Food and Agriculture Organization of the United Nations

TECHNICAL GUIDELINES FOR SUSTAINABLE MANAGEMENT OF FALL ARMYWORM IN ITS YEAR-ROUND BREEDING AREAS

GUIDANCE NOTE 9

INTERNATIONAL YEAR OF PLANT HEALTH 2020

Food and Agriculture Organization of the United Nations (FAO) Director-General Qu Dongyu:

“... plant health is our health... As with human or animal health, prevention in plant health is better than cure. By preventing the spread and introduction of pests into new areas, governments, farmers and other actors of the food chain, such as the private sector, can contribute to save billions of dollars and ensure access to quality food.”

Introduction

Fall armyworm (*Spodoptera frugiperda*) (FAW) is a major transboundary insect pest that has become a significant threat to food security and agricultural sustainability worldwide. FAW, a polyphagous pest native to tropical and sub-tropical regions of America, was first detected in Africa in 2016 and then spread to over 109 countries in Africa, the Near East and Asia.

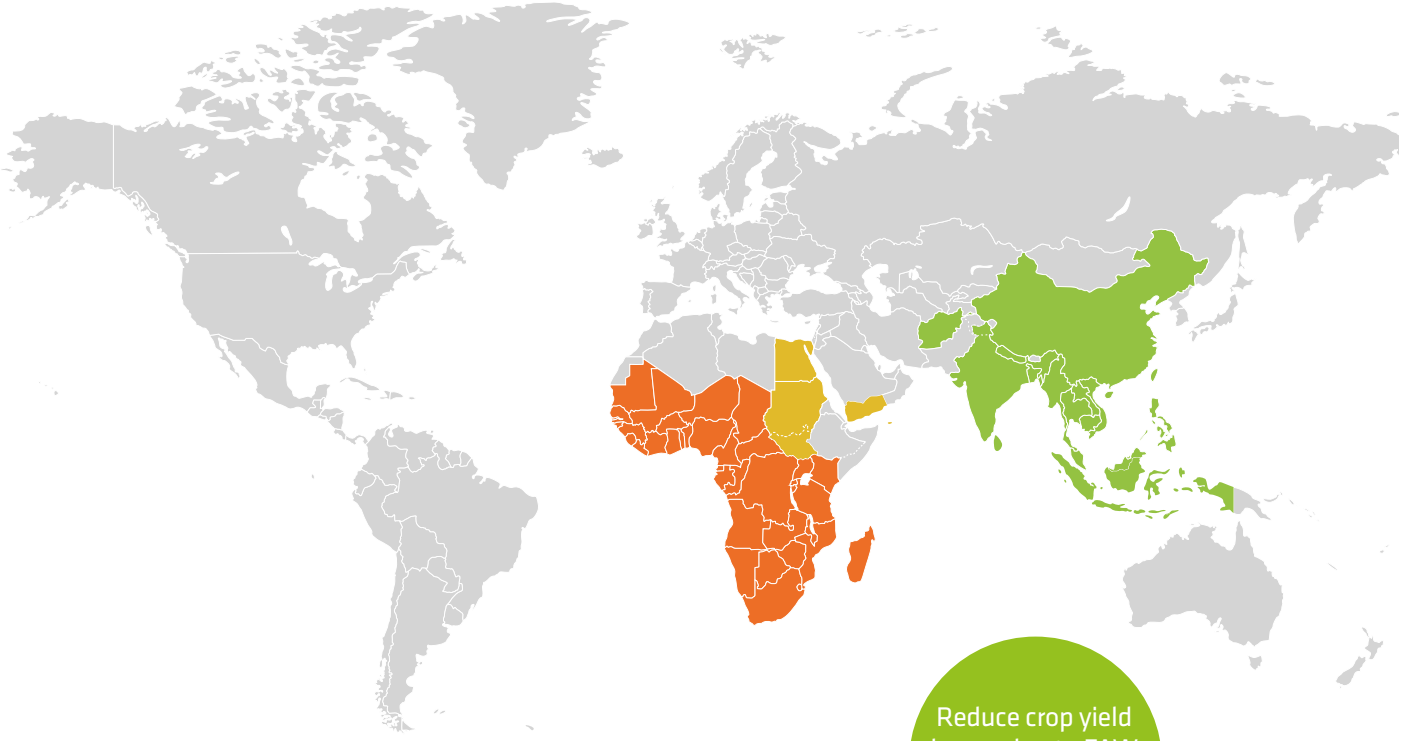
The Food and Agriculture Organization of the United Nations (FAO) has launched the Global Action for Fall Armyworm Control, continuing from 2020 to 2022, to prevent further spread of FAW and reverse the trend of FAW infestation. The Global Action establishes a coordination mechanism that will connect the national FAW response efforts directly to global, political-level support, facilitating adoption of new FAW control technology with a long-term sustainability perspective. These technical guidelines are developed as recommendations for decision makers and extension specialists to develop national and local strategies for achieving sustainable management of FAW using practices that are environmentally-friendly and safe from a human health perspective.

FAW does not have a diapause mechanism and cannot survive low temperatures. Several studies have found that 13.8 °C was the minimum threshold for development below which egg, larval and pupal development stops (Early *et al.*, 2018, Li *et al.*, 2019). However, long-range migration is a well-known behaviour of FAW that helps the moth to seasonally expand its geographic range. Year-round survival and breeding typically occurs in warmer regions, where host plants are always available and temperatures rarely or never dip below certain thresholds. Long-range seasonal migration takes place in spring and summer toward new regions that allow FAW survival during warm months only. Such seasonal migration can take multiple generations. This means that FAW can arrive in an area along a seasonal migration pathway, and establish itself with new generations of individual pests continuing the migration to new areas as a function of host plant availability and climatic factors.

Fall Armyworm (*Spodoptera frugiperda*)

In North America, for example, areas in southern Texas and southern Florida are known to be year-round breeding areas, with seasonal migration towards northern states such as Minnesota and Pennsylvania occurring in spring and summer (Nagoshi *et al.*, 2012). Indeed, seasonally migrating FAW populations are found as far north as Canada (Mitchell *et al.*, 1991).
In Africa, the Near East and Asia, new patterns of seasonal migration are expected. In Asia, for example, modelling studies have predicted trajectories and timing of such seasonal migration from year-round breeding areas in southern China to the northeastern part of the country (Li *et al.*, 2019, Wu *et al.*, 2019).

By considering the seasonal migration pattern, it is possible to envision two broad approaches for FAW management: one for regions where year-round survival and breeding of FAW occurs; and another for regions along FAW seasonal migration pathways. Area-wide integrated pest management (IPM) principles in which the management objectives and strategies adopted for one region complement those of another region should be promoted. In this context, coordinated action among regions is crucial to ensure economical, effective and environmentally-friendly management of FAW.



Reduce crop yield losses due to FAW in the regions to less than 5%

Scope of guidelines

These technical guidelines focus on delineating management strategies for regions in Africa, the Near East and Asia in which FAW can survive and breed year-round. As of March 2020, countries in these regions include:

- **Africa**: all sub-Saharan African countries
- **Near East**: Egypt, the Sudan, Yemen
- **Asia**: Afghanistan, Bangladesh, Cambodia, China (southern), India, Indonesia, the Lao People's Democratic Republic, Myanmar, Nepal, the Philippines, Sri Lanka, Viet Nam

Objectives

In principle, the FAW management strategies described below aim to:

- sustainably manage FAW populations to limit infestations in the region, as well as to reduce the initial size of seasonal migration populations;
- reduce crop yield losses due to FAW in the regions to less than five percent.

Science-based strategies for FAW management in its year-round breeding areas

In FAW's year-round breeding areas, management strategies emphasize habitat management, which involves manipulation of the environment to reduce its suitability for FAW multiplication. This is achieved by removing environmental elements that are favourable for FAW or by optimizing environmental elements that inherently regulate FAW populations.

Best agronomic/cultural practices

The practices below are among best maize agronomic practices that will contribute to FAW management by ensuring the general health of maize plants or reducing the likelihood of FAW infestation.

1. Use high-quality seed and balanced fertilization to ensure healthy plants (Morales *et al.,* 2001).
2. Manage planting dates to avoid high FAW infestation during seedling stages. Avoid staggered planting as the practice provides continuous habitat for FAW and may lead to increased overall FAW population in an area. Staggered planting also exposes the late-planted fields to higher FAW infestations.
3. Crop-rotation patterns can contribute to reducing FAW populations. These can include rotation with crops less preferred by FAW, such as ground nuts or other legumes; or paddy rice, or flooding the fields after maize season, Flooding kills FAW pupae in the soil. Please note that although FAW may survive and reproduce on other hosts around fields, its population is often reduced through such strategies.
4. Soil management techniques that increase general soil health, such as mulching, no- or low-tillage, as well as the abundance and function of soil predators may help to reduce survival of FAW pupae in the soil (Rivers *et al*., 2016). Ants, for example, were found to kill over 95 percent of FAW pupae in the soil in fields with healthy soil biota (Perfecto *et al*., 1991). Healthy soils, with good soil organic matter content, promote balanced release of nutrients that ensure general plant health.

Symptoms of entomopathogen infection on FAW.
Left and below: Fungus infected larvae of FAW in Malawi
Right: Virus infected larvae of the African Armyworm

Intercropping

Intercropping, defined as planting additional crops in strips or alleys among maize plants, has a number of potential benefits, including (Harrison *et al*., 2019):

1. increasing general plant health by contributing to soil health;
2. interfering with FAW host-plant searches by introducing contradictory cues, such as repellent volatiles;
3. inhibiting larval movement between rows;
4. increasing natural enemies' abundance by providing extra food sources and shelter.

The realized benefits of intercropping are highly dependent on the choice of plants involved in the scheme as well as the environmental and socio-economic contexts of the field (Hailu *et al*., 2018, Kassie *et al*., 2020). The intercrop should be planted at the same time or earlier than the main crop, so they grow up together, and FAW control appears better where intercrops with abundant vegetative growth are used. Alley cropping can often be an effective strategy, as it enhances the growth of the intercrop but limits competition with the main crop.

The push-pull system is an example of an intercropping system that was found to be effective as a FAW management strategy. In this system, maize is intercropped with silverleaf or greenleaf desmodium (Desmodium uncinatum or Desmodium intortum, respectively), a trailing perennial legume species that produces volatiles that repel FAW; and Napier grass (Pennisetum purpureum), a perennial grass that attracts FAW (hence the name 'push-pull') (Khan *et al*., 2018, Midega *et al*., 2018). The plants that attract FAW can then become a focus of further management action.

Conservation and enhancement of natural enemies

In both its center of origin and invasive range, numerous natural enemies regulate FAW populations. These include organisms such as insects, spiders, birds and bats that feed on FAW larvae, eggs and moths. It is possible to conserve and even enhance the abundance and effectiveness of these natural enemies by introducing a diversity of habitats around fields. This strategy forms the cornerstone of FAW habitat management. Some examples of this strategy include:

1. Leaving **strips of wild flowers** on the field margin is an example of increasing habitat diversity to enhance natural enemies. This approach increases the availability of supplementary food for natural enemies in the form of nectar and pollen, which in turn increases the numbers of natural enemies and results in lower FAW survival rates (Wyckhuis and O'Neil, 2007; Hay-Roe *et al*., 2016).
2. **Integrating crops with woody perennials** – such as fertilizer trees (e.g. *Glircida sepium, Faidherbia albida*); trees planted on boundaries or as live fences – and maintaining forest fragments and uncultivated patches of natural regeneration are other ways of increasing habitat diversity for natural enemy conservation. The abundance of insect predators has been found to decline with distance from forest fragments, leading to corresponding increases in FAW infestations. Trees are likely to increase the abundance of vertebrate natural enemies such as bats and birds, both with good potential as natural enemies of FAW moths (Jones *et al*., 2005, Maine and Boyles, 2015).

3. **Protection of predators' nests**. Ants and social wasps are very important predators of FAW. Protecting ant and social wasp nests in and around fields is a simple and effective strategy for FAW control. Unfortunately, farmers often remove these nests because they think they are a menace and do not appreciate the service these organisms provide.

Lastly, but most importantly, conservation of natural enemies requires avoiding adverse agricultural practices such as indiscriminate use of pesticide, which can harm the beneficial insects, spiders and other beneficial organisms (Meagher *et al*., 2016).

Augmentative biological control and other biorational approaches

In addition to conservation biological control, there are a number of other ways to leverage various biological mechanisms to control FAW, including:

1. **Augmentative biological control**

   It is possible to augment the existing levels of natural enemies with extra numbers of beneficial organisms. Some have advocated for classical biological control, in which FAW's natural enemies from its center of origin are imported to the pest's new range. However, it is highly possible that endemic natural enemies in the new geographic range are already feeding on FAW populations as demonstrated in a number of Asian and African countries.

   In this approach, identified natural enemies are mass-reared in laboratories with specialized rearing facilities. The resulting populations are released –either in large numbers as needed (**inundative release**) or in repeated smaller pulses with the expectation of natural enemy establishment and self-perpetuation (**inoculative release**). Inundative releases are expected to provide immediate control of FAW populations and are appropriate for medium levels of the pest population. Inoculative releases are expected to provide long-term regulation of FAW populations and are appropriate for low population levels of the pest.

2. **FAW mating disruption**. This is achieved by strategically releasing FAW pheromone in the fields.

3. **Microbial** and/or **botanical** pesticide use. A number of microbial and botanical pesticides, such as neem extract, *Azadirachta indica,* Bt (*Bacillus thuringiensis*) and an entomopathogenic fungus, *Beauveria bassiana*, are effective against FAW (Bateman *et al*., 2020). Biopesticides are usually target-specific, with relatively low environmental persistence. These properties make biopesticides especially relevant for sustainable management of FAW.

Rational and safe use of synthetic pesticide for control

A number of important considerations for the use of chemical control in FAW's year-round breeding areas include:

1. **Optimize the use of non-synthetic pesticide management strategies** before considering pesticide use. Think carefully about whether a pesticide is needed and take steps to reduce pesticide reliance. In accordance with IPM principles, **routine scouting** and **economic thresholds** should guide the decision, using selective and safe insecticides as a last option. FAO Guidance Note 2 describes a scouting protocol for FAW.

2. Harmonize the use of synthetic pesticides with conservation of natural enemies. Indiscriminate use of synthetic pesticides can disrupt natural enemy-pest populations in FAW habitat, leading to increases in the abundance of FAW. To avoid this scenario, **deploy a selective synthetic pesticide** that affects the target pest only and not FAW's natural enemies (Jepson *et al*., 2020, Torres and Bueno, 2018).

3. If the use of pesticides is deemed necessary due to FAW populations crossing above the economic thresholds, for example, **select products with the lowest risk to humans, the environment and non-target organisms** from the list of available registered products that are effective against FAW.

4. **Ensure proper use** of the selected products for approved applications and **comply with international standards** (Guidance on Pest and Pesticide management, FAO 2010; FAO/WHO International Code of Conduct on Pesticide Management).

5. **Rotate the active ingredients** among the selected synthetic pesticides to avoid development of insecticide resistance among FAW populations.

TERMS

Geographic ranges

These are geographical areas where a species is found. In the case of fall armyworm before 2016, its geographic range was limited to the Americas. Since 2016, FAW's geographic range has been expanding to include Africa, Near East, Asia and Australia.

Center of origin

This is a geographical area where a species is considered to have first appeared. For FAW, the tropical and sub-tropical regions of the Americas are considered the center of origin.

Habitat

Habitat is a location where conditions allow for the completion of the entire life-cycle and multiplication of an organism, species or community. For FAW, this includes availability of certain host plants (e.g. maize, sorghum and numerous other plants) and temperature range.

Year-round breeding areas

There are geographical areas that allow for year-round completion of whole-life cycles and multiplication of a species. For FAW, these areas serve as year-round habitat due to their host plant's availability and climatic range. Year-round breeding areas also serve as the starting points for FAW seasonal migration.

Seasonal migration

Population-wide movement of a species from one geographic area to another during a certain time of the year is seasonal migration. For FAW, seasonal migration typically occurs during warmer times during which FAW populations move from the year-round breeding areas to more northerly or southerly regions as large swath of host plants (e.g. maize) become available and the climatic factors enter the range that make them suitable as FAW habitat.

Area-wide IPM

Area-wide integrated pest management (IPM) is an IPM strategy applied against an entire target pest population within a delimited geographical area.

Using FAMEWS in the field to detect FAW damage

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MORE INFORMATION

AGP-Director@fao.org
Fall-Armyworm@fao.org
http://www.fao.org/fall-armyworm

CONTACT US

Plant Production and Protection Division
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla, 00153 Rome, Italy
E-mail: AGP-Director@fao.org

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