........ (Ton/Ha)

Q1.5. Did you get any advice on how to deal with the FAW attack?
If not move to Q.1.7

Yes ☐
No ☐

Q1.6. If yes, who did provide this advice and what type of advices were you given?

<table>
<thead>
<tr>
<th>Adviser (i.e. extension officer, neighbours, agro-dealer, etc.)</th>
<th>Type of advice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q1.7. Can you please describe the main strategies you have adopted to reduce the negative effects of the FAW attack?
N.B. Do not read the actions allow farmers to mention them and tick the ones that apply

<table>
<thead>
<tr>
<th>List of actions</th>
<th>Reasons why</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bought and sprayed pesticide</td>
<td></td>
</tr>
<tr>
<td>Requested advice from relevant authority (MoA)</td>
<td></td>
</tr>
<tr>
<td>Nothing (I did not know what to do)</td>
<td></td>
</tr>
<tr>
<td>Nothing, because I did not consider the pest infestation severe</td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
</tr>
<tr>
<td>..................................................................................</td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
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<tr>
<td>..................................................................................</td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
</tr>
<tr>
<td>..................................................................................</td>
<td></td>
</tr>
</tbody>
</table>

Q1.8. If you did apply pesticides, please indicate the names of the pesticides, the source of purchase, the number of application you made and the time span considered among each application.

<table>
<thead>
<tr>
<th>List of crops (up to 5 affected crops)</th>
<th>Crop Variety</th>
<th>Commercial names of pesticides</th>
<th>Source</th>
<th>Number of pesticide applications</th>
<th>Rates (Dosage) of pesticide application</th>
<th>Time span in-between applications (days)</th>
</tr>
</thead>
</table>
Q1.9. What are the main three sources of seeds you generally use? (Rank in order of importance 1=most important  3= least important)

<table>
<thead>
<tr>
<th>Name of the five most common planted crops</th>
<th>Sources of seed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bought from local market</td>
</tr>
</tbody>
</table>

Q1.10. Do you generally have any challenge in accessing seeds?

Yes ☐
No ☐

Q.1.11. If yes, what are the main three challenges in accessing seeds? (Rank in order of importance 1=Least important, 2=important, 3= Most important)

N.B Do not read the options allow farmers to express themselves and tick the one that applies

<table>
<thead>
<tr>
<th>Name of the five most common planted crops</th>
<th>Lack of markets</th>
<th>Limited access to market (too far)</th>
<th>Limited access to market (not enough money)</th>
<th>Others (specify)</th>
</tr>
</thead>
</table>

2. **Impact on labour**

Q.2.1 Do you generally hire agricultural casual/seasonal workers to spray pesticide?

Yes ☐
No ☐
Q2.2. If yes, can you please indicate the proportion of casual/seasonal workers (men and women) hired to spray pesticide before and during the FAW attack, as well as the duration of the hiring and the daily wage provided?

<table>
<thead>
<tr>
<th>Before the FAW attack</th>
<th>Casual labour activities</th>
<th>Men (%)</th>
<th>Women (%)</th>
<th>Children (%)</th>
<th>Duration (Days)</th>
<th>Daily wage- (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Man)</td>
<td>(Woman)</td>
</tr>
<tr>
<td>Mixing pesticide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Children)</td>
<td>(adult)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>During the attack or soon after</th>
<th>Casual labour activities</th>
<th>Men (%)</th>
<th>Women (%)</th>
<th>Children (%)</th>
<th>Duration (Days)</th>
<th>Daily wage- (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pesticide application</td>
<td></td>
<td></td>
<td></td>
<td>(Man)</td>
<td>(Woman)</td>
</tr>
<tr>
<td></td>
<td>Mixing pesticide</td>
<td></td>
<td></td>
<td></td>
<td>(Children)</td>
<td>(adult)</td>
</tr>
</tbody>
</table>

3. **Recovery Needs**

Q3.1. What type of support would commercial farmers like you need most to reduce the negative impact of the FAW, thus resume / enhance crop production?

<table>
<thead>
<tr>
<th>Importance</th>
<th>Off season / minor season</th>
<th>Next main growing season</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fourth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.4. IMPACT OF THE FALL ARMY WORM AT HOUSEHOLD LEVEL

Please refer to the soft copy of the instruction manual for enumerators and supervisors that is provided as an annex to this training manual.

FORM NUMBER:

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

FALL ARMYWORM IMPACT ASSESSMENT

Post-Harvest Household Questionnaire
Section 1:  IDENTIFICATION

1.1. Country........................................................................................................

1.2. Agricultural Ecological Zone ........................................................................

1.3. Region...........................................................................................................

1.4. District name................................................................................................

1.5. Village Name................................................................................................

1.6. Name of Enumerator.....................................................................................

1.7. Gender of the Enumerator

1.8. Name of respondent......................................................................................

1.9. Gender of the respondent............................................................................

1.10. GPS coordinates:  

    Longitude:  
    Latitude:
Section 2: household composition and income

2. 1. Please fill in the table

<table>
<thead>
<tr>
<th>Name of the members of the household</th>
<th>Head of household</th>
<th>Age</th>
<th>Gender</th>
<th>Education</th>
<th>Education level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What is the relationship to the head of the household?</td>
<td></td>
<td></td>
<td>Is the person attending school</td>
<td>What is the highest level of Education completed?</td>
</tr>
<tr>
<td></td>
<td>1. Head</td>
<td></td>
<td></td>
<td>1. Yes</td>
<td>1. No education</td>
</tr>
<tr>
<td></td>
<td>2. Spouse</td>
<td></td>
<td></td>
<td>2. No</td>
<td>2. Primary school</td>
</tr>
<tr>
<td></td>
<td>5. Other family member</td>
<td></td>
<td></td>
<td></td>
<td>5. Tertiary-</td>
</tr>
<tr>
<td></td>
<td>6. Unrelated</td>
<td></td>
<td></td>
<td></td>
<td>College/unv/polyt</td>
</tr>
<tr>
<td>First name should always be of the respondent</td>
<td>1 2 3 4 5 6</td>
<td>1 2</td>
<td>1 2</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
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<td>1 2 3 4 5 6</td>
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<td>1 2 3 4 5 6</td>
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<td>1 2 3 4 5</td>
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<td>1 2 3 4 5 6</td>
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<td>1 2 3 4 5</td>
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<td>1 2 3 4 5 6</td>
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<td>1 2 3 4 5</td>
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<td>1 2 3 4 5 6</td>
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<td>1 2 3 4 5</td>
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<td>1 2 3 4 5 6</td>
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<td>1 2 3 4 5</td>
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<tr>
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<td>1 2 3 4 5 6</td>
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<td>1 2 3 4 5</td>
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<td>1 2 3 4 5 6</td>
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<td></td>
<td>1 2 3 4 5 6</td>
<td>1 2</td>
<td>1 2</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

102
2.2. Does this household rely entirely on agriculture produce for an income?

1. Yes…………………………….. |___|
2. No…………………………… |___|

2.3. What are other sources of income/cash for this household? (Many answers possible) (to be asked if Q2.2 is “No”)

1. Sells part of the agriculture produce
2. Monthly Salary
3. Remittance-money from relatives
4. Work for other people for an income
5. Pension/old age grant
6. Other, specify…………………………………………..

2.4. How important is your farm produce (crops only) for your household income?

1. A very minor part (less than < 10%)
2. A minor part (less than a half 10% to 40%)
3. About half (40% to 60%)
4. A major part (60% to 90%)
5. The entire area (> 90%)

2.5. What is the ratio of your expenditure on food to your total expenditure?
Section 3: Farming

3.1. Which crops were grown in the just ended season (2016/2017 cropping season)?

1. Maize
2. Pearl Millet
3. Sorghum
4. Other (specify)
5. None

3.2. How much did you produce of each crop in the ended season (2016/2017 cropping season)?

<table>
<thead>
<tr>
<th>Maize</th>
<th>Pearl Millet</th>
<th>Sorghum</th>
<th>Non cereals (specify)</th>
<th>Other (specify)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

- Half a bucket = 10 kg, 1 bucket = 20 kg,
- Half metal drum =100kg ;1 drum=200kg,
- Granary—small =  100kg; Medium= 150kg, large=200kg
- Bags, ask the size of the bag in Kg

3.3. How many hectares did you harvest during the ended cropping season (for each crop selected in 3.1)?

<table>
<thead>
<tr>
<th>Maize</th>
<th>Pearl Millet</th>
<th>Sorghum</th>
<th>Non cereals (specify)</th>
<th>Other (specify)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.4. What proportion (0-100%) of your agricultural land is irrigated/rainfed?
1. Irrigated
2. Rainfed

3.5. When was the maize planting date? (if maize was selected in 3.1)

Jan    Feb    March    April    May    June
July   August   September  October  November  December

3.6. When was the date of the last harvest? (if maize was selected in 3.1)

Jan    Feb    March    April    May    June
Section 4 - Screening questions

This section will help the enumerators to record if the farmer being interviewed has seen FAW in his/her field or not.

4.1. In the ended season (2016/2017 cropping season), did you experience any of the following problems in your crop field?

Shows to the farmer the pictures illustrating presence of FAW at different reproductive stages and ask if he/she recognizes any.

1. Young caterpillars
2. Leaves with external feeding creating “windowing” effect
3. Damage near the tunnel
4. Caterpillar with Y on head
5. Larvae within leaves with deep feeding
6. Holes on maize cobs
7. Larva feeding on cob
8. NO  ----------------------------------------------------- go to section 7.

4.2. Which crops were affected by the fall army worm in your crop field in the ended season (2016/2017 cropping season)?

6. Maize
7. Pearl Millet
8. Sorghum
9. Non-cereals (e.g. beans, watermelons, etc.) (please specify)
10. Other (specify)
11. None

-----------------------------------------------------

4.4. Which season have you seen the fall army worm for the **first time**?
1. This cropping season (2016/17)  
2. The previous cropping season (2015/16)  
3. A few cropping seasons ago (before 2015/16)

Section 5-Impact

5.1 At what stage of crop development were your maize plants affected?

(This question is applied for maize only and for the ended cropping season (2016/2017))

Show to the farmers the picture with the 8 stages of growth and ask to select the correspondent stage.

1. 0  
2. 0.5  
3. 1  
4. 2  
5. 3  
6. 4  
7. 5  
8. 6-7

5.2. Without fall armyworm infestation, how much would you have produced of each crop in the ended season (2016/2017 cropping season)? (for each crops selected in Q4.2)

<table>
<thead>
<tr>
<th>Maize</th>
<th>Pearl Millet</th>
<th>Sorghum</th>
<th>Non cereals (specify)</th>
<th>Other (specify)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Half a bucket=10 kg, 1 bucket=20 kg,
- Half metal drum = 100kg; 1 drum = 200kg,
- Granary—small = 100kg; Medium = 150kg, large = 200kg
- Bags, ask the size of the bag in Kg

5.3. How much of your area cultivated was affected by FAW during the last cropping season? (for each crop selected in 4.2)

The enumerator should try to pull out the answer from the farmer using a participatory approach

1. A very minor part (less than <10%)
2. A minor part (less than a half 10% to 40%)
3. About a half (40% to 60%)
4. A major part (60% to 90%)
5. The entire area (>90%)

5.4. In the field(s) that was affected, what proportion of plants were affected? (for each crop selected in 4.2)

1. A very minor part (less than <10%)
2. A minor part (less than a half 10% to 40%)
3. About a half (40% to 60%)
4. A major part (60% to 90%)
5. The entire area (>90%)

5.5. Have you been engaged in any of the following actions in response to the FAW attack?

<table>
<thead>
<tr>
<th>List of coping mechanisms</th>
<th>Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sold household assets/goods (radio, furniture, refrigerator, television, jewellery, etc.)</td>
<td></td>
</tr>
<tr>
<td>Reduced non-food expenditures on health (including drugs) and education</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Sold productive assets or means of transport (sewing machine, wheelbarrow, bicycle, car, etc.)</td>
<td></td>
</tr>
<tr>
<td>Spent savings</td>
<td></td>
</tr>
<tr>
<td>Borrowed money/food from a formal lender/bank</td>
<td></td>
</tr>
<tr>
<td>Sold house or land</td>
<td></td>
</tr>
<tr>
<td>Withdrew children from school</td>
<td></td>
</tr>
<tr>
<td>Sold last female animals</td>
<td></td>
</tr>
<tr>
<td>Begging</td>
<td></td>
</tr>
<tr>
<td>Sold more animals (non-productive) than usual</td>
<td></td>
</tr>
</tbody>
</table>
Section 6 – Control Practices

The following questions are for [crops selected in Q4.2] and for the ended cropping season (2016/2017)

6.1 Did you do anything to control the fall army worm attack on [crops selected in Q4.2]?

1. Yes
2. No go to section 7

6.2 If YES in 6.1, what intervention did you put in place for [crops selected in Q4.2]? (Many answers possible)

Circle the answer related to what the farmer is telling you

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Early planting (plant early so the plant is well established when the pest comes, and it has more chance to survive)</td>
</tr>
<tr>
<td>2.</td>
<td>Plant resistant varieties/tolerant varieties</td>
</tr>
<tr>
<td>3.</td>
<td>Crop rotation - recommended to rotate with non-host plants e.g. legumes, cotton, sunflower, etc. (to avoid buildup of pests)</td>
</tr>
<tr>
<td>4.</td>
<td>Frequent weeding (to remove alternative host plants)</td>
</tr>
<tr>
<td>5.</td>
<td>Improve soil fertility - manure or chemical fertilizer (to stimulate strong plant growth and ability to sustain pest attack)</td>
</tr>
<tr>
<td>6.</td>
<td>Apply ash on larvae when larvae are really young (once the larvae gets old it is too late).</td>
</tr>
<tr>
<td>7.</td>
<td>Application of Neem based products powder – can be mixed (1:1) with dry clay or sawdust – wood dust (natural insecticide and irritants)</td>
</tr>
<tr>
<td>8.</td>
<td>Intercrop maize with non-hosts non legumes crops like cassava or others</td>
</tr>
<tr>
<td>9.</td>
<td>Intercrop maize with non-host legumes like cowpea or others</td>
</tr>
<tr>
<td>10.</td>
<td>Trap cropping: use a trap plant e.g. Napier grass as a border crop (to draw/pull pest out of maize crop and into this preferential host plant)</td>
</tr>
<tr>
<td>11.</td>
<td>Push-pull: use a trap plant e.g. Napier grass as a border crop (to draw/pull pest out of maize crop and into this preferential host plant) and intercrop with a repellent plant e.g. legume such as Desmodium (to ‘push’ repel pest out of the crop area) (these options work also alone but more effective together)</td>
</tr>
<tr>
<td>12.</td>
<td>Remove crop residues that are damaged by pests or diseases (to remove pest from the field and avoid build up in following year)</td>
</tr>
<tr>
<td>13.</td>
<td>Uproot and burning of infected plants (to destroy larvae and pupae)</td>
</tr>
<tr>
<td>15.</td>
<td>Handpicking egg masses and caterpillars (needs labour and only effective for early larval stages before larvae enter the stem)</td>
</tr>
<tr>
<td>16.</td>
<td>Replanting</td>
</tr>
<tr>
<td>17.</td>
<td>Biological control options - Encouraging natural enemies (predators &amp; parasites) into field by planting their host plants in field boundaries – the plants are the ones that host the predators and parasites. Larvae can be eaten by birds, spiders, ants and killed by parasitic wasps, wasp lays its eggs inside the larvae and when they grow they kill the larvae.</td>
</tr>
<tr>
<td>18.</td>
<td>Other (specify) ..................................................</td>
</tr>
</tbody>
</table>

6.3 Do you think the interventions [read the interventions selected in 6.2 used for crops selected in Q4.2] was successful?
Ask for each of the interventions selected

1. Extremely successful
2. Somewhat successful
3. Not successful

<table>
<thead>
<tr>
<th>Type of intervention</th>
<th>Degree of success</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.4. Were there other interventions you wanted to apply but did not? Please refer to the list of Q. 6.2

1. Yes
2. No

6.5. If YES, specify what other intervention the farmer wanted to apply but did not

3. Early planting (plant early so the plant is well established when the pest comes, and it has a better chance to survive)
4. Plant resistant varieties/tolerant varieties
5. Crop rotation - recommended to rotate with non-host plants e.g. legumes, cotton, sunflower, etc. (to avoid build up of pests)
6. Frequent weeding (to remove alternative host plants)
7. Improve soil fertility - manure or chemical fertilizer (to stimulate strong plant growth and ability to sustain pest attack)
8. Apply ash on larvae when larvae are really young (once the larvae gets old it is too late).
9. Application of Neem based products powder – can be mixed (1:1) with dry clay or sawdust – wood dust (natural insecticide and irritants)
10. Intercrop maize with non-hosts non legumes crops like cassava or others
11. Intercrop maize with non-host legumes like cowpea or others
12. Trap cropping: use a trap plant e.g. Napier grass as a border crop (to draw/pull pest out of maize crop and into this preferential host plant)
13. Push-pull: use a trap plant e.g. Napier grass as a border crop (to draw/pull pest out of maize crop and into this preferential host plant) and intercrop with a repellent plant e.g. legume such as Desmodium (to push repel pest out of the crop area) (these options work also alone but more effective together)
14. Remove crop residues that are damaged by pests or diseases (to remove pest from the field and avoid build up in following year)
15. Uproot and burning of infected plants (to destroy larvae and pupae)
16. Application of Pesticide – if selected don’t ask question 6.9
17. Handpicking egg masses and caterpillars (needs labour and only effective for early larval stages before larvae enter the stem)
18. Other (specify)…………………………………………..
6.6. For each of the intervention [read the interventions selected in 6.5] the farmer wanted to apply but did not, specify the reason(s) for not applying

1. Too expensive
2. Time consuming
3. Inputs are not available
4. Inputs are too far and not easily accessible
5. Did not know where to obtain the inputs
6. I didn’t understand how to apply the commendation
7. It is not up to me to make the decision to do things differently
8. Other – specify ..............................................................

<table>
<thead>
<tr>
<th>Type of intervention</th>
<th>Reasons for not applying</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.7. Through which sources did you receive information on FAW?

Choose from the menu of options the sources of information on FAW for farmers

<table>
<thead>
<tr>
<th>Sources of information</th>
<th>What was the provider of the information</th>
</tr>
</thead>
<tbody>
<tr>
<td>My own experience</td>
<td></td>
</tr>
<tr>
<td>Another household member</td>
<td></td>
</tr>
<tr>
<td>Neighbors, friends and family</td>
<td></td>
</tr>
<tr>
<td>Agricultural programs on the radio</td>
<td></td>
</tr>
<tr>
<td>Agricultural programs on the TV</td>
<td></td>
</tr>
<tr>
<td>Extension officers</td>
<td></td>
</tr>
<tr>
<td>Books/flyers/pamphlets</td>
<td></td>
</tr>
<tr>
<td>Agro-dealers</td>
<td></td>
</tr>
<tr>
<td>Demonstration plots / field days</td>
<td></td>
</tr>
<tr>
<td>Farmers promoters</td>
<td></td>
</tr>
<tr>
<td>NGO (specify)</td>
<td></td>
</tr>
<tr>
<td>Agricultural shows</td>
<td></td>
</tr>
<tr>
<td>Newspapers/magazines/bulletins</td>
<td></td>
</tr>
<tr>
<td>Mobile sms and voice services</td>
<td></td>
</tr>
<tr>
<td>Farmers field schools (FFS) – farmers facilitators</td>
<td></td>
</tr>
<tr>
<td>Plant clinics/plant doctors</td>
<td></td>
</tr>
<tr>
<td>Women’s’ group</td>
<td></td>
</tr>
</tbody>
</table>
6.8. If you applied fertilizer, could you tell us:

*This question is intended for application of fertilizer linked with management of FAW for the last cropping season.*

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Type</th>
<th>Quantity</th>
<th>Unit</th>
<th>Price per unit</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. manure/organic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. chemical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.9. If you applied pesticide, could you tell us:

*This question is intended for application of pesticide linked with management of FAW. We will be recording information only for the last cropping season.*

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Name / active ingredient</th>
<th>Quantity</th>
<th>Unit</th>
<th>Price per unit</th>
<th>Source</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Activity</th>
<th>No. of times applied</th>
<th>No. of HH members involved in spraying</th>
<th>Hours per day</th>
<th>No. of days per week</th>
<th>No. of weeks in the previous cropping season</th>
<th>No. of hired people</th>
<th>Hour s per day</th>
<th>No. of days per week</th>
<th>No. of weeks in the previous cropping season</th>
<th>Cost of hired labour</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprayin g pesticide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.10. Did you or any member of the household received any agricultural input for free during the last season?

1. Yes [ ]
2. No [ ]

6.11. If YES, what input did you received and from whom?
<table>
<thead>
<tr>
<th>Input type</th>
<th>Received [yes or no]</th>
<th>Source of input</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1. NGO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Government</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Other (specify)</td>
</tr>
<tr>
<td>Fertilizer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeds (specify for what crop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Section 7: Shocks**

*This section will help to understand if the farmer went through any other shock pest/disease and non pest/disease related.*

7.1 In the ended cropping season (2016/17), did you experience crop failure due to? –*Read the answers below*

1. Drought or insufficient water
2. Excess rain or flood
3. Pests/diseases (different from FAW)
4. Hails
5. Crop destroyed by livestock/theft
6. Sickness (human)
7. Other (specify)..............................

**Section 8: Needs**

8.1 Bearing in mind the difficulties / shocks which you have highlighted, including the FAW, if applicable, which type of support would you prioritize?

<table>
<thead>
<tr>
<th>Importance</th>
<th>Off season / minor season (winter cropping)</th>
<th>Next main growing season (summer season)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fourth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

End – Thank you very much for your time and the information provided which will be treated confidentially.
4. MANAGEMENT OPTIONS FOR FAW

Many governments in Africa have responded to the invasion of FAW by providing emergency pesticides to farmers as a first step and frequent insecticide applications have been used to protect maize crops against damage by FAW. Although it may be accepted that pesticides will continue to be a component of pest management for the present until alternative management systems have been fully developed, resistance to some pesticides by FAW has been noted, giving urgency to the need to develop and adopt alternative sustainable integrated programs to fight this pest in Africa. This module explores the various management options that are available, highlighting the merits and challenges posed by each system. Adoption of an integrated approach to managing the pest is encouraged which should be effective, economic and pose the least possible hazard to humans and the environment. A section of this module is dedicated to expounding risks posed by incorrect pesticide use and technologies available for smallholder farmers.

a. Biopesticides
Entomopathogens as potential control option against the fall army worm, *Spodoptera frugiperda*

Dr Justin L. Hatting
ARC-Small Grain
Bethlehem

INSECTS ARE PRONE TO INFECTION BY VARIOUS MICROORGANISMS

...referred to as ENTOMOPATHOGENS
Current status of insect resistance against chemical insecticides

FAW resistance to pyrethroids: 2- 216-fold
FAW resistance to organophosphorus insecticides: 12- to 271-fold
FAW resistance to carbamates: 14- to >192-fold

STRATEGIES CONSIDERED WHEN USING EPs

(1) Conservation Biological Control (CBC)
Promote survival of naturally occurring EPs – “ecosystem services”
• Know the species complex
• Understand EP phenology
• Understand impact of pesticides (compatibility?)
Agricultural production based on AGRO-ECOLOGICAL principals

(2) Development of bio-insecticides based on EPs
Isolate, test & select, mass produce, formulate, commercialize
(in partnership with industry)

(3) Development of bio-inoculants
‘Induced Systemic Resistance’ through endophytes
### INSECT PATHOGENS AND THEIR USE IN PEST CONTROL

**5 ENTITIES:**

1. **Bacteria**
   - Live cells applied (e.g., *Serratia entomophila* – grubs in New Zealand)
   - Toxin applied (e.g., *Bacillus thuringiensis* produces Cry toxins)
   - Transgenic plants (e.g., Bt toxin expression within the host plant)

2. **Viruses**
   - Virions applied (e.g., *Baculoviridae*: NPV / GV – against Lepidoptera)

3. **Protozoa**
   - Spores applied (e.g., *Nosema locustae* – grasshoppers and crickets)

4. **Nematodes**
   - Infective juveniles (LJ’s) applied (e.g., *Heterorhabditis bacteriophora* – white grubs
     *Steinernema carpocapsae* – root weevils)

5. **Fungi**
   - Spores applied (e.g., *Metarhizium* – spittlebugs, locusts
     *Bacillus* – aphids, whiteflies)

* Including endophytic associations with host plant

### 2. DEVELOPMENT OF BIO-INSECTICIDES: 7 KEY STEPS

Bio-insecticides against FAW very limited!

1. **Identification** of problem pests (could be due to resistance (efficacy), residues
   (reduced MRL’s), withdrawal of chemical active from market due to health and/or
   environmental issues, chemical costs (importation, etc.), and/or organic market
   requirements)

2. **Survey/collection** of pathogens (directly: diseased insects and/or indirectly from
   soil using the insect-trap method)

3. **Isolation** of pathogens with potential for development as bioinsecticide/s (verify
   pathogenicity – Koch’s Postulates)

4. **Bioassays** (LC50 and LT50) to select most virulent isolate/s

5. **Mass production and formulation** (quality control in terms of germination, purity
   and shelf-life)

6. **Field trials to generate data for registration** (the package would include
   efficacy, shelf-life, quality and possibly toxicological data)

7. **Marketing/distribution**
Course of infection by microorganisms in an insect host

FAW life-cycle: summary (pertinent to spread/ control)

Life cycle, 24 - 40 days

- Adult ♂ live up to 21 days, av. 10 days
- Pupal stage, 7 - 13 days
- Larval stages, L1 - L6 about 14 - 22 days
- Pre-oviposition period, 3 - 4 days
- 100 to 200 eggs mass up to 2000, 2 - 3 days

Dead moths a natural occurrence, but diseased moths possible

Dead larvae, pupae and/or moths should be taken notice of. These may harbour potential pathogens!
Pathogen types most likely to infect FAW

**VIRUSES**
- Nucleopolyhedrovirus (NPV) and Granulovirus (GV) in the family Baculoviridae – LARVAE
- Species-specific pathogens, e.g. Spodoptera frugiperda Baculovirus-multiples embedded nucleopolyhedrovirus (SiMNPV) – no impact on beneficials
- Infection through ingestion (per os) of occlusion bodies (OBs) called polyhedra (NPVs) or granules (GV), encapsulated in a protein matrix
- The occlusion bodies are alkali-soluble and are dissolved by high pH of the insect midgut (FAW: 2nd – 5th instars are most susceptible; 6th least susceptible)
- Diseased insects typically become liquefied (easily rupturing to release OBs)
- Small scale farmers: 11 to 14g of dead larvae/ha (Valicente et al., 2013) (https://link.springer.com/content/pdf/10.1007/s13744-013-0108-6.pdf)

Bollworm infected with NPV

Pathogen types most likely to infect FAW

**BACTERIA**
- *Bacillus thuringiensis* (BT) in the family Bacillaceae – LARVAE
- Several strains commercially available, worldwide. Eg. B. thuringiensis var. aizawai, Bt var. kurstaki, Bt var. israelensis
- Insecticidal proteins known as Cyt (Cytolysins) and Cry (Crystal α-endotoxin)
- Infection through ingestion (per os) of protein crystals
- The crystals are alkali-soluble and are dissolved by high pH of the insect midgut
- Emergency reg. of Florbac WG® (Bt var. aizawai) requested in SA (Philagro)
- Note, resistance to Bt has been documented in several pests
- GM Crops expressing Bt toxin in use today against several pests, but resistance has been documented (IPM approach is advised!)
- Comprehensive paper on Bt:

[Image of Bacterial infection]
Pathogen types most likely to infect FAW

** FUNGI **

- *Metarhizium brunneum, Metarhizium rileyi* in the *Clavicipitaceae* – ALL STAGES (Eggs?)
- *Beauveria bassiana* and *isaria fumosorosea* in the *Cordycipitaceae* – ALL STAGES (Eggs?)
- *Zoophthora radicans* in the *Entomophthoromycota*
- Direct penetration of the insect cuticle (spore germtube), but *per os* infection also possible. Ensure good contact with target!
- Insecticidal compounds produced, e.g. Beauvericin by *B. bassiana*
- Insect death also brought about by physical destruction of vital organs
- External growth and sporulation on cadaver may lead to secondary recycling in the environment
- Emergency reg. of Eco-Bb WP® (*B. bassiana*) in SA (Plant Health Products Pty. Ltd)

![Larva infected with *Z. radicans*](image1)

![Larva infected with *M. rileyi*](image2)

Pathogen types most likely to infect FAW

** FUNGI **

1. Fungal spore (infective unit) coming into contact with insect
2. Germination on insect cuticle (skin) and penetration
3. Internal growth causing death of insect through physical organ damage and/or production of toxic compounds
4. External fungal growth on cadaver and production of spores, released into environment

** Typical disease cycle of an insect-killing fungus **
TYPICAL SIGNS OF INFECTION WITH **BEAUVERIA**

- Larval stage infected with *B. bassiana* (left). Photo: J.L. Hatting
- Fungal growth mainly confined to cadaver. Photo: T. Goble
- Adult beetle infected with *B. bassiana*. Photo: J.L. Hatting

Also look for other infected Coleoptera!

TYPICAL SIGNS OF INFECTION WITH **METARHIZIUM**

- Larval and adult stage infected with *Metarhizium*. Photo: T. Goble
- Dry spore columns (‘sporocarps’) on insect cuticle

As a general rule, if the fungus is white, purplish or yellow/green to orange in colour, and mainly confined to the insect body, collect it!
Bioassay against *Helicoverpa armigera* - mortality and feeding response post inoculation (per os)

% Mortality

Days

Chickpeas consumed

CBC: IMPACT OF PESTICIDES

Effect of different insecticides at 5 concentrations on fungal radial growth (mm)

<table>
<thead>
<tr>
<th>EPF + Chemical</th>
<th>9% (control)</th>
<th>9%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>100%</th>
<th>(controls)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. bassiana</em> + Pyrimicarb</td>
<td>28±2a</td>
<td>37±1a</td>
<td>32±3a</td>
<td>50±5a</td>
<td>36±2a</td>
<td>37±2a</td>
<td></td>
</tr>
<tr>
<td><em>B. bassiana</em> + Acetamiprid</td>
<td>30±3ab</td>
<td>32±2b</td>
<td>30±2ab</td>
<td>32±1ab</td>
<td>32±1ab</td>
<td>32±1ab</td>
<td></td>
</tr>
<tr>
<td><em>B. bassiana</em> + Chlorpyrifos</td>
<td>30±2a</td>
<td>30±1a</td>
<td>40±1a</td>
<td>40±1a</td>
<td>40±1a</td>
<td>37±2a</td>
<td></td>
</tr>
<tr>
<td><em>B. bassiana</em> + Cypermethrin</td>
<td>28±2a</td>
<td>30±1a</td>
<td>34±1a</td>
<td>36±2a</td>
<td>35±1b</td>
<td>35±1b</td>
<td></td>
</tr>
<tr>
<td><em>M. brunneus</em> + Pyrimicarb</td>
<td>37±2a</td>
<td>35±1a</td>
<td>37±2a</td>
<td>37±2a</td>
<td>37±2a</td>
<td>37±2a</td>
<td></td>
</tr>
<tr>
<td><em>M. brunneus</em> + Acetamiprid</td>
<td>24±2ac</td>
<td>25±1c</td>
<td>27±2a</td>
<td>26±3ab</td>
<td>26±3ab</td>
<td>26±3ab</td>
<td></td>
</tr>
<tr>
<td><em>M. rifeti</em> + Oxamtheon</td>
<td>27±3b</td>
<td>30±1ab</td>
<td>31±1ab</td>
<td>33±2ab</td>
<td>30±3ab</td>
<td>34±2ab</td>
<td></td>
</tr>
<tr>
<td><em>M. rifeti</em> + Cypermethrin</td>
<td>49±1c</td>
<td>49±1c</td>
<td>49±1c</td>
<td>49±1c</td>
<td>49±1c</td>
<td>49±1c</td>
<td></td>
</tr>
</tbody>
</table>

- **Stimulate**
- **Neutral**
- **Inhibit**

Effect of fungicides on EPF more pronounced:
No growth of *Conidiotobolus thomboideus* at Field Rate, FR:10, FR:100, FR:1000 of Folicur, Alto Ambel, Sportak and Sportak Alpha (triazole and imidazole compounds)
Quantify fungal virulence (LC<sub>50</sub>) through bioassays

Pathogen types most likely to infect FAW

NEMATODES (EPN)

- *Heterorhabditis bacteriophora* and *H. indica* as well as *Steinemema carpocapsae*—LARVAE AND PUPAE
- Vectors for insect-killing bacteria (*Xenorhabdus* spp. and *Photorhabdus* spp)
- Infection through natural openings (mouth, anus, spiracles) or directly through intersegmental membranes (*Heterorhabditis* spp. only)
- Capable of causing mortality within 48h!
- Most effective against soil-borne stages but larvae also highly susceptible
- Emergence of infective juveniles (IJs) followed by searching and infection of new hosts may lead to secondary recycling in the environment
- Generally compatible with chemical insecticides (e.g., Chlorpyrifos, Deltamethrin, Diflubenzuron, Spinosad and Triflumuron) (Negrisoli et al., 2010)

TYPICAL COLOUR VARIATION ACCORDING TO EPN TYPE

*Heterorhabditis* infected cadavers

*Steinemema* infected cadavers
PROTOCOL FOR COLLECTION, BASIC IDENTIFICATION AND SHIPMENT OF DISEASED INSECTS

Compiled by Justin L. Hatting
ARC-Small Grain Institute
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Bethlehem
9700
South Africa

PROMOTE THE INTEGRATION OF BIO-INSECTICIDES INTO MAIN-STREAM CROP PROTECTION THROUGH...

1. Establishment of realistic requirements for product registration under Act 36 of 1947

2. ‘Boot-strapping’ of products for a specific pest-crop system
   (‘Don’t bring the market to the product – bring the product to the market’)

3. Quality control, quality control, quality control....
   (Companies must take responsibility)

4. Knowledge of the product and target (through education of end-users via agents, etc.)
   (‘Spray 10% of the time and get 90% control versus spray 90% of the time and get 10% control’)

5. Use and development of novel application strategies and/or equipment
b. Biological control

Biological Control of Fall Armyworm in Southern Africa: A Synthesis

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What is biological control?

• It is the exploitation of natural enemies to suppress pest densities.

Why biological control?

• As predatory insects and parasitoids actively search for prey and hosts, biological control can be a permanent feature in agro-ecosystems.
• When established, it has a high benefit–to–cost ratio (DiTomaso et al. 2017. Biological Control).

Types of natural enemies

• Predators,
• Parasitoids,
• Entomopathogens.
Predators of FAW

Predators on plants (8 spp.)

- Earwigs *Doru* spp. (Dermaptera: Forficulidae), South America
- Spined soldier bug *Podisus* spp. (Heteroptera: Pentatomidae), Brazil, Central and North America
- Predatory wasp *Pachodynerus guadulensis* (Hymenoptera: Vespidae), Brazil
- *Isodontia* sp. (Hymenoptera: Sphecidae), Brazil
- *Trypoxylon nitidum* (Hymenoptera: Crabronidae), Brazil
- *Orius* sp. (Heteroptera: Anthocoridae), Mexico
- *Castorius* sp. and *Zeus longipes* (Heteroptera: Reduviidae), Mexico
- Spiders?
- Ladybird beetles?

Efficacy evaluation

- On the plants - densities and diversity on the crop,
- On the soil – pitfall traps to estimate densities and diversity,
- All – need to confirm if they consume the target pest.
- Molecular gut content analyses.
- Effective when they prevent crop damage.
Parasitoids of FAW

Egg parasitoids

Hymenoptera: Trichogrammatidae

- *Trichogramma* spp., South America, Mexico

Hymenoptera: Scelionidae

- *Telenomus remus*, Brazil

Hymenoptera: Braconidae

- *Cheilonus* spp., Argentina, Central America, USA.

Larval parasitoids

Hymenoptera: Ichneumonidae (4 spp.)

- *Campoletis* spp., Argentina, USA; *Pristomerus spinator*, Mexico, USA; *Ophion flavidus*, South America, Mexico, USA; *Hyposoter annulipes*, USA

Hymenoptera: Braconidae (5 spp.)

- *Cotesia marginiventris*, USA; *Aleyodes la phygmae*, Brazil, Mexico, USA; *Meteorus* spp., South America, Mexico, USA; *Habrobracon*, Mexico; *Hololobus truncator*, Mexico

Hymenoptera: Eulophidae (2 spp.)

- *Euplectrus platyhyphenae*, South America, Mexico, USA; *Horusmanus* sp. nr. *ignotus*, USA

Diptera: Tachinidae (3 spp.)

- *Archytas* spp., Americas; *Lespesia* spp., USA; *Eucelatoria rubentis*, USA
Pupal parasitoids

- *Trichospilus diatraceae* (Hymenoptera: Eulophidae), South America

Efficacy evaluation

- Parasitism rates.
- Effective when maintained above 50%.

---

Classical Biological Control
Biological control in Southern Africa

• Southern Africa has a rich biodiversity of indigenous organisms with great potential for biological control.

• Majority of parasitoids are Ichneumonidae (500 spp.), Tachinidae (377 spp.) and Braconidae (80 spp.).

Parasitoids of FAW

South Africa

• April 2017, Pretoria

Tachinidae (2 spp.)

Diseased larvae
Scouting for FAW parasitoids

Pest incidence on the crop
- Number of plants sampled have to be representative of field size.
- Random sampling – avoid re-scouting/sampling plants.
- Record the pest densities on each scouting event.
- At least once a week over 2 years.

Evaluating parasitism
- Take representative samples (healthy and sickly) of host life stages.
- Place samples individually in vials in a cooler box.
- Label samples in the lab, and provide them with food.
- To determine effect of total parasitism on the pest population.
- Impact of each natural enemy.
- Fields must be dedicated to biological control.

Case study: the diamondback moth system
- Universally distributed pest of Brassica crops, causing 100% crop losses.
- Global losses and management costs estimate – US$ 4-6 billion annually (Zalucki et al. 2012).
Aims
• Impact of indigenous parasitoids on pest density in South Africa.
• Use of pheromone trap catches to predict crop infestations.

Study
• About 2,500 cabbage seedlings were transplanted three consecutive times a year (Feb 2002 – Jan 2008).
• No insecticides were applied.
• Three synthetic sex pheromone traps were deployed around 50 X 30m plots. They were serviced weekly, and pheromones changed every 6 weeks.
• At weekly intervals, numbers of DBM larvae, pupae and parasitoid cocoons found on 30 randomly selected plants were recorded.
• To determine parasitism, samples were collected. Taken to the laboratory and placed singly in glass vials, and Petri dishes. Provided with fresh honey.

DBM population dynamics
Impact of parasitoids

Notemelia, 2010. *Entomologia Experimentalis et Applicata*

Effect of temperature

Notemelia, 2010. *Entomologia Experimentalis et Applicata*
Effect by individual species

![Bar graph showing the effect by individual species with error bars.](image)

Primary parasitised species:
- C. vestalis
- O. sokolowskii
- D. molipla
- D. collaris
- A. halfordi

Efficacy evaluation:
- C. vestalis & A. halfordi
- Diadegma molipla
- Oomyzus sokolowskii
- Diadromus collaris

Nofemele, 2013. Biological Control
• Each cocoon represents a dead host.

• Thus, ratios of parasitoid cocoons to infestations have a potential to estimate background parasitism levels reliably during scouting events.

Efficacy evaluation

\[ r^2 = 0.6666, P < 0.001, y = 0.0030 + 0.0595x \]
Relationship between trap catches and infestations

Nofemela, 2010. *Entomologia Experimentalis et Applicata*
Relationship between trap catches and infestations

Nofemela, 2010. *Entomologia Experimentalis et Applicata*

Relationship between trap catches and infestations

Nofemela, 2010. *Entomologia Experimentalis et Applicata*
Case study: the diamondback moth system

![Graph showing proportion of plants infested vs. Plutella xylostella per plant with a linear regression line and equation.]

Bopape, 2013. MSc thesis, UNISA

### Case study: the diamondback moth system

<table>
<thead>
<tr>
<th>Treatments</th>
<th>October–December 2011</th>
<th>March–May 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Infestation per plant</td>
<td>Infestation per plant</td>
</tr>
<tr>
<td>Control</td>
<td>4.53 ± 0.36a</td>
<td>0.86 ± 0.08a</td>
</tr>
<tr>
<td>Dipel1</td>
<td>0.54 ± 0.06bd</td>
<td>0.03 ± 0.01c</td>
</tr>
<tr>
<td>Dipel2</td>
<td>2.22 ± 0.25c</td>
<td>0.09 ± 0.02c</td>
</tr>
<tr>
<td>Dichlorvos1</td>
<td>3.21 ± 0.24b</td>
<td>0.21 ± 0.03b</td>
</tr>
<tr>
<td>Dichlorvos2</td>
<td>4.86 ± 0.41a</td>
<td>0.25 ± 0.03b</td>
</tr>
</tbody>
</table>

Means in a column with the same letter are not significantly different at P = 0.05 Fisher’s LSD.

1Weekly insecticide applications until one week before harvest.
2Bi-weekly insecticide applications until one week before harvest.

Bopape, 2013. MSc thesis, UNISA
c. Cultural practices

Cultural Control for Fall Armyworm

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CIMMYT Global Maize Program
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Outline

- Field observations made in 2016/17 growing season
- Relationship between management options and pest stages
- Suggested cultural practice interventions for maize

Visual observations in the field 2017

- Less damage in early planted crops (depending on environment)
- Less damage in fields with many diversification elements (intercrops, shrubs, trees)
- Less damage under CA with residue retention
Hypothetical relationship between management options and pest stages at different scales

Inclusion of perennials in maize cropping systems: buffering microclimate and controlling pests

(from Kebede et al., in prep)
Suggested SI management trials:

*What crop management practices offer better protection (and reduced losses to farmers) under FAW incidence?*

- **Intercropping** of maize with legumes
- **Hedgerows** (particularly with nectar producing species)
- Combinations of **tillage/no-tillage** and mulching
- **N fertilization** (rate and timing)
- **Planting date** manipulation per agro-ecology
- **Rotations** of maize with other crops

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Suggested agronomic monitoring

*On-farm trials to test management options reducing FAW infestation*

- **Document** FAW infestations by different planting dates by agro-ecology
- Establish **susceptibility of maize varieties** used in southern Africa to FAW infestations and establish key **vulnerability characteristics**
- Use existing CA trials in southern Africa to **monitor FAW infestations**
- **Assess yield losses** and potential impacts of FAW damage at national scales (with inputs from Socio-economists)
- Test **effectiveness of control** of different indigenous and recommended chemicals in different environments
Key Concluding Message

Very little is know about interaction between FAW and the cultural environment!

We therefore need to generate information for better understanding the behaviour and dynamics of FAW at field, farm and landscape scale to enable development of effective cultural interventions to reduce impact of FAW in farmers’ fields

d. Varietal resistance

Breeding for Host-Plant Resistance to Fall Armyworm

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and S. Mugo

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Outline

• Need to breed for host-plant resistance
• What is host plant resistance?
• Components necessary for HPR Breeding for FAW
• HPR breeding for FAW in Southern Africa
• Expected outcomes of a program to breed for HPR
• Molecular breeding for FAW resistance
• How about transgenics for FAW Resistance?
• CIMMYT’s experience in host plant resistance
  breeding in maize
• Concluding remarks

Need to breed for host-plant resistance

• **FAW is here to stay!**....just like most transboundary pests/diseases
• Reducing/eliminating the **cost** of insecticides and application equipment *(panic application was common in 2016/17)*
• Protecting human **health**, animal health and the **environment**
• **Preventive** rather than reactive measure to pest build-up and control
• Breeding for HPR provides a substantially greater **return to investment** on each research dollar invested compared to research on the development of insecticides
• Insect control is available for little more than the cost of the **seed**
• Added advantage of building HPR to **other economic traits**
• HPR is one of the most important components of Integrated Pest Management (**IPM**) **strategy**
What is host plant resistance?

HPR - the collective heritable characteristics by which a plant species can reduce the possibility of successful use of the plant as a host by an insect species (Beck 1965)

- HPR is available to farmers encapsulated in the seed, which ensures that after purchasing the seed, farmers need not invest heavily in any more inputs to control the pest

What is host plant resistance?

HPR is a genetically controlled trait that manifests itself as:

- **Antibiosis** - where the biology of the pest is adversely affected after feeding on the plant or the seed
- **Antixenosis / non-preference** - where the plant and the seed are not desirable as a host and pests seek alternative hosts
- **Tolerance** - the plant is able to withstand or recover from pest damage
- **Resistance** - may be controlled by different allelochemicals that kill or impair the growth of the pest
Process for development and deployment of FAW resistant varieties

HPR Breeding, evaluation and verification

Agronomic improvement / incorporation of various traits (+ biotech)

• OPVs
• Inbreds
• Hybrids

Scale-up

• NARs
• Seed co’s
• NGOs

Deployment

Farmers in Southern Africa

Personnel and resources to execute the programme

Partnership - CIMMYT, public institutions, and the private-sector

Key components for HPR breeding

FAW Pest Colony

Mass Rearing Capability

Uniform artificial infestation methods

Collaboration between entomologists and breeders
Key components for HPR breeding

Screenhouse

Open field

Screening capacity

Rating scales and evaluation

Key components for HPR breeding

Appropriate maize germplasm

- CIMMYT, during the 1980s and 1990s, developed populations as well as CMLs (~60) with partial resistance to FAW, derived mainly from the Caribbean maize germplasm.

- USDA-ARS (Mississippi) also developed and registered inbred lines with FAW resistance (e.g., Mp704-Mp708, Mp713, Mp714 and Mp716).

Documented Sources of FAW Resistance

Elite locally-adapted materials with proven performance should form the base germplasm for in building FAW resistance.
FAW breeding program for Southern Africa

identify, develop and deploy conventionally-derived FAW-resistant elite Africa-adapted, (sub)tropical CIMMYT maize germplasm for the benefit of public and private sector partners engaged in maize R&D in SSA

Outcomes of a HPR breeding for FAW

- Established insect-rearing and screen-house facilities (Centralized screening facilities for partners)
- First-generation FAW-resistant lines and hybrids identified
- Potential trait donors for FAW resistance identified and deployed to partners
- A collaborative breeding program for FAW resistance in Southern Africa initiated and conducted
• Germplasm from NARS, private Sector, CIMMYT and others screened for FAW resistance

• Data on promising FAW-resistant maize lines and pre-commercial generated

• Promising sources of resistance to FAW disseminated to public and private sector partners in Africa as international public goods

Outcomes of a HPR breeding for FAW

• FAW resistant hybrids developed and allocated to both private and public sector for scaling up in southern Africa

• Early generation seed of parents of FAW resistant hybrids bulked and disseminated to both public and private sector for seed hybrid makeup in southern Africa.
Potential Challenges

- Excluding other borers in the experiments
- Build up of FAW resistance
- Appearance of another transboundary pest or disease

CIMMYT’s experience in HPR breeding in maize in Southern Africa

- Maize Streak Virus Resistance (80’s)
- Grey Leaf Spot Resistance (90’s)
- Maize Lethal Necrosis (current)
Molecular Breeding

- USDA-ARS has identified some major QTL/genomic regions conferring resistance to FAW
- Marker-assisted breeding programs could be initiated for speeding up development of FAW resistant varieties

How about Transgenics?

Bt Maize in Brazil

FAW has developed resistance to Bt at multiple locations (Brazil, Argentina) across different countries

Pyramiding different Bt events is fundamental to prevent resistance build-up in transgenic FAW resistant varieties
Summary

• There is **no silver bullet** for effectively tackling the transboundary insect-pests!

• Breeding and deploying FAW resistant maize varieties could offer farmers **an option**

• FAW resistant varieties should be part of an overall **IPM strategy** and not a standalone solution

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**Key Concluding Message**

**FAW is here to stay!**

Breeding and deploying FAW resistant maize hybrids could be a medium to long-term strategy, but is important to provide expanded options to smallholder farmers, and to minimize the environmental and ecological damage caused by Synthetic Pesticides.
Below is the latest guide providing information on management options for FAW prepared by FAO and its partners.

**Fall Armyworm**

*Spodoptera frugiperda*

**Prevention**
- Plant early and use early maturing or resistant varieties if available to avoid peak immigration of adults.
- If possible avoid planting in infested areas.
- Keep field and surroundings weed free and clean; removing alternate hosts and crop residue covering pupae on the soil.
- Do not move infested maize materials from one area to another to reduce spreading the pest, instead graze livestock on them or make silage.
- Use mixed cropping systems such as maize, legumes, other root and tuber crops: cucurbits e.t.c., depending on local practices.

**Monitoring**
- Regularly monitor fields for early detection of moths using traps even before planting.
- Look for cream/grey egg masses covered in a felt-like layer of grey-pink scales on the underside of leaves, beginning one week after germination.
- Look for light green to dark brown larvae with 3 thin yellowish white stripes down the back and a distinct white inverted "V" on a dark head. Look for small shot or large ragged and elongated holes on the leaves and inside whorls of young plants.
- Look for patches of small (window panes) to large ragged and elongated holes in the leaves emerging from the shoot with yellowish brown frass.

**Direct Control**
- On small-scale farms, handpick and destroy egg masses and caterpillars.
- Use light or pheromone traps (2-4 traps/ha) to capture and destroy adult moths in water mixed deterrents or kerosene.
- Spray with sugar solution to attract ants that prey on young caterpillars.
- Put soil, lime, ash, sawdust or hot pepper powder in the whorl of the attacked plants to kill larvae.
- Spray early mornings or late evenings with:
  - Bt products like neem-based or tephrodo-based products
  - Biopesticides like Bacillus thuringiensis and/or virus-based products with adjuvants: fungi such as metabolites, or organic products like malathion.

**Direct Control - synthetics as last resort!!**
- Use synthetic chemicals registered in your country at the recommended dose (avoid those in WHO Classes 1a and 1b).
- Direct sprayer nozzle into the whorl (funnel of cereal leaves) for effective control.
- Apply a spoonful of a mixture of ground corn cobs and recommended synthetic chemicals into whole (leaf funnels). This stops chemicals, protects beneficial insects and adapted to those who don’t have knapsacks or boom sprayers.
- Insecticides are more effective on young larvae and before they enter the funnel and ear.
- Always wear protective clothing and follow instructions on product label.
- Powder and granule formulations can be especially dangerous.
- Rotate active ingredients. Do not use chemicals with the same mode of action repeatedly within a season, as this can lead to pest resistance to them.
- Always consult the most recent list of registered pesticides.

**Restrictions**
- Use of OP and synthetic pyrethroids in maize is not recommended.
- Use of OP and synthetic pyrethroids must be preceded by a reference to the North American Pesticide Information Exchange (NAPEX) for approval.

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**CABI**

*Authors: CABI & FAO*

**Plantwise**

*LOSE LESS, FEED MORE*

Plantwise is a CABI-led global initiative. [www.plantwise.org](http://www.plantwise.org)
MORE IPM OPTIONS
Outline

- The Challenge
- IPM Principles
- IPM Options for FAW
- Pesticides
- Potential bio-control options
- Further Research

Introduction

- Migration & Dispersal rate
- Wide host range
- Rate of reproduction
- Damage caused
- Generations per season
- Resistance to pesticides
- Research Gaps on FAW
What is IPM

- IPM means 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 (FAO, 2012)

IPM Principles

- Surveillance and forecasting
- Use thresholds to time pesticide application
- Eliminates the most hazardous pesticides (Class 1a&b)
- Use locally available nationally registered pesticides that are not restricted or banned by international conventions
- Alternate pesticides of different modes of action to avoid resistance
- Maximum number of applications per season
- Pre-harvest interval and re-entry interval
Possible IPM Options

- Resistant Varieties
- Sanitation/ Crop hygiene
- Exclusion & Physical barriers
- Cultural
- Biological
  - egg and larval parasitoids
  - predators
- Bio- pesticides
- Pesticides

They need to be verified in Africa, need testing

Fall Armyworm IPM Initiatives in Africa

- Literature review (Americas, South Africa)
- Consultations with other countries
- Farmer Sensitization(Government/ FAO support)
- Diagnostic guides
- Extension materials
- Pest Management Decision Guides
Cultural practices to prevent
(Not tested in Africa-needs verification)

- Avoid late or off-season planting, plant early to avoid pest population build up
- Plant maize varieties with hard husk cover to prevent the pest from entering the cob
- Keep field weed free to remove alternate hosts
- Plant at correct spacing and ensure optimum use of fertilizer

- Plant at correct spacing and ensure optimum use of fertilizer
- Avoid planting new crop near infested plants
- Do not move infested maize materials from one area to another to reduce spreading the pest instead graze livestock on them or make silage
Cultural Controls (Small scale farmers)

- Handpick and squash or drop caterpillar in hot water.
- Put a half handful of sand / sawdust or soil in the whorl of the attacked plants to kill the larvae
- Apply a pinch of 50gm ground hot pepper + 2kg ash into plant funnel at knee-high

Are there other effective cultural methods ??

Community based early warning

- Use Pheromone traps to predict entry of the moths
- Identify the risk areas (High, medium, low)
- Start monitoring for larvae as soon as moths are trapped

Has worked for African armyworm not yet tested for FAW
Monitoring

- Start monitoring for the pest one week after germination
- Check 20 consecutive plants from 5 points
- Look for cream / grey egg masses covered in a layer of grey-pink scales anal hairs) on the top and underside of leaves

- Look for a green, brown larva. Mature caterpillar has a distinct white line between the eyes which forms an inverted “Y” pattern, more visible from third larval instar

- Pronounced four black spots aligned in a square on the top of the 8th segment near the back end

- Window panes, small shot or large ragged and elongated holes on the leaves and inside whorls of young plants
Thresholds for pesticide application

- ≥5% plants have egg masses
- ≥20 plants show damage (window panes and pinholes), larvae present
- Continue monitoring, and consider further treatment if more young larvae appear

**Question/Research needed**

- What thresholds to use in Africa?
- Is it the same for irrigated and rain fed crops?
- Thresholds are likely to be different in different crops, at different stages of crop development

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**Pesticides**

- Several pesticides varying in toxicity levels, WHO class and modes of action
- Countries registering and recommending different pesticides e.g. 40 in Brazil, 19 in South Africa
- Different trade names for the same pesticides
- Rotate active ingredients of different modes of action to reduce risk of resistance developing
Pesticide options (Americas)

- Chloropyriphos
- Deltamethrin
- Alpha Cypermethrin
- Indoxcarb (Steward)
- Spinosad
- Acetamiprid + Abamectin
- Lufenuron + Emamectin Benzoate (Match fit)
- Flubendiamide (Belt)

Also registered in Southern Africa/ need to be tested in other African countries

Pesticides

- Spray early or late in the day
- For maximum effectiveness, insecticide must be placed inside funnels
- Follow label instructions
- Most of the insecticides are effective on early larval instars; higher dosages are needed to kill medium- to large-sized larvae.
Botanicals

- Commercial products (eg neem) and plants with insecticidal and/or antifeedant effect on FAW
- What are the rates?
- Are there any other effective ones used by farmers?
- Any efficacy trials?

Mass rearing and release of Parasitoids

- Because eggs occur in masses egg parasitoids are more suitable
- Mass rearing and release of parasitic wasps (~100,000/ha). Egg parasitoids Trichogramma pretiosum, T. atropovirilis, Telenomus remus (2,500-3,000 per ha)

Effectiveness

- Reported as effective. Not clear how widespread in Africa
- No trials conducted for FAW

Constraints

- Might not be cost effective

Questions

- What local parasitoids are attacking FAW and how much mortality?
- Could a sustainable local business model be developed?
Rearing/release of predators

- Mass rearing and large scale release of insect predators. *Doru luteipes* (earwig) and *Orius insidiosus* (pirate bug)

**Effectiveness**
- Brazil recommends *Doru*. *Orius* is commercially produced; not clear if used for FAW.
- Africa
  - No trials have been conducted

**Question**
- What predators are attacking FAW in Africa and how much mortality?

Virus-based biopesticide

- Naturally occurring virus: SfMNPV
- Products available: AgBiTech has factory in Texas

**Effectiveness**
- Effective when used correctly. Host specific, very low non-target risks
- Africa
  - AgBiTech interested in conducting trials
  - IITA has SfMNPV strains from US

**Constraints**
- Registration of an exotic insect pathogen

**Question**
- Is the virus present in Africa?
Bacillus thuringiensis (Bt)

- Spray based on a naturally occurring bacterium
- Main subspecies used: kurstaki and aizawai

Effectiveness
- Effective: genetic modification has been used to try and improve its efficacy

Africa
- Available but not known if any testing done

Constraints
- In the Americas resistance has been reported to Bt-based products

Questions
- Are available Bt products effective?
- Did resistance come with the immigrants?

How Can we Make IPM Work

- Identify Research gaps
- Scout for more biocontrol agents
- Work together with regulatory agents to relax the requirements and fasten registration process of biocides
- Farmer sensitization and training on IPM (FFS), scouting, diagnostics
- Conduct verification trials of potential IPM packages and repackage for farmers
- Educate farmers on safe use of pesticides
Further Research

Efficacy trials on potential biocontrol agents:
- parasitoid species e.g. Cotesia sp. and a tachinid parasitoid.
- Nucleopolyhedroviruses (NPV) and iridoviruses
- Metarhizium anisopliae and Beauveria bassiana Eco-Bp Wp
- Classical biocontrol e.g introduction of egg parasitoid Telenomus remus
- Heterorhabditis bacteriophora, Steinemema Sp.

- Verify efficacy of use of cultural practices such as:
  - sand/soil mixed with ash/lime
  - planting time, intercropping
  - stem borer “push-pull” strategy
- Research on pheromones for monitoring and management either mass trapping or mating disruption
- FAW biology, ecology, population dynamics, action thresholds
f. Pesticides

i. Resistance, human health and effects on environment: managing the risks during pest control operations

PART ONE
MANAGING RESISTANCE
Resistance is a simple biological survival technique

Living organisms are constantly under pressure from natural stressors or anthropogenic stressors

Darwin said: survival of the fittest, but in biological terms it is survival of the adaptable individuals of species or populations of species

Organisms are constantly adapting to changing environments to cope with, or overcome stressors

Natural selection (culling) allows the adaptable individuals to survive and pro-create

Plant pest resistance development in agriculture

Resistance development in arthropods and micro-organisms is simply a consequence of anthropogenic induced selection:

A small portion of the pest population harbours resistance genes that allow individuals or select populations of pest species to survive. These genes already exist naturally in a pest population, and will develop further through mutation in response to stressors.

WITH PEST CONTROL:

An anthropogenic stressor (pesticide) impacts on the pest, thus preventing susceptible individuals from surviving & reproducing, and leaving individuals that harbour resistant genes to survive and reproduce.
Hastening plant pest resistance development

Every time the anthropogenic stressor impacts upon the species, it removes susceptible individuals or populations to the point of virtually none of them remaining.

The balance (make-up) of the species or population progresses to the adaptables (survivors):

Resistant individuals continue to grow in proportion of the population, multiply and ultimately become predominant in the population.

A totally resistant species or population is the end-point of an uncontrolled resistance development cycle.
Resistance management failure

The failures will transpire due to:

1. Not following PPP label instructions meticulously:
   a. Overdosing: will remove all susceptible individuals and leave only resistant individuals to survive and breed a resistant population. Repeated application of same AI will have the same effect.
   b. Underdosing: will not effectively remove major part of population and leave too many semi-susceptible & susceptible individuals behind that will mutate and develop resistance.
   c. Incorrect application technology and methodology will lead to overdosing and underdosing with results as described above.
   d. Incorrect application time may also result in not removing the susceptible individuals and harm beneficial predators.
Managing resistance

Based on a few very important principles:

2. Following PPP label instructions meticulously.
3. Active ingredient rotation or mixing (when instructed by the label) is important to prevent resistance.
4. Adhere to the applications per season as instructed by the label (especially PYs and CHP).
5. Strict adherence to dosage per application – underdosing or overdosing is fatal.
6. Correct application technology and methodologies are critically important (aerial vs tractor vs centre pivot).
7. Resistant cultivars if available (GM crops).
8. Choosing the right application time (application window) is critically important; early instars of the FAW.

The downside of resistance development for food producers & food security

1. Certain PPP active ingredients will lose their efficacy against certain plant pests rapidly (diamides & PYs).

2. Producers have to try other active ingredients that may also:
   a. experience resistance, and
   b. may not be registered for that application, and
   c. may leave residues above MRL thresholds and cancel fresh produce from local and export market access.

3. Producers have to wait for new chemistry that will be expensive due to development costs:
   a. development of a new active ingredient is between 400 and 500 M€
   b. registration process is very slow
Plant pest resistance management

Best practices to follow:

1. Integrated pest management is the overarching principle.
2. Meticulous following of label instructions.
3. Maintaining a situation where susceptible individuals will be “left over” after application of PPPs to interbreed with resistant individuals and perpetuate susceptible genotypes for successful control with PPPs.
4. Rotating PPP active ingredients will add ammunition to the arsenal against plant pests.

Benefits to agriculture:

1. Active ingredients will remain active much longer in the market and will generate a cost benefit for producers

PART TWO

MANAGING SAFETY, HEALTH & ENVIRONMENT
Principles of pesticide safety

ACCESS

Secure, lockable storage sites

No access for uninformed people, animals and children

Fire fighting & spill containment equipment

LABEL INSTRUCTIONS

Warnings
Precautions
Application instructions

DO ONLY AS INSTRUCTED!!
Principles of pesticide safety

PERSONAL PROTECTIVE EQUIPMENT

AFTER APPLICATION CARE

WASH
RINSE
DRY
STORE
EMPTY CONTAINER MANAGEMENT

Triple rinse: three times rinse with quarter container volume and decant rinse water into spray tank

Cut triple rinsed container into quarts
Recycle

NO SECONDARY USE!!!!
NO FOOD OR BEVERAGE STORAGE!!!!
NO DECANTING ONTO SOIL OR INTO WATER BODIES!!!!

ENVIRONMENTAL PROTECTION

No spraying over wetlands or water bodies

Chase wildlife & livestock out of application area

Prevent spray drift onto non-target areas

Do not rinse containers in water bodies or decant left-over spray mixture into water bodies
ii. Safe use of Pesticides

Safe use of Pesticides
29 June 2017

Fall Armyworm Training Workshop: Identification, Monitoring, and Early Warning: Impact Assessment and Management Options at National Level
ARC-PPR, ARC-VOP Training Centre, Roodeplaat, Pretoria.

Etienne van der Walt  ARC-PPRI,
Pesticide Science and Impact Programme
Pesticide Use Safety: Overview

- Cradle to Grave Management
- Simplified Risk Model
- Hazard and classification
- Exposure component
- Symptoms
- Local Study Results
- PPE
- Findings
- Conclusion

Pesticide Use Safety

- Very inefficient process
- < 1% of pesticide reaches the target (Pimentel et al)
- > 99% of pesticides available to enter the environment.
Pesticide behavior and contamination during and after application.

Safe use of Pesticides

Risk a function of Hazard and Exposure:
Risk = f(Hazard × Exposure)

<table>
<thead>
<tr>
<th>Hazard:</th>
<th>Exposure:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Toxicity</td>
<td>Dermal</td>
</tr>
<tr>
<td>Chronic Toxicity</td>
<td>Inhalation</td>
</tr>
<tr>
<td>Delayed Toxicity</td>
<td>Oral</td>
</tr>
<tr>
<td>(Various Physiological Endpoints)</td>
<td>Behaviour</td>
</tr>
<tr>
<td></td>
<td>Fate</td>
</tr>
<tr>
<td></td>
<td>Persistence</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WHO Class</th>
<th>LD50 for the rat (mg/kg body weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Oral</td>
</tr>
<tr>
<td>Ia</td>
<td>Extremely hazardous</td>
</tr>
<tr>
<td>Ib</td>
<td>Highly hazardous</td>
</tr>
<tr>
<td>II</td>
<td>Moderately hazardous</td>
</tr>
<tr>
<td>III</td>
<td>Slightly hazardous</td>
</tr>
<tr>
<td>U</td>
<td>Unlikely to present acute hazard</td>
</tr>
</tbody>
</table>
### Classification of Pesticide Hazards

#### Carcinogenicity

<table>
<thead>
<tr>
<th>Category</th>
<th>Description (WHO, March 2016)</th>
<th>Hazard statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcinogenicity</td>
<td>Known or presumed human carcinogen</td>
<td></td>
</tr>
<tr>
<td>1A</td>
<td>Known to have carcinogenic potential for humans; the placing of a substance is large based on human evidence.</td>
<td>May cause cancer</td>
</tr>
<tr>
<td>1B</td>
<td>Presumed to have carcinogenic potential for humans; the placing of a substance is largely based on animal evidence.</td>
<td>May cause cancer</td>
</tr>
</tbody>
</table>

#### Mutagenicity

<table>
<thead>
<tr>
<th>Category</th>
<th>Description (WHO, March 2016)</th>
<th>Hazard statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mutagenicity</td>
<td>Substances known to induce heritable mutations or to be regarded as if they induce heritable mutations in the germ cells of humans.</td>
<td>May cause genetic defects</td>
</tr>
<tr>
<td>1A</td>
<td>Substances known to induce heritable mutations or to be regarded as if they induce heritable mutations in the germ cells of humans. Substances known to induce heritable mutations in germ cells of humans.</td>
<td>May cause genetic defects</td>
</tr>
<tr>
<td>1B</td>
<td>Substances which should be regarded as if they induce heritable mutations in the germ cells of humans.</td>
<td>May cause genetic defects</td>
</tr>
</tbody>
</table>

#### Reproductive Toxicity

<table>
<thead>
<tr>
<th>Category</th>
<th>Description (WHO, March 2016)</th>
<th>Hazard statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive Toxicity</td>
<td>Known or presumed human reproductive toxicant</td>
<td></td>
</tr>
<tr>
<td>1A</td>
<td>Known human reproductive toxicant.</td>
<td>May damage fertility or the unborn child.</td>
</tr>
<tr>
<td>1B</td>
<td>Presumed human reproductive toxicant</td>
<td>May damage fertility or the unborn child.</td>
</tr>
</tbody>
</table>

### Pesticide Classification According to Health Hazard

<table>
<thead>
<tr>
<th>Health Hazard Class (WHO, GHS 2016)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acute toxicity (Oral)</td>
</tr>
<tr>
<td>1</td>
<td>Acute toxicity (Dermal)</td>
</tr>
<tr>
<td>1</td>
<td>Acute toxicity (Inhalation: Gases)</td>
</tr>
<tr>
<td>1</td>
<td>Acute toxicity (Inhalation: Vapours)</td>
</tr>
<tr>
<td>1</td>
<td>Acute toxicity (Inhalation: Dusts and mists)</td>
</tr>
<tr>
<td>2</td>
<td>Skin corrosion/Irritation</td>
</tr>
<tr>
<td>3</td>
<td>Serious eye damage/eye irritation</td>
</tr>
<tr>
<td>4</td>
<td>Respiratory sensitization</td>
</tr>
<tr>
<td>4</td>
<td>Skin sensitization</td>
</tr>
<tr>
<td>5</td>
<td>Germ cell mutagenicity</td>
</tr>
<tr>
<td>6</td>
<td>Carcinogenicity</td>
</tr>
<tr>
<td>7</td>
<td>Reproductive toxicity</td>
</tr>
<tr>
<td>8</td>
<td>Specific target organ toxicity - Single exposure</td>
</tr>
<tr>
<td>9</td>
<td>Specific target organ toxicity - Repeated exposure</td>
</tr>
<tr>
<td>10</td>
<td>Aspiration hazard</td>
</tr>
</tbody>
</table>
Pesticide Classification
Pictograms and colour codes.

Results from Gauteng Province Study (2014 – 2016)

Smallholder Farmer Pesticide usage

Use pesticides

Do not use pesticides
Clinical Symptoms of Pesticide Toxicity

- Weakness and fatigue
- Headache
- Excessive sweating
- Blurred vision
- Vomiting
- Muscle twitching
- Dizziness, confusion
- Extreme salivation
- Difficulty with breathing
- Itching and burning of the eyes
- Skin irritation
- Narrow pin-point pupils
- Abdominal pain, diarrhoea
- Unconsciousness

Pesticide exposure assessments

- Dermal exposure:
  - Glass microfiber & paper filter patches
- Inhalation exposure:
  - High volume air-borne pesticide residue sampling.
Potential Dermal Pesticide Exposure: Open field, Knapsack Sprayer

Pesticide deposition (ug/sq.cm)

Body position

Pesticide Inhalation Exposure:
High volume air-borne pesticide monitoring vs height above ground

Pesticide conc. (ug/cub.meter air)

Pesticide application category
**ERRONEOUS USE OF PPE: DUST MASK**

Pesticide Break-through exposure Dust Mask (ug pesticide)

- Before: 0.09
- 22% Exposure: 0.02

Examples of dust mask use.

---

**Certified codes for PPE**

- The selection, use and maintenance of respiratory protective equipment SANS 10220:2010
- Agriculture, Pesticides, Insecticides ABEK1P2 R

- White – Particulate Protection
- Brown – Organic Vapours Protection
- Grey – Inorganic Vapours Protection
- Yellow – Acid Gases Protection
- Green – Ammonia and its Derivatives
Findings

- Lack of certified PPE and availability
  - (Dust mask problem)
  - Respirator cartridges left open
- Reliance on cheap over the counter pesticides
  - Lack of support from merchant
  - No rotation of MOA’s for resistance prevention
- Lack of record keeping
- Lack of storage facilities
- Lack of Pesticide Management Training
- No proper disposal of Pesticide containers
- Likely exposure of homesteads to pesticides
  - Close proximity to sprayed fields
- Incorrect sprayer operation
  - Nozzle height not followed
  - Spraying speed not uniform.
- Re-entry waiting period not followed
- Harvest withholding periods not followed
- Lack of resources
  - Water availability
  - Fertiliser etc.
- Environmental effects catastrophic
  - Rain (too much or too little)
  - Temperature (too high or below zero)
- Vandalism, theft impacts.

In Conclusion

Identified Priorities.

- Responsible use and handling of Pesticides
  - Insecticides, herbicides, fungicides
  - Calibration
  - Aspects of Act no. 36 of 1947
  - PPE
  - Training of master trainers
- Pest, weed and disease identification
- Selection of pesticide - Resistance (MOA Rotation)
- Adherence to Legislation / Conventions
- OHS Act, SANS codes etc.
  - International conventions
  - Web Resources
- Enforcement of Standards & Guidelines
- Linkages with Agrochemical Company Partners.
iii. Application Technologies for Smallholder Farmers

**Application Technologies for Smallholder Farmers.**
29 June 2017

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ARC-PPR, ARC-VOP Training Centre, Roodeplaat, Pretoria.

Etienne van der Walt ARC-PPRI,
Pesticide Science and Impact Programme

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**Overview**

- Pesticide Application theory
- Atomization and droplet spectra
- Factors influencing pesticide application efficacy
- Case Study, Gauteng Province
Use of Pesticides

- Pesticides must cover the target area effectively, for best control
- Contamination of the environment must be minimized
- Good coverage of the target is directly dependent on the droplet size and not necessarily the spray volume applied
PESTICIDES ARE APPLIED USING SPRAY NOZZLES WHICH PRODUCES DROPLETS: ATOMISATION

Ligand formation  Sheet formation

Droplet size and Behavior

- Droplet size
- Influence of evaporation
- Influence of gravity
- Influence of air temperature
- Droplet precipitation
PESTICIDES ARE APPLIED USING SPRAY NOZZLES WHICH PRODUCES DROPLETS

These droplets can be measured.

Laser spectrometry  Microscope graticule

\[ \text{Vol. of sphere} = \left( \frac{4}{3} \right) \pi r^3 \]

Droplet image analyser
Classification of droplet size

<table>
<thead>
<tr>
<th>Droplet size micron (μm)</th>
<th>Droplet size - classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 50</td>
<td>Aerosol</td>
</tr>
<tr>
<td>51-100</td>
<td>Mist spray</td>
</tr>
<tr>
<td>101-200</td>
<td>Fine spray</td>
</tr>
<tr>
<td>201-400</td>
<td>Medium spray</td>
</tr>
<tr>
<td>&gt; 400</td>
<td>Coarse spray</td>
</tr>
</tbody>
</table>
DEFINITIONS OF VMD AND NMD

NMD Definition: Numerical median diameter
That droplet diameter which divides the number of droplets in two equal halves by NUMBER.

Relationship between Droplet Deposition, VMD and Spray Volume

\[ N = \frac{60}{\pi} \left( \frac{100}{d} \right)^3 Q \]

- N= Theoretical number of droplets deposited per cm\(^{-2}\)
- d= droplet diameter (\(\mu m\))
- \(\pi = \pi (3.1416)\)
- Q= Spray volume in (L.ha\(^{-1}\)).
Case Study: Smallholder Farmers in Gauteng Province

Knowledge of the Pesticide Application Process

<table>
<thead>
<tr>
<th>Process</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knapsack Operation</td>
<td>54.7</td>
</tr>
<tr>
<td>Pesticide Mixing</td>
<td>41.5</td>
</tr>
<tr>
<td>Read Pesticide Label</td>
<td>39.6</td>
</tr>
<tr>
<td>Pesticide Calibration</td>
<td>7.5</td>
</tr>
<tr>
<td>Flow Rate / Ha</td>
<td>9.4</td>
</tr>
<tr>
<td>Explain Label Instruction</td>
<td>39.6</td>
</tr>
</tbody>
</table>

Pesticide Application Process

Pesticide Drift: Atrazine as tracer: 150 litres / Ha Application rate

Drift Study setup, Standerton RSA.

High volume air sampling
Climatological guidelines for spraying

- For effective spraying give special attention to the following:
  - Stop spraying if there is a sudden blast of wind
  - Stop spraying when the wind speed is higher than 15 km/h for insect and plant disease control
  - For herbicides speed >8 km/h must be avoided
  - Application must stop when the wind direction changes in the direction of a susceptible crop
  - Stop spraying when there is a difference of 8°C between the wet and dry bulb temp
  - Plants which are wet with dew, rain or irrigation must not be sprayed
  - When a systemic pesticide is sprayed make sure that the bottom parts of the plant are thoroughly wetted with the spray solution
Effect of temperature

- Spray under neutral atmospheric conditions
- If present a ground level spray within inversion conditions.
- Do not spray above or below a temperature inversion.

Water quality

- Solids in the water
- Neutral pH
- Low salt levels
- Water "softness"

Psychrometric chart for determining RH% from wet and dry bulb temperatures.
Adjuvants

- Compatibility aids
- Spreaders
- Sticking agents
- Drift control gents
- Anti-evaporants
- Anti-foam agents
- Penetrating agents

Use adjuvants recommended by Company

FAW Application Strategy

- Droplet size: 150 – 200 um (??)
- High volume application > 150 L / Ha
- > 400 L/Ha results in wash-off
- Small window of opportunity 1st to 2nd instar
- 3 – 5 Days
- Recommendations for Resistance
  MOA rotation critical
- Prolong life of Active ingredients
- MUST be part of IPM Strategy
- Knapsack sprayer, CDA initially,
  Vehicle mounted booms
- Squeegee Bottle may work -
  penetrating whorl
- Hand lance, Full cone

Knapsack nozzle setup for increased coverage
Flat fan nozzle types

FIGURE 1: Flat fan spray pattern

FIGURE 4: Even spray pattern

Cone nozzle types

FIGURE 5: Hollow cone spray pattern

FIGURE 6: Full cone spray pattern
Calibration

Full Cover Application.

NOTE: Units of measure: meters, km/h, L/min and L/ha

\[
\text{Application rate (L/ha)} = \frac{600 \times \text{total sprayer flow rate (L/min)}}{\text{swath width (m) \times travel speed (km/h)}}
\]

Convert ml to Liter (L) = 1 ml/1000 = 0.001 Liter

Forward speed \( \left( \frac{m}{sec} \right) = \frac{\text{distance measured (m)}}{\text{time (seconds)}} = \text{meter/second} \)

Convert m/s to km/h:

\[
1 \text{ meter per second} = \frac{1 (m/s)}{3.6} = 0.278 \text{ km/h}
\]

Convert km/h to m/s:

\[
1 \left( \frac{km}{h} \right) = 1 \text{km/h} \times 3.6 = 3.6 \text{ meter/second}
\]

Flow Rate \( \left( \frac{L}{m} \right) = \frac{\text{Liter measured}}{30 \text{ sec}} \times 2 \)
Amount of pesticide required per knapsack.

Required information:
1. Dosage rate of pesticide:
   liter of pesticide per Hectare
2. Volume of knapsack sprayer
3. Sprayer application rate:
   Liter per hectare

Example:
1. Dosage rate of pesticide: liter of pesticide per Hectare = 2 L per Ha
2. Volume of knapsack sprayer = 20 Liters
3. Sprayer application rate: Liter per hectare = 150 L/Ha

\[
\text{Amount of pesticide req per 20 L knapsack} = \frac{\text{Knapsack volume}}{\text{Spray volume per Ha}} \times \text{Pesticide dosage rate}
\]

\[
= \frac{20 \text{ L}}{150 \text{ L per Ha}} \times 2 \text{ L Pesticide}
\]

Amount of pesticide required per knapsack = 0.267 L Pesticide per 20 L knapsack.
5. ADDITIONAL RESOURCES

..\FAW info\How to Identify Fall Armyworm.pdf

..\FAW info\FAW management FAO CABI.pdf

..\FAW info\Identify Fall Armyworm A5 Flyer.pdf


201
Plantwise PEST MANAGEMENT DECISION GUIDE: GREEN LIST Fall armyworm on maize
