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Review on Status and Sustainable Management of the Fall Armyworm in Ethiopia

[1]Alemu Habebe and [2]Abebe Chaka
1. Department of Plant Science, College of Dryland Agriculture, Samara University, Ethiopia
[1]Corresponding author: alemuh2@gmail.com

Abstract.

The fall armyworm (FAW) is a major pest of maize in America and its outbreaks in 2017 in Africa which threatened maize, a staple food crop in the region. Due to its rapid spread and distinctive ability to inflict widespread damage across multiple crops, fall armyworm poses a serious threat to the food and nutrition security and livelihoods of hundreds of millions of farming households in Ethiopia particularly when layered upon other drivers of food insecurity. These invasion and rapid spread required multiple approaches of management that ranged from biological, chemical, and botanical control methods. The effective synthetic insecticides, insecticidal plant extracts and entomopathogenic fungi, thus, could be recommended in management of fall armyworm in maize production. Reliance on pesticides spray may, in the long run, increases the likelihood of FAW resistance to pesticides, environmental pollution, health hazards and Killing of natural enemies. *Hence, to overcome the present problem and find out the sustainable solution in management of fall army worm using biological control and IPM compatible product will be a firsthand to reduce the pest and to save our environment.*

Keywords: Fall Armyworm, insecticide, insect pest, integrated management, maize, pheromone trap

1. Introduction

The Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) (Insecta: Lepidoptera: Noctuidae, is one of the major insect pests causing substantial yield losses of maize. FAW which is indigenous in the America is a polyphagous pest causing economic damage of various crops such as maize, sorghum, beans and cotton (Roger *et al*., 2017). Fall armyworm was first reported in West Africa in late 2016, and early 2017, the pest invaded Eastern and Southern Africa. Recent report confirmed the occurrence of FAW in 28 countries in Africa (Abrahams *et al*., 2017b; Roger *et al*., 2017) indicating the rapid spread of the pest in the African continent threatening food security of millions of people.

In maize, fall armyworm attack all stages of the plant from seedling until tasseling and earing causing defoliation, killing young plant, tunnel into the stem and attack ears resulting in grain damage and subsequently reduce quantity and quality of yield (Peairs and Sanders, 1979). Recent studies conducted by Center for Agriculture and Bioscience International (CABI) in 12 maize-producing African countries showed that without proper management, FAW can cause maize yield losses of between 8 – 21 million tonnes, leading to monetary losses of up to US$ 6.1 billion, while affecting over 300 million people in Africa, who, directly or indirectly, depend on the crop for food and well-being (Abrahams *et al.*, 2017b; Midega *et al.*, 2017).

As common with other major agricultural pest, the common management strategy for the FAW in its native ranges of Americas has been the use of insecticide spray and genetically modified crop (Bt maize). Nevertheless, the FAW has developed resistance for several insecticides (Abraham *et al.*, 2017a; Yu *et al.*, 2003), which suggests the use of integrated management strategy for sustainable management of this invasive pest.

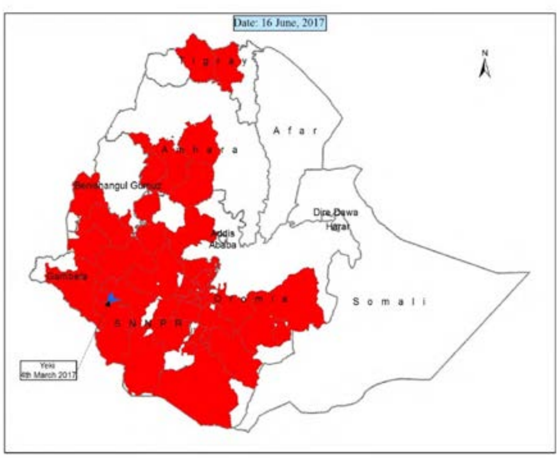
2. Spread of the Pest in Ethiopia

Maize production has been threatened in America and recently it has been a new invasion and devastating pest in Africa. Recent reports on fall army worm (*Spodoptera frugiperda*) in Africa indicated rapid spread that already invaded 28 countries within a year. The pest attacks all stages of maize plant from seedling to cob. The fall armyworm was first detected in West Africa in December 2016 and has since appeared in Zimbabwe, Zambia, Malawi, the Democratic Republic of Congo (DRC), Mozambique, Lesotho, South Africa and Tanzania, and recently in Ethiopia. Ethiopia confirmed in Bench Maji, Sheka and Kefa zones of Southern Nations in January 2017 which then spread to Jimma, Sidama, East shewa, East Gojam and West Gojam zones, and recently in Tigray and Hararghe.

R.No	No of Zones	No of Districts	No of Villages	Total area planted	Area infested	Control by chemical	Control hand picking	Total area	Amount pesticide (lt)
South	16	121	2,161	488,093.58	92,194.48	41,804.61	39,537.93	81,342.53	49,950.81
Oromia	18	166	2,414	951,949	225,327	72,961.7	76,475.51	149,437	65,111.25
Amhara	6	54	699	547,939.1	98,480.72	28,422	62,307	90,729	19,419.2
Tigray	3	16	107	81,768.8	1,718.85	356.875	1,258.25	1,615.12	296.625
Benshangul	3	20	399	296,257.04	32,840.18	2,096.525	12,830.85	14,927.372	2,430.5
Gambella	3	8	79	9,022.6	4,520	3,134	-	3,134	6,068
Total	49	385	5,859	2,375,030.12	455,081.23	148,775.6	192,409.5	341,185.	143,276.
					19%	**32.69 %**	**42.28**	**74.97%**	

Table 1: Area infested and management of fall armyworm in Ethiopia

Fall Armyworm Distribution in Ethiopia



Current status:
- 6 Regions
- 49 zones
- 385 woredas(district)
- 5,859 villages
- Close to 2,35,030 Ha planted area
- infested (19 % of M. Ha) 455081ha

Source: Ethiopian plant protection directorate, 2017

3. Fall Armyworm Description and Life Cycle1

The FAW life cycle is completed in about 30 days (at a daily temperature of ~28°C) during the warm summer months but may extend to 60-90 days in cooler temperatures. FAW does not have the ability to diapause (a biological resting period); accordingly, FAW infestations occur continuously throughout the year where the pest is endemic

3.1 Egg Stage

The egg is dome shaped: the base is flattened and the egg curves upward to a broadly rounded point at the apex. The egg measures about 0.4 mm in diameter and 0.3 mm in height. The number of eggs per mass varies considerably but is often 100 to 200, and total egg production per female averages about 1,500 with a maximum of over 2,000. The eggs are sometimes deposited in layers, but most eggs are spread over a single layer attached to foliage. The female also deposits a layer of grayish scales between the eggs and over the egg mass, imparting a furry or moldy appearance. Duration of the egg stage is only 2 to 3 days during the warm summer months.

3.2 Larval Stage

The best identifying feature of the FAW is a set of four large spots that form a square on the upper surface of the last segment of its body (Figure 1E). The face of the mature larva may also be marked with a white inverted “Y” and the epidermis of the larva is rough or granular in texture when examined closely. Larvae tend to conceal themselves during the brightest time of the day. Duration of the larval stage tends to be about 14 days during the warm summer months and 30 days during cooler weather. Mean development time was determined to be 3.3, 1.7, 1.5, 1.5, 2.0, and 3.7 days for instars 1 to 6, respectively, when larvae were reared at 25°C (Pitre and Hogg 1983).

3.3 Pupal Stage

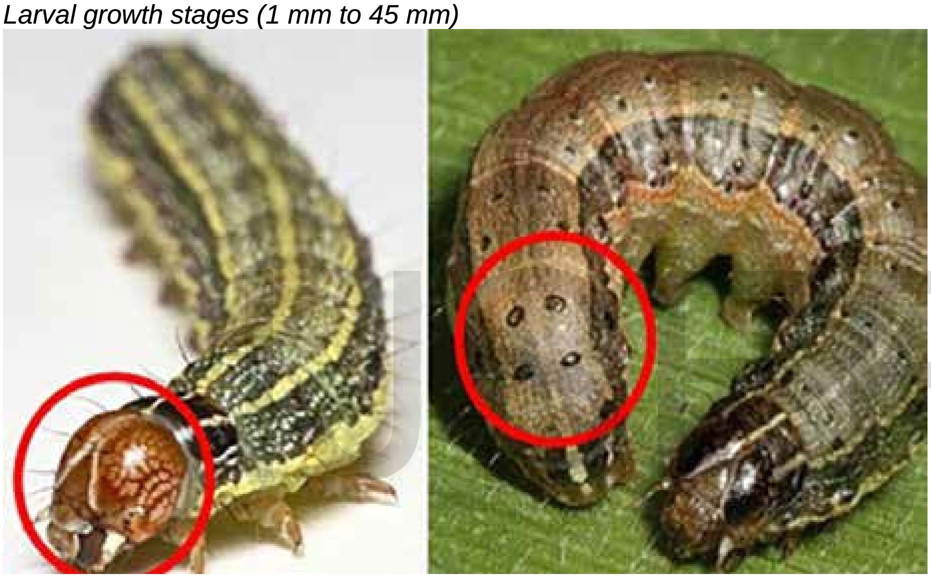
The FAW normally pupates in the soil at a depth 2 to 8 cm. The larva constructs a loose cocoon by tying together particles of soil with silk. The cocoon is oval in shape and 20 to 30 mm in length. If the soil is too hard, larvae may web together leaf debris and other material to form a cocoon on the soil surface. The pupa is reddish brown in color (Figure 1F), measuring 14 to 18 mm in length and about 4.5 mm in width. Duration of the pupal stage is about 8 to 9 days during the summer, but reaches 20 to 30 days during cooler weather. The pupal stage of FAW cannot withstand protracted periods of cold weather (Pitre and Hogg 1983)

3.4 Adult Stage

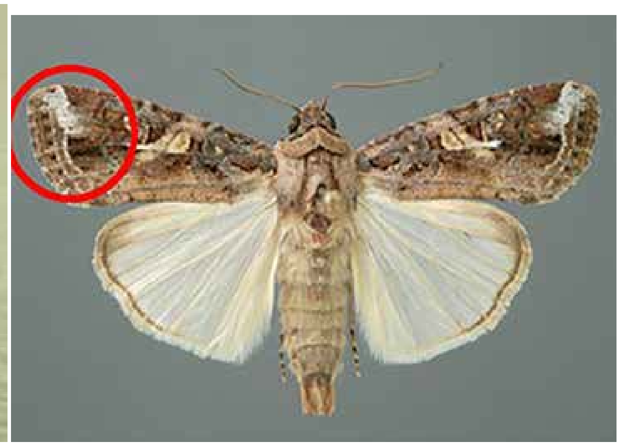
Adult FAW moths have a wingspan of 32 to 40 mm. In the male moth, the forewing generally is shaded gray and brown, with triangular white spots at the tip and near the center of the wing (Figure 1G). The forewings of females are less distinctly marked, ranging from a uniform grayish brown to a fine mottling of gray and brown. The hind wing is iridescent silver-white with a narrow dark border in both sexes. Adults are nocturnal, and are most active during warm, humid evenings. After a preoviposition period of 3 to 4 days, the female moth normally deposits most of her eggs during the first 4 to 5 days of life, but some oviposition occurs for up to 3 weeks. Duration of adult life is estimated to average about 10 days, with a range of about 7-21 days (Luginbill 1928).

Egg mass placed on stem (left) or leaf (right) at early stage of maize plant

Larval growth stages (1 mm to 45 mm)



Distinguishing marks on medium to large-sized larvae



Reddish-brown pupa *Male moth with conspicuous white spot on tip of forewing*

Figure 1. Various stages of FAW life cycle (Source: Ivan Cruz, Embrapa).

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4. Nature of Damage

Marenco *et al*. (1992) indicated that infestation by FAW on sweet corn causes more injury at late whorl stage compared to early and mid-whorl stages. Larvae of FAW burrow into the growing point of plants (buds, whorls, etc.) and destroy the growth potential of plants, or clip the leaves. In corn, they also burrow into the ear and feed on kernels like that of corn earworm, *Helicoverpa zea* (Boddie). But, unlike corn earworm, fall armyworm will feed by burrowing through the husk on the side of the ear. Leaf damage by FAW and stem borer is also confusing. However, it is possible to determine which species is responsible for the damage through close examination as the holes formed by FAW have smooth edges whereas holes cut by maize stem borer larvae have raged edges (Goergen *et al.,* 2016).

Larva of *S. frugiperda*

Infested maize cob

Crop damaged by *S. frugiperda*

5. Management Options for fall armyworm

Detecting fall armyworm infestations before they cause economic damage is the key to their management (Ferreira, 2015

5.1 Cultural

Cultural control is an important component of pest management strategies including FAW. Sole maize cropping systems offer favorable environment to FAW to spread fast. FAW adult female moths find the preferred conditions to lay egg masses and increase the number of generations within a season, favoring increased levels of infestation. Plant diversity, including intercropping systems and the use of multiple varieties, can reduce the rate of oviposition by confusing the FAW female moth, therefore helping reduce the level of infestation (FAO, 2018). A recent study has established that a climate-adapted version of Push-Pull, an already widely used technology developed by *icipe* and partners is effective in controlling the fall armyworm, providing a suitable, accessible, environmentally friendly and cost-effective strategy for management of the pest.

These findings represent the first documented report of a readily available technology that can be immediately deployed in different parts of Africa to efficiently manage the fall armyworm. The study revealed fall armyworm infestation to be more than 80% lower in plots where the climate-adapted Push-Pull is being used, with associated increases in grain yields, in comparison to monocrop plots. The findings were supported by farmers' perceptions through their own observations regarding significantly reduced presence of fall armyworm in Push-Pull plots (Midega, 2018). Similarly, most of subsistence farmers in Africa do not apply pesticides to maize to control pests; nevertheless, they do practice cultural control methods which deter or kill pests, such as maize intercropping, handpicking and killing of caterpillars, application of wood ashes and soils to leaf whorls (Tsedeke *et al*., 2000). Survey conducted in Ethiopia and Kenya showed that 14% and 39% of the farmers practiced cultural methods (such as handpicking) for FAW managements (Teshome *et al*., 2018).

5.2 Biological

Biological control can be considered as a powerful tool and one of the most important alternative control measures providing environmentally safe and sustainable plant protection. The success of biological control will depend on understanding the adaptation and establishment of applied biological control agents in agricultural ecosystems. Microbial pathogens and arthropod biocontrol agents have been successfully used in agricultural systems. They are safe for non-target vertebrates and for the environment, and production costs have been significantly reduced in recent times as they are mass produced in liquid media (Mahmoud, 2017). Even though biological control may not replace conventional insecticides a number of parasitoids, predators and pathogens readily attack larval and adult stages of FAW.

5.2.1 Parasitoids and Predators

The migratory behaviour of the FAW away from over-seasoning and reproduction sites makes the natural enemies less efficient. Various insects have been reported parasitizing *S. frugiperda* larvae and eggs. Ashley (1979) listed 53 species of parasitoids reared from *S. frugiperda* eggs and larvae. Only 18 of these are common to the continental United States, while 21 are present in South America and Central America, including Mexico. Ashley (1986) studied the impact on *S. frugiperda* population of eight native and one imported parasite in south Florida. These included: *Apanteles marginiventris, Campoletis grioti, Chelonus insularis, Meteorus autographae, Ophion spp., Rogus laphygmae, Ternelucha spp.* and *Eiphosoma vitticole* (imported). Although 63% of the first four larval instars were destroyed by parasitoid, they concluded that *S. frugiperda* has the reproductive potential to increase its population beyond regulation by native parasites.

The predators of FAW are general predators that attack larvae of other lepidopterans. The most important predators of FAW include various ground beetles (Coleoptera: Carabidae); the striped earwig, *Labidura riparia* (Pallas) (Dermaptera: Labiduridae); the spined soldier bug, *Podisus maculiventris* (Hemiptera: Pentatomidae); and the insidious flower bug, *Orius insidiosus* (Hemiptera: Anthocoridae) (Capinera, 2001). Among the vertebrate predators, birds, skunks, and rodents are important ones that feed on larvae and pupae of FAW (Capinera, 2005)

5.2.2 Entomopathogens

The development of resistance to synthetic insecticides is one of the driving forces for changes in insect pest management (Mahmoud, 2017). The use of microbial control is a potentially valuable alternative to chemical pesticides with their high cost, possible pest resurgence, development of resistance, and environmental contamination (Lezama-Gutiérrez *et al*., 2001). Entomopathogens may be used to suppress insect population in at least three ways: (1) optimization of naturally occurring diseases, (2) introduction and colonization of pathogens into insect population as natural regulatory and (3) repeated application of pathogens as microbial insecticides (Wayne *et al*., 1980).

Fall army worm is susceptible to at least 16 species of entomopathogens including viruses, fungi, protozoa, nematodes and bacteria (All et al., 1996; Wayne *et al.*, 1980). Among the pathogens, *Bacillus thuringiensis*, *Metarhizium anisopliae and Beauveria bassiana* are cause significant level of mortality in FAW population and help to reduce leaf defoliation in crops (Molina-Ochoa *et al*., 2003).

Fungal pathogen such as *M. anisopliae and B. bassiana* can cause a common disease in FAW larvae (Molina-Ochoa *et al*., 2003). Many of them occur naturally in fall armyworm population.

5.2.3 Pheromone Lure

Insect traps are important tools for monitoring pest populations in surveys and integrated pest management (IPM) programs. Traps can help detect invasions by novel pest species, the onset of seasonal pest activity, determine the range and intensity of pest infestations, and track changes in pest populations, all of which help informed decision making for pest management (Wyatt, 1998). Traps typically use olfactory (chemical) and/or visual cues or stimuli to attract pest insects. Phermone lures are a critical tool for detecting and managing insect pest populations (Spears, 2016). Lepidopteran pheromones have been successfully used for insect monitoring, mass trapping, and mating disruption for diverse of insect pests (Wyatt, 1998).

5.2.4 Botanicals

The use of botanical pesticides is considered as a substitute to hazardous synthetic pesticides such as pyrethroid and organophosphorus pesticides due to the disturbance in the environment, increasing user cost, pest resurgence and pest resistance to pesticide (Arya and Tiwari, 2013). As a result of serious impacts of the use of persistent and deleterious insecticides, research on the identification of eco-friendly and locally available alternative tools for pest control has been agenda of entomologist. Because of affordability and availabilities, farmers of developing countries used botanical insecticides for centuries to control insect pests of both field crops and stored produce (Schmutterer, 2009). Neem products were effective for control of stem borers, including the spotted stalk borer. According to Asmare *et al*. (2006), botanicals like *N. tabacum* and *J. Curcas* were found superior and better than untreated controls in reducing insect damage and increasing yield of maize similarly, extracts of many plants show insecticidal activity against FAW, but relatively few have been successfully commercialized.

The aqueous extract of neem seed cake is more toxic than the leaf extract which is usually used by farmers to control *S. frugiperda* (Silva *et al*., 2015). According to Afonso and Teixeira (2003) the mortality level of *S. frugiperda* caterpillars was low during the first three days, after initial feeding, and high by 10 days using an aqueous extract of neem leaves.

5.3 Synthetic Insecticides

As it is true in many other insect pest species, insecticides are important management options in FAW control (Capinera, 2001). In Florida, fall armyworm is the most important pest of corn and insecticides are applied against FAW to protect both the early vegetative stages and reproductive stage of corn (Capinera, 2001). High volume of liquid insecticide is required to obtain adequate penetration and kill larvae feeding deep in the whorl of the plants. In situations where overhead sprinklers are used for irrigation, insecticides can also be applied in the irrigation water. Keeping plants free of larvae during the vegetative period can help to reduce the number of sprays needed at the silking stage (Foster, 1989). Hence, sprays should be spaced evenly during the growing period instead of concentrating at silking period.

6. Conclusions

Maize production has been threatened by fall army worm in America and recently it has been a new invasion and devastating pest in Africa. Recent reports on fall army worm in Africa indicated rapid spread that already invaded 28 countries within a year. The pest attacks all stages of maize plant from seedling to cob. The fall armyworm was first detected in West Africa in December 2016 and recently in Ethiopia. Ethiopia confirmed in Bench Maji, Sheka and Kefa zones of Southern Nations in January 2017 which then spread to Jimma, Sidama, East shewa, East Gojam and West Gojam zones, and recently in Tigray and Hararghe. These invasion and rapid spread required multiple approaches of management that ranged from biological, chemical, and botanical control methods. Furthermore, management of fall army worm using biological control and IPM compatible product will be a firsthand to reduce the pest and to save our environment. In addition to this, strengthen early warning system and avail specific pheromone traps, scouting and monitoring of the insect year round will play great role in fall armyworm management

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