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FALL ARMYWORM, *Spodoptera frugiperda* OUTBREAK IN NIGERIA: IMPACTS AND MANAGEMENT ON MAIZE FIELDS - A REVIEW

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Abstract

The recent invasion of fall armyworm (FAW, Spodoptera frugiperda) on maize in Africa has threatened food security in Nigeria and across African region. The arrival of fall armyworm in Nigeria since 2016 has significantly affected maize production and caused severe economic losses to farmers in the country. The spread of FAW in Nigeria cut across the 36 states of the country in 2018 incurring more damages due to the invasive nature of this pest. At the onset of the FAW attack between 2017 and 2018 farmers adopted chemical control method which proved ineffective against the pest. The current management approach for FAW in Nigeria is integrated pest management (IPM) which comprises combination of chemical application, cultural practices and botanicals from neem plants. The IPM program adopted by farmers have not yet achieve appreciable success in FAW eradication in the country. This paper therefore reviews the status, impacts and current management of the fall armyworm to provide useful information to scientists and relevant stakeholders on the need to intensify efforts in conducting relevant research to improve FAW management or possible eradication in Nigeria and West Africa to enhance food security in the region.

Key Words: *Maize, Invasive species, Biology, Control, Spread, Damage, Nigeria*

Introduction

Insect pest outbreak is a function of population dynamics. The population of insect is controlled by their ability to increase and this is greatly determined by both biotic and abiotic factors. According to Hasting (2004), an outbreak is when an insect reaches a very high population which is far above the normal. From an ecological point of view 'an outbreak is an explosive increase in the abundance of a particular species that occurs over a relatively short period of time (Singh and Satyanarayana, 2009). There is a general consensus that insect pest outbreak is more frequent and do more damage in host plant in large and continuous host stands; that is a vegetation where one or a few plant species are dominant, abundant or aggregated (Carson *et al*., 2008). Fall Armyworm (FAW) *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera:

Noctuidae) is an invasive and highly significant economic pest native to the Americas (Nagoshi *et al*., 2012). The FAW was first confirmed in the rainforest zone of Southwestern Nigeria in maize fields at the International Institute of Tropical Agriculture (IITA) and Institute of Agricultural Research and Training (IAR&T) at Ibadan and Ikenne in 2016 and later spread to other parts of African countries. (Goergen *et al*., 2016; IAR&T, 2016; Cock *et al*., 2017). The invasion of FAW caused massive destruction of several hectares of maize field resulting in huge economic loss to majority of the farmers (Odeyemi *et al*., 2020)

The invasion of the pest is indeed of a great concern, because, aside the fact that maize is an important raw material for most agro-based industries used in the production of animal feed and breakfast, it also forms major components of the diet of more than 180 million people of Nigeria. The outbreak of the pest in Nigeria is still of a great concern, because it constitutes threat to the food security of the nation as well as farmers' livelihood. The caterpillar of FAW is ravaging maize field at an alarming rate. It is a well-known pest of agricultural crops in the western Hemisphere and endemic to some part of United States such as Florida , Texas and Columbia (Sparks, 1979; Clark *et al*., 2007 Garcia *et al*., 2002;).

The pest host range include; grasses, maize, sorghum, sweet corn, cotton, rice, peanut, cowpea, soybean, vegetables, broadleaf plants and others (Sparks 1979; Andrew 1980; Scott 1991; Santos *et al*., 2003). The pest is known to be capable of causing severe damage by feeding on the foliage of suitable crop, leading to heavy skelotonization/defoliation. Leaves of heavily infested maize usually appear ragged. Maize tassels and cobs are also attacked under severe infestation. The activity of this pest is so insidious to the farmers, which makes its presence unnoticed until havoc is done. Armyworms are strong fliers and can migrate across thousands of kilometres of land. Rain shower after a long dry spell is one of the possible factors that could lead to a pest outbreak. Similar armyworm outbreaks have been reported in the past in some Africa countries like Tanzania, part of South Africa, Ethiopia (Goergen *et al*., 2016).

Nigeria is one of the very first country that reported the presence of fall armyworm in Africa, however, there is no clear evidence on the source of introduction of the pest to Nigeria (IART, 2016, Goergen *et al*., 2016). There is high possibility that the pest could be introduced across the borders, moth migration by flight, wind dispersal or through imported maize materials as a result of international trades (Dent, 2000). The major infestation of FAW in Nigeria since its introduction is mostly on maize crop, though it has been recorded in other crops but the damage on maize in more severe than in other crops. A quick survey conducted in the year 2016 revealed that fall armyworm is present in most of the farms visited. In some areas as high as 90% of visited farms were infested by fall armyworm with varied levels of severity (Odeyemi *et al*., 2020). Till present, fall armyworm constitute a great threat to successful maize production in Nigeria. This pest problem if not address urgently, will further widen the maize supply gap, especially in the phase of the current COVID- 19 pandemic, maize importation ban and farmer-herdsman situations.

Biology and Life Cycle of FAW

FAW is a moth of American origin, widely known as one of the devastating pests of many agricultural crops across the region. Until recently, FAW has not been established outside the America, but have now entered Africa and spread throughout the tropical and subtropical regions of the continent (Day *et al*., 2017). They can breed constantly under a suitable climatic condition in area and are capable of migrating a long distances on prevailing wind (Day *et al*., 2017). Fall armyworm life cycle comprises of egg, six to seven larval instars, pupa and adults with multivoltine generations depending on environmental conditions and food availability (CABI, 2017). The complete life cycle takes about 30 days at temperature above 28°C during the warm season and can last up to 60-90 days in cold temperatures (Prasanna *et al*., 2018). The egg is dome in shape with flattened base that curves upward to a wide rounded point at the upper part, it is about 0.4mm by 0.3mm for diameter and height respectively (Capinera, 2017). Mature larvae usually have black dorsal pinaculae with long primary movable bristles and distinct marked reversed yellow "Y" shape , the epidermis is rough or granular in texture (Capinera, 2017).The changes in temperature and environmental conditions can affect the period of larva growth from hatching to pupa formations, ranged from 11 to 50 days (Luginbill, 1928). Feeding by larvae and adult activities are active towards late evening and early morning but most often at night (Jarrod *et al.,* 2015). Cannibalism is often observed among the larvae when they are together, where the older ones often feed on the young ones. Cannibalism in FAW larvae usually occur even when food was not limiting, but more frequently at low food quantities and/or high rearing densities (Jason *et al*., 2001). The adult have 32 to 40 mm wingspan, the forewing of the adult male is grey in color with clear white spots on the center while female wings are grayish brown in color but not distinct as that of male (Fig. 1) Adults are nocturnal (active in the night) and are most active during warm, humid evenings. Adult female lays egg within the first five day of emergence after the pre oviposition period. About 1000 eggs can be laid by each female and egg maturity takes 2 -3 days (20-30°C) (FAO, 2018a). The complete life cycle in tropical climate is shown in figure 2.

Fig. 1: Adult fall armyworm; A = Male, B = Female
Source: UF/IFAS (2017)

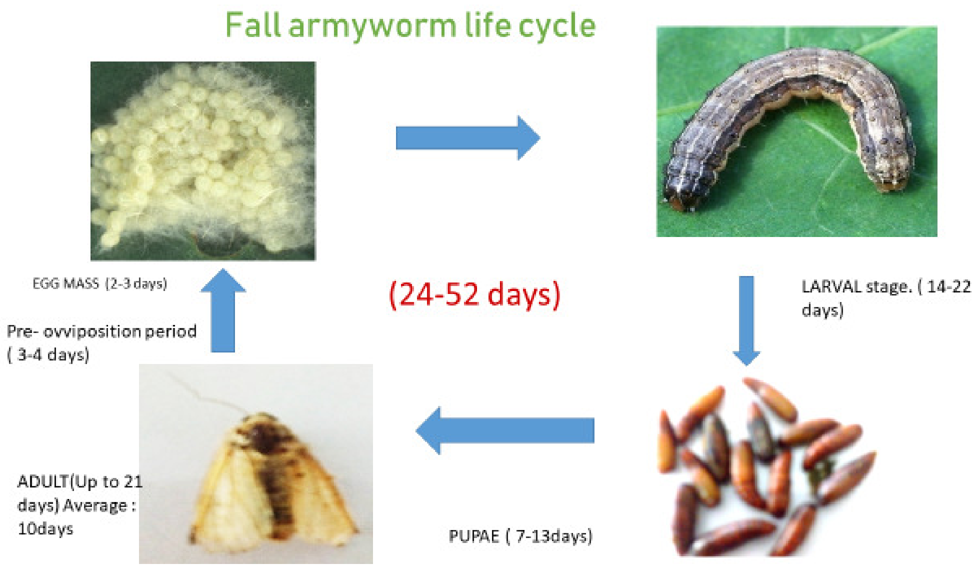

Fig. 2: The complete life cycle of Fall armyworm, *Spodoptera frugiperda* in the tropical climate

Ecology of Fall Armyworm

The survival and population upsurge of FAW is favored by warm and humid rainy seasons and it cannot develop at temperature below 10°C (Stokstad, 2017). FAW has wide host range of about 80 plant species but they sporadically cause major economic damages to their major host plants such as maize, rice sorghum, wheat, alfalfa, cotton, turf, millet, soybean and grasses (CABI, 2017c; Pogue, 2002).

According to Ram, (2019) FAW attack more than 180 plant species in 42 families. *S. frugiperda* is a tropical species adapted to the wormer parts of world with optimum temperature of 28°C for larval development and requires lower temperature for oviposition and pupation. The suitable soil for the pupation and adult emergence of FAW are Sandy-clay or clay. Emergence in sandy-clay and clay-sand soils was found to be directly proportional to temperature and inversely proportional to humidity development (Ramirez *et al*., 1987). At high temperature of about 30°C and above the adult female wing tend to get distorted (Ramirez *et al*., 1987). Two strains of fall army worm has been recognized, rice strain (Rstrain) and corn strain (C strain). The R strain is assumed to feed preferably on rice and several pasture grasses while C strain feed on maize cotton and sorghum (Lu and Adang; 1996; Lewter *et al*., 2006; Nagoshi *et al.,* 2007). The two stains are morphologically similar but differs when genetically characterized. According to (Nagoshi *et al.,* 2018 the diversity of FAW that invaded Africa is larger than the formerly known type comprising a strain (haplotype) that has not yet been detected in the Western Hemisphere. In South Africa, two strains (R and C strans) has been confirmed (Jacobs *et al*., 2018). In Uganda, FAW populations consist of two stains, which are maize-preferred, and rice-preferred strains (Otim *et al*., 2018). Reports from Ghana and Togo submits that the FAW populations are similar to the stains in Caribbean region and the eastern coast of USA (Cock *et al*., 2017; Nagoshi *et al*., 2018). Two stains has also been confirmed in Nigeria (Goergen *et al*., 2016).

Distribution of FAW in Nigeria

The FAW was first was confirmed in the rainforest zone of South-Western Nigeria in maize fields at the International Institute of Tropical Agriculture (IITA) and Institute of Agricultural Research and Training (IAR&T) at Ibadan and Ikenne in 2016 and later spread to other parts of African countries. (Goergen *et al*., 2016; IAR&T, 2016; Cock *et al*., 2017). After the first alert in Ibadan, the attack of FAW in high population was reported in the Northern Nigeria later in the maize planting season. By June 2016, the Federal Government of Nigeria raised distress call over the proliferations of armyworm on maize farm in Edo state and some adjacent states in the south Nigeria (Goergen *et al*., 2016). The spread was very fast and malicious that by June 2017 it has spread to about 22 countries with confirmed cases and the damage they impact on the planted maize in different countries. (Goergen *et al*., 2016; CGIAR, 2019). The spread continues so fast that by 2018, it was reported in all countries in Sub-Saharan Africa except Djibouti and Lesotho (Rwomushana *et al.,* 2018). The spread of FAW continues in Nigeria after its first detection in January 2016 in Ibadan that all the south- Western states and south east reported the attack of FAW in their maize farms by the late planting season of 2016. By 2018, FAW had spread across the 36 states of the country including Federal capital territory damaging maize plants across the country (CGIAR, 2019) (Fig. 3). FAWs of a single generation can swiftly spread over 500 kilometers using wind currents and storm fronts, (Nagoshi *et al*., 2010; Westbrook *et al*., 2016).

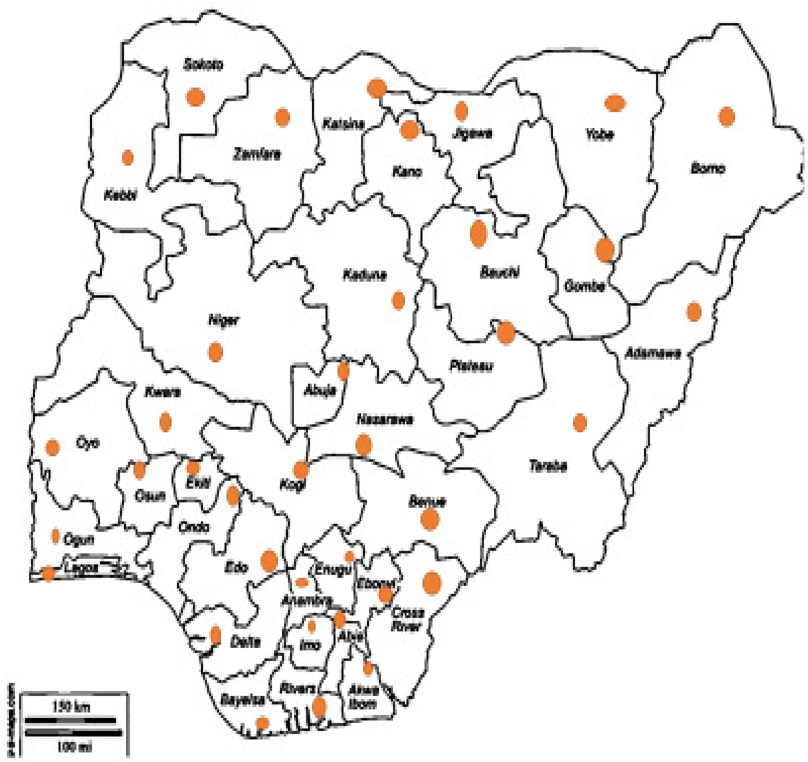

Fig. 3: Current Distribution of FAW Nigeria

Economic Impacts of FAW across Africa

Maize is a major staple crop for the most African continent and is the most widely cultivated crop in Africa. It is cultivated across various agro-ecological zones where over 200 million people depend on the crop for food security (Day *et al*., 2017). The major calories and protein consumptions by Southern and Eastern Africa is attributed to maize and it also account to the one – fifth of sources of carbohydrates and protein of the West Africans (Macauley, 2015). The FAW has displayed preference to maize host in Africa, thus threatens food security in Nigeria and African continent as a whole. The potential economic impacts of FAW on agriculturalproduction across Africa are relatively significant. According to CABI (2017) FAW has potential to cause economic damage on maize that can result in yield losses of about 8.3 to 20.6 M metric tons within a year in 12 African maize producing countries if proper control measures were not applied (Table 1). The estimated values of losses are between US$2.48 billion and US$6.19 billion. The estimated earnings lost due to FAW attack in four states (Abia, Ekiti, Ondo and Oyo States) out of 36 States in Nigeria was USD 268 million in 2018 with 7.8 million hectares of crop estimated to be damaged and >1.5 million households estimated to be affected (FAO, 2018b). FAW attack on maize threatens the food security and livelihood of several masses of household farmers in sub Saharan Africa due to its ability to spread very rapidly and the potential to causes damages across multiple agricultural host crops (Prasanna *et al*., 2018).

The attack of FAW also affect the quality of seed production for planting and consequently reduce seed supply to farmers during the planting season and also affect financial income of young private seed sectors in Africa (Prasanna *et al*., 2018).

Table 1: Estimated Lower and upper yield and economic losses in the 12 maize-producing countries included in the study (lower and upper losses based on lower and upper quartile of significance in yield loss value for each agro-ecological zone)

Production (three-year mean) (thousand tonnes)	Maize (three year average FAO stats)US$ million	(lower) (thousand tonnes)	(upper) (thousand tonnes)	Yield losses(thous and tonnes)	Loss (lower) (US$ million)	Loss (upper) (US$ million)	
Benin	1,285.3	376.5	295.6	735.8	530.4	86.6	215.6
Cameroon	1,665.7	697.8	319.2	794.4	687.4	133.7	332.8
Democratic Republic of Congo	1,173.4	343.7	254.5	633.4	484.2	74.5	185.5
Ethiopia	6628.3	1580.2	1227.2	3054.7	2735.2	292.6	728.3
Ghana	1825.5	629.8	401.6	1213.9	824.3	138.5	418.8
Malawi	3344.9	979.7	769.3	1915.0	1380.3	225.3	561.0
Mozambique	1247.2	365.3	99.7	239.2	514.7	35.0	84.1
Nigeria	9302.7	3271.8	2129.1	5299.7	3838.7	748.7	1863.6
Uganda	2748.3	805.0	558.9	1391.1	1134.1	163.7	407.5
Tanzania	5732.6	1679.1	1301.3	3239.0	2365.6	381.2	948.8
Zambia	2913.0	500.9	728.1	1456.1	1154.0	125.2	250.4
Zimbabwe	1104.1	360.7	234.8	584.4	455.6	76.7	190.9
Total	38971	11590.5	8319.3	20556.7	16104.7	2481.7	6187.3

Source: CABI (2017)

Management of Fall Armyworm in Nigeria

The process of arrival, establishment, integration and spread goes a long way to determine the success of any introduced pest in a new area (Wainhouse, 2005; Venette and Carey, 1998; Williamson, 1996; Liebhold *et al*., 1995). In Nigeria, fall armyworm has progressed through the stages of introduction, settlement, blending and spread, evidenced by the presence of the pest in most parts of the country. Different control strategies have been used to manage FAW in Nigeria including chemical control, cultural control, use of botanicals, mechanical control, use of resistant planting materials, biological control and integrated pest management (IPM). Due to the nature of the pest and the rate of its spread across Africa and beyond, majority of the farmers relied on the use of insecticide, despite the deleterious effect of its excessive use.

Chemical Control

Majority of farmers in Nigeria depend on chemical insecticide for the control of FAW in maize field. At the onset of the outbreak in the 2016, many affected farmers resulted to the use of arrays of insecticide belonging to different chemical groups which include; Cypermethrin, Scorpion, Perfect Killer, Furadan, DDforce, Caterpillarforce, and Combat among (Odeyemi *et al*., 2020). Most of the insecticides used by the farmers were reported not to be effective against the pest (IAR&T 2016; Odeyemi *et al*., 2020). Recently, farmers in Nigeria have resulted to the use of arrays of chemical insecticides especially Ampligo (Chlorantranilipole+Lambda Cyhalothrin) and Caterpillarforce (Emamectin Benzoate) (Unpublished). Several insecticides like esfenvalerate, carbaryl, chlorpyrifos, malathion, permethrin, and lamba-cyhalothrin (are recommended for control of *Spodoptera spp*, However, the use of these chemical insecticides proved ineffective. In Ghana and Zambia farmers adopted the used of Cypermethrin mostly for the control of FAW but Lambda cyhalothrin was reported more successful. The use Emamectin benzoate was also reported moderately effective against FAW in Ghana, whilst majority of farmers that used Chlorpyrifos found it deemed it fairly effective for FAW control (CABI, 2017). According to Togola *et al*. (2018) five insecticide compounds (cypermethrin, deltamethrin, lambda-cyhalothrin, permethrin, and chorpyrifos used against fall armyworm are retained in the soil. Most of the cheapest and most widely used pesticides in Africa fall into the mode-of-action classes which has developed resistance to FAW in America. Thus it was not ascertained if FAW that arrived -Africa has developed resistance to some of these chemicals before arrival to Africa hence proving ineffective as they were applied.

FAW being a new pest in 2016, farmers initially lack basic information on its biology, ecology and management. It is worth to note that the level of awareness on the biology, ecology and management of FAW is on the increase, especially due various interventions by Nigeria government, research institutions and other organizations such as, Federal Ministry of Agriculture and Rural Development (FMARD), Food and Agriculture Organization (FAO), Institute of Agricultural Research and Training (IAR&T), Ibadan, International Institute of Tropical Agriculture (IITA) and others. Integrated Pest Management (IPM) continues to be the target for FAW control in Nigeria. Farmers and extension officers trained under the FAO intervention program have been promoting IPM.

Cultural Control

Cultural control aims at the manipulation of farm activities in order to create a non-conducive environment for the growth and development of a pest, so as to keep its population lower, and also the provision of an enabling environment for the development of the natural enemies.

Cultural control methods include; crop rotation, manipulation of time of planting, plant spacing, fertilizer regime, planting of trap crops, inter cropping, tillage, burning of crop residue, crop variety selection, weed management, Good Agricultural Practices (GAP) and other related activities (Horne and Page, 2008). Cultural control is a very vital component of pest management strategy for FAW. Mono cropping of maize offer a favourable environment for fast spread of

FAW (Assefa and Ayalew (2019). According to FAO (2018) intercropping and rotating maize with non-host crops like sunflower and cowpea could be useful to minimize the attack of FAW (FAO, 2018c). In Nigeria, several of these cultural practices were adopted by farmers but no appreciable results were reported. According to Mitchell (1978), early planting and planting of early maturity varieties are the most vital cultural practice against FAW attack. Trap crops are crops planted to attract insects away from the main crop.

A "climate adapted push pull" technology developed for the control of stemborer in maize, was adapted for fall armyworm control in East Africa. The technology is based on intercropping maize with green *Desmodium*, *Desmodiumintortum* and planting *Brachiaria*cv Mulato II as a border crop around the intercrop. The idea is that the intercrop will repel the pest (Push) from the maize field, while the *Brachiaria* will attract the pest (Pull) out of the field (Fig.4).

The technology had been found to reduce the average number of fall armyworm larvae per plant by 82.7%, and plant damage by 86.7% in a climate-adapted push-pull plots, compared to maize monocrop plots, also, 2.7 times higher yield was reported (Midega *et al*., 2018; Hokkanen, 1991). Push Pull technology is usually non-toxic and could be integrated with other methods (Cook *et al*., 2007). Many maize farmers in Nigeria practice intercropping system combining maize with different crops but this method did not deter or minimize FAW infestation.

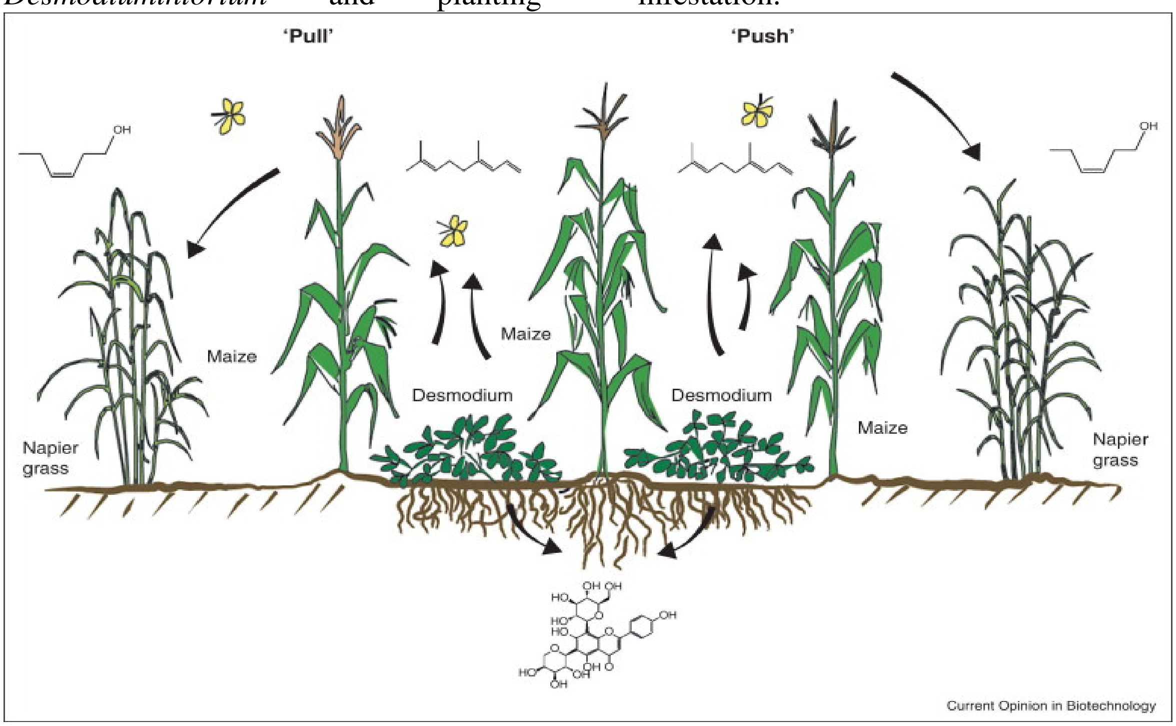

Fig. 4: The pull and Push system for FAW control in maize farm

Rotation of crops grown on the same piece of land has been an age-longed practice in agriculture. Cultivation of the same crop repeatedly over a long period of time on the same land serves to provide a continuous food source for any pest associated with the grown crop. Therefore, if a non-host crop is planted following a host crop, the pest life cycle is interrupted, and will help to reduce the next pest population. Fall armyworm is known to attack more crops in the Poacea family, therefore rotating crops in this family with crops from other less susceptible family will help to manage the pest. The crop rotation system of farming is a common practice among farmers in Nigeria.

Use of Botanical

Plant botanicals has proved effective in the management of several agricultural pests. The awareness of the hazardous effects of synthetic pesticides to the environment, non-target organisms, and residues in crops, pest resistance and pest resurgence has necessitated the recommendation and adoption of botanical pesticides as alternate to synthetic pesticide in crop production (Arya and Tiwari, 2013). Farmers in the developing countries have been using botanical pesticide for ages in the management of insect pests and diseases in the field and storage due to its availability and affordability (Schmutterer, 1985). In Nigeria, several plant extracts were reported to be effective for the control of fall armyworm, which include; extracts from neem plants, Mexican sunflower (*Tithonia diversifolia*). Other plant extracts like cassia leaf extract, wood ash, chili and garlic are also recommended.

Use of Resistant Materials

The use of resistant materials in combination with other methods could proffer a lasting solution for the management of FAW. In South Africa, commercial farmers are encouraged to adopt Bt-technology. MON 810 (YieldGard), MON 89034 (YiledGard 11) by Monsanto and Bt 11(Agrisure) by Syngenta are being promoted for FAW management (IRAC, 2018). Some institutions in Nigeria are presently engaged in researches to develop and identify FAW resistant maize lines (personal communication, CGIAR, 2019).

Mechanical/Physical Control

Some smallholders maize farmers in Nigerian employed hand picking and crushing of FAW which has been considered as a possible control option. However, the success of his methods depends on farm size, availability of labor and level of infestation

Biological Control

Biological control is one of the best pest control approach that is environmentally more sustainable with no negative effect on human health. A good number of biocontrol agents like parasitiods, predators and pathogens has been discovered attacking FAW larvae and adults. Over 150 parasitoid species have been reported to attack *S. frugiperda* in its native range in America (Molina-Ochoa *et al*., 2003; Estrada Vírgen *et al*., 2013; Meagher, 2016). *Archytas marmoratus* (tachinid fly) and *Charops ater* were reported parasitoids of FAW with 12.5% and 6-12 % parasitism respectively in Kenya While *Coccygidium luteum* was discovered parasitizing FAW with 4–8.3% in Tanzania (Birhanu *et al*., 2018). Birhanu (2018) reported that three species of parasitoids *Cotesia icipe Palexorista zonata* and *Charops ater* were collected from FAW larvae in Ethiopia at three different locations with varied level of parasitism Recently, *Telenomus remus*, an egg parasitoid of various Lepidoptera species that has been successfully used as a classical biocontrol agents in several countries was found in Africa (Kenis *et* *al*., 2019). Several predators like ground beetles, the striped earwig, the spined soldier bug and flower bug were reported to be the most important predators of FAW larvae in America (Jones *et al*., 1988; Capinera, 2001; Romero Sueldo *et al*., 2014; Silva *et al*., 2018). FAW has been reported to be susceptible to not less than 16 species of entomopathogens like viruses, fungi, protozoa, bacteria, and nematodes (Gardner and Fuxa, 1980; Molina Ochoa *et al*., 1996; Richter and Fuxa, 1990). The presence of *T. remus* in Africa presents ample opportunity to develop a classical biocontrol strategy towards the control of FAW in the region

Integrated Pest Management (IPM) Program for FAW in Nigeria

Over the years, the concept of IPM has been seen to metamorphosed from not only monitoring of pest populations in the field and use of pesticides when economic thresholds are exceeded, but to embrace other techniques such as the use of biocontrol, resistant host plant, manipulation of agronomic practices and managing host stress (Norton *et al*., 2019, Pretty and Bharucha 2015; Peterson *et al*., 2018).

The recommended IPM components for FAW include; Crushing the egg masses by hand, Early planting of cereal crops in combination with maize, mixed planting with tree crops such as in agro forestry approaches, use of botanicals, local preparation of pathogens formulations like NPV, Bt, Metharihyzium, application of local materials like wood ashes, soil, soap and pesticide application based on monitoring and thresholds not as preventive measures (CABI, 2017). Currently in Nigeria, a standard IPM program for FAW control has not been developed but serious efforts are undertaking by some scientists at Institute of Agricultural Research and Training IAR&T, Obafemi Awolowo University to develop eco-friendly strategies for effective control of FAW (Odeyemi *et al*., 2020).

Conclusion

The fall armyworm *(Spodoptera frugiperda)* was detected in Nigeria in 2016 and has spread to all parts of the country. The arrival of the pest in the country caused reduction in maize production in the country due to its associated damages. The weather condition in Nigeria during the cropping season of maize is very favorable to the invasive worm and has contributed to its successful establishment and spread to the whole parts of the country. The multiple host nature of the pest has contributed to its survival tenacity and spread in the country despite the efforts to bring the pests to check since its introduction in the country. The current adopted control measure has not fully brought the infestation to minimal level. Thus, there is need to intensify efforts towards developing a sustainable management approach to eradicate FAW in Nigeria. Moreover, there is urgent need to fund more research towards finding the lasting solution to the problem of FAW in the region by the government and non-governmental organizations in order to enhance food security especially in the current era of COVID -19 and problems of headsmen in Nigeria.

Recommendations

1. There is need to further strengthen and expand the training of farmers and extension workers on the biology of FAW so that they can monitor their farms for early detection and to know

the appropriate time to apply control measures.

2. The quarantine measures should be tighten up in the country to restrict further entrance from the neighboring countries.
3. Since FAW has a wide host range, there is need to develop a classical biological control measures for its management and eradication in the country by the researchers hence the need for urgent funding of research toward this area.
4. Farmers should be supported with traps and pheromone lures for FAW monitoring and adult suppression.

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