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FALL ARMYWORM *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae): THREAT TO MAIZE PRODUCTION IN NIGERIA

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Abstract
Outbreak of Fall Armyworm (FAW) *Spodoptera frugiperda* occurred for the first time in Nigeria in 2016. This necessitated an urgent survey to determine the extent and level of damage caused by FAW. A total of seventy-four (74) farms were surveyed and information was collected using a guided questionnaire. The survey revealed that the pest was widely spread, evidenced by its high presence recorded in most of the farms visited. The number of farms under attack was about 92.3% in Ogun, 87.5% in Ondo and 87.0% in Oyo States. However, damage severity varied from one State to the other. The States of Ogun (76.9%) and Oyo (52.%) situated in the rainforest and derived savannah transitional zones recorded highest damages. There was a significant positive correlation between the severity of damage and farm size ($r=0.27$; $p<0.05$), with significant negative correlation between severity of damage and age of plant($r = -0.30$, $p < 0.05$). The study therefore recommends the need to give adequate sensitization to farmers on pest management as soon as they are noticed on the farm. There is need to also assist in the design of an appropriate Integrated Pest Management (IPM) strategy against FAW infestation and efficiency in management of this pest, especially with large farm sizes and plants at their early stages of development.

Keywords: Invasive pest, pest outbreak, severity, and IPM

Introduction

Maize (*Zea mays* L.) is an important cereal crop cultivated worldwide. It is also one of the most important cultivated crops in Nigeria. Maize forms a major component in the diet of the majority of the people and is also a source of raw material for agro-based industries like animal feed production (Iken and Amusa, 2004; Abdulraham and Kolawole, 2006). Maize cultivation in Nigeria cuts across different agro-ecologies including; the forest ecology, derived savannah and the guinea savannah (Olaniyan, 2015). Maize is raw material used in the production of alcohol, starch, pulp abrasive, oil in the pharmaceutics and recently for fuel production (Ellis *et al.*, 1998; Acharya and Young, 2008; Ranum *et al.,* 2014).

Despite maize being a promising crop that could ameliorate hunger and help to attain food security, there are factors militating against its production, one of which is the problem of insect pests (Sanchez *et al*., 1997). Insect pests are serious menace to crop production worldwide. Failure to reduce the damage caused by insects on cultivated crops could lead to total failure in terms of yield and quality of produce. Losing crops to insect pests constitutes a great constraint to the realization of food security worldwide. Therefore, in order to meet the food demand for the ever increasing world population, it is necessary to address the issue of crop loss to insect pest damage (Berenbaum, 1995).

FAW is an invasive pest which continues to be a great threat to the successive cultivation of maize crop since its invasion in Nigeria in 2016. It is a well-known pest of agricultural crops in the western hemisphere and endemic to some parts of the United States such as Florida and Texas (Scott, 1991; Clark *et al.,* 2007; Nagoshi and Meagher, 2008), and a primary pest of maize in Columbia (Garcia *et al*., 2002). It is an important phytophagous migrant pest with a wide host range, which is known to cause great economic loss whenever present. The pest host range includes: maize, sorghum, sweet corn, cotton, rice, peanut, cowpea, soybean, vegetables and broadleaf plants (Sparks, 1979; Andrew, 1980; Scott, 1991; Santos *et al*., 2003; Nagoshi

and Meagher, 2008). The pest is capable of causing severe damage by feeding on the foliage of suitable crops, leading to heavy skelotonization/defoliation. Leaves of heavily infested maize usually appear ragged. Feeding of army worm larva on maize leaves disrupt the process of photosynthesis by destroying the photosynthetic apparatus while **c**lipping of maize tassel and silk could result in poor pollination, reduced fertilization, kernel abortion and reduced yield (Darby and Lauer, 2000; Nielson, 2018).

The activity of this pest is so insidious that its presence is unnoticed until havoc has been done. The fall armyworm is a nocturnal pest with the peak of its larva activity in the late evening, during the night and early morning (Sparks, 1979; Santos, 2003; Clark *et al.,* 2007). The attack of fall armyworm on maize fields in Nigeria has been of great concern, because of the threat posed to the food and nutrition security of the nation and farmers' livelihood. The wide spread of the pest immediately after its detection in Nigeria in early 2016, is a clear evidence that the pest is a potential danger to neighbouring countries. This is as a result of its strong flying ability to migrate across thousands of kilometres of land. The sudden appearance of the pest in Africa is still not clear, however, the likely source of pest invasion into any new area could be through trade, transport routes and moth migration (Early *et al*., 2018; Dent, 2000). Thus, in response to the outbreak, a survey was carried out to investigate its spread, extent of damage and economic loss due on cultivated maize.

Materials and Methods

The Study Area

The large population and drastic feeding rate of a particular type of caterpillar was noticed on maize fields at the Institute of Agricultural Research and Training (IAR&T), Ibadan and its environs around March/April in 2016. Samples of maize plants showing the same pattern of damage, and caterpillar specimens were later brought to IAR&T by Ogun State Agricultural Development Programme officers and farmers. Adult and caterpillar specimens were collected from the Ibadan field (N7°26′5.3″, E3°53′14.5″) and Ikenne (N6°50′58.8″, E3°42′20.6″) and sent to the International Institute of Tropical Agriculture (IITA), Cotonou for identification. After morphological and molecular examination by Dr. Georg Goergen, the insect was identified to be *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae). A survey was carried out in May 2016 covering six states: five South-West States (Ogun, Oyo, Osun, Ondo, Ekiti and part of Kwara State) of Nigeria (Fig. 1). The states selected were maize growing areas covered by the research mandate of IAR&T, Ibadan. The area surveyed cut across different agro ecologies: rain forest, derived savannah and guinea savannah. The climate is equatorial with dry and wet seasons, and relatively high humidity. The farms visited were guided by the Agricultural Development Programme (ADP) officers of each State. Seventy-four (74) fields were visited. More than 60% of the sampling sites were located between 10 to 25km range. It is estimated that the cost of production on 1 ha of land is N120,000 in the forest and N112, 000 in the savannah agro ecologies. The average yield is estimated to be about 1.5t/ha which is sold at N85,000/t. Thus, the revenue generated is N127, 500ha^{-1}. The profit margin is N7,500 and N15,500 for forest and savannah ecologies, respectively. On the basis of this, the economic loss was calculated.

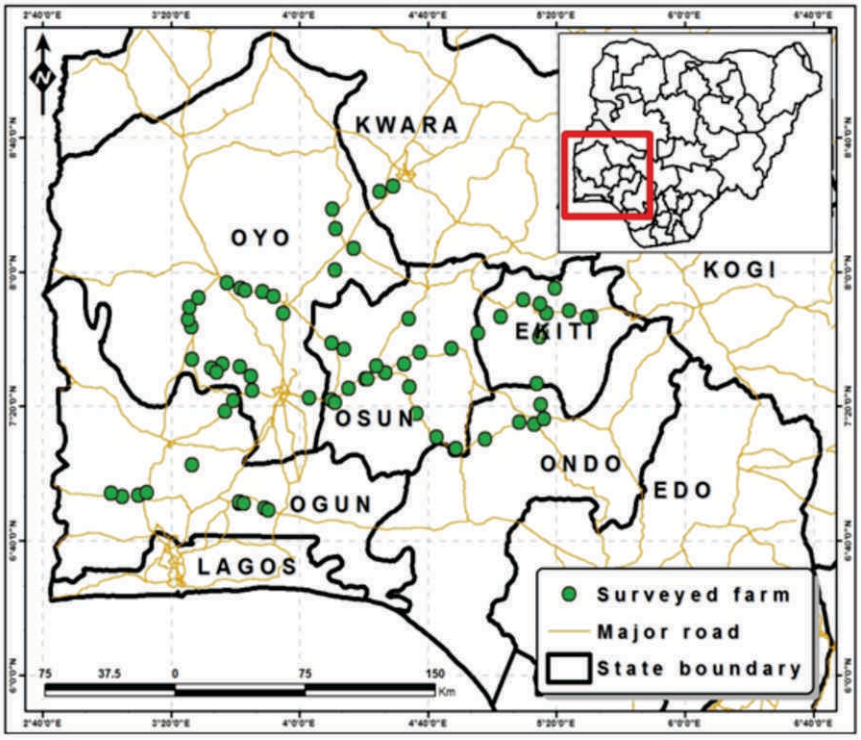

Figure 1: Study location in South Western Nigeria

Data Collection and Analysis

Fields were physically assessed using a non-destructive method. The pattern of leaf damage and the presence of armyworm frass were used as indicators of the presence of the pest. The characteristic pattern of damage caused by armyworm and the physical presence of the armyworm caterpillar and frass were similar across outbreak sites. Therefore, the damage could be attributable to the pest. Observations were made on some parameters including: the presence of the pest (the presence or absence of larvae was recorded from ten plants randomly selected at five locations at each field), the size of the infested field, the severity of damage, (based on the level of leaf tattering using a rating scale of 1 to 5, 1-very low damage and 5-very high damage) and age of plant infested. Information was also obtained about type(s) of crop planted, planting date, maize variety planted, source of seed, farm size, age of plant when damage was noticed, degree of damage, level of infestation and methods of control employed. The percentage of severity of damage was computed relative to the number of farms visited. Collected data were analysed using simple descriptive statistics and correlation analysis was done with SAS (version 9).

Results and Discussion

Spread of the pest

As shown in Table 1, Ogun state recorded the highest number of armyworm infested farms (92.3%), followed by Ondo and Oyo states (87.5 and 87.0% respectively).

Table 1: Percentage of maize field infested by fall armyworm in the states surveyed

States	Number of farms visited	Infested field (%)
Ogun	13	92.3
Oyo	23	87.0
Osun	16	75.0
Ondo	8	87.5
Ekiti	12	66.7
Kwara	2	50.0

The presence of the pest was also recorded in Osun State, although, the level of infestation was low. The survey revealed that infestation of farms by armyworms was widespread across the five States visited. Many components are present in an agricultural landscape which includes the cultivated field, the weeds surrounding the cultivated field, other agricultural fields nearby and other vegetation around the field. All these are components that could determine the site where an insect can stay and develop, and the ability of the insect to find a good habitat and food source (Price, 1976; Perrin, 1980; Duelli *et al*., 1990). Wind direction and speed are other likely factors that could aid the spread of armyworms (Rose *et al*., 1987; Rose *et al*., 1995). Farms situated in the dense forest were observed to have less attack than farms in more open land (e.g. in urban areas). Since adult armyworms are strong fliers, it is possible that the insect finds it easier to move from field to field in urban areas with less obstruction than the free movement of insects in the forest which may be hindered by trees and other crops. According to Karlsson *et al*., (2003), range expansion of an insect during an outbreak could also be attributed to egg survival and synchronization with the time when host or alternate host are flourishing. Also, the direction of range expansion may be determined by the wind direction and vegetation of the area of colonization.

Damage severity

The severity of damage caused by the pest varied among the surveyed states. Ogun, Oyo and Ondo States recorded the highest percentage of severely affected fields (high to very high), 69.2, 43.5 and 50.0% respectively (Table 2). This was in contrast to low pest severity recorded in Ekiti and part of Kwara States. The ages of sampled plants were between two to eleven weeks and armyworm was found to be deleterious to all growth stages of the maize crop (including the seedling, vegetative and reproductive stages). Leaf tattering, one of the damage symptom associated with armyworms, was observed to be more prominent between two to six weeks after planting. The severity of damage varied from location to location, while most farms had moderate to very high damage (Fig. 2). The characteristic pattern of damage caused by armyworms and the physical presence of caterpillar and frass were similar across outbreak sites. Several hectares of maize fields destroyed by the pest were re-ploughed, leading to great economic loss to the farmers. However, there were a few pockets of farms with no infestation. There was a significant positive correlation between the damage severity level and farm size, with a significant negative correlation between the damage severity level and plant age (Table 3). The attack by *S. frugiperda* was found to cut across the various growth stages of the maize plant (the leaves, tassels and cobs). However, plant susceptibility to armyworm damage had earlier been reported to be primarily at seedling stage (Young, 1979). Larvae may have preference for younger plants probably because of their succulent nature, thereby reducing the photosynthetic potential, the general plant growth and development, which may consequently lead to yield reduction.

Table 2: Severity of damage in maize fields infested by *S. frugiperda* across the study locations

States	Number of farms visited	Damage severity (%)					
		very low	low	moderate	high	very high	Absent
Ogun	13	0.0	15.4	7.7	15.4	53.8	7.7
Oyo	23	30.4	4.3	8.7	8.7	34.8	13.0
Osun	16	31.3	6.3	12.5	0.0	25.0	25.0
Ondo	8	12.5	12.5	12.5	0.0	50.0	12.5
Ekiti	12	8.3	33.3	0.0	0.0	25.0	33.3
Kwara	2	50.0	0.0	0.0	0.0	0.0	50.0

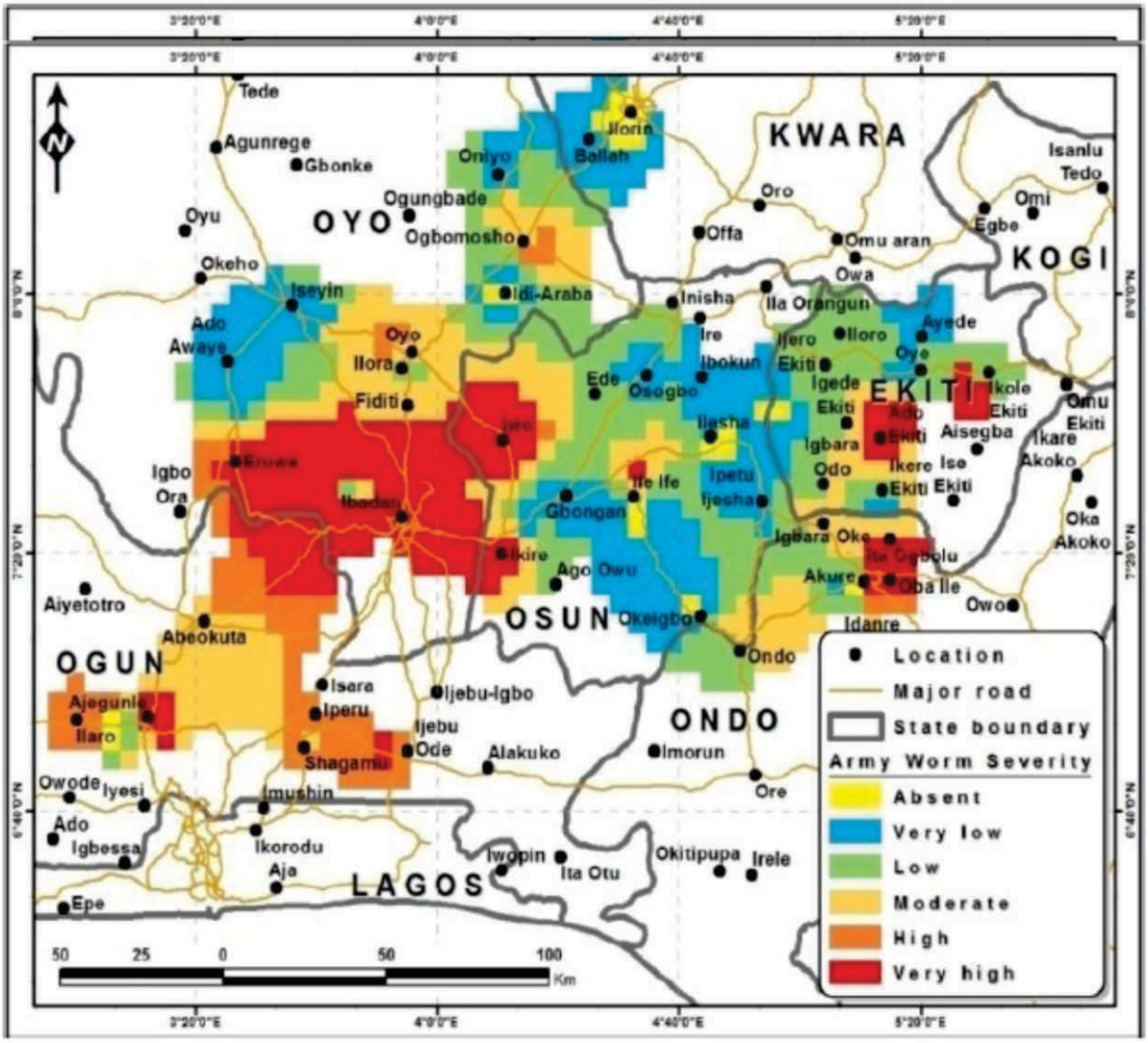

Figure 2: Survey fields and severity of damage due to fall armyworms

Table 3: Correlation matrix of some variables and severity of damage by armyworms infested maize fields

	Farm Size	Severity	Age of Plant	Cropping System
Farm Size	1.00			
Severity	0.27*	1.00		
	(59)			
Age of Plant	-0.06	-0.30*	1.00	
	(56)	(63)		
Cropping System	-0.27*	-0.04	0.01	1.00
	(58)	(66)	(62)	

***P <.05**

Source of seed planted by the farmers

The source of seeds planted by farmers varied across all the areas surveyed. Majority of the farmers planted seed from previous harvest and those purchased from the market (68%), while only a few (32%) planted certified seeds (Fig. 3). The certified seeds were obtained from ADP offices in each State and from certified seed vendors. Seed quality is known to be an important factor in determining plant vigour. In spite of extensive research efforts to improve seed, farmers are yet to maximize the opportunity because most of the farmers could not plant certified seeds. Although, some of the farmers reported that some maize varieties (especially borer resistant varieties) exhibited some level of tolerance to armyworm attack. This was expected because different maize varieties have different attributes and differ in their response to insect attack. Host Plant Resistance is a promising and attractive pest control option, especially in developing countries where the utilization of other control options such as pesticides is difficult and unwise (Bosque-Perez and Buddenhagen, 1992).

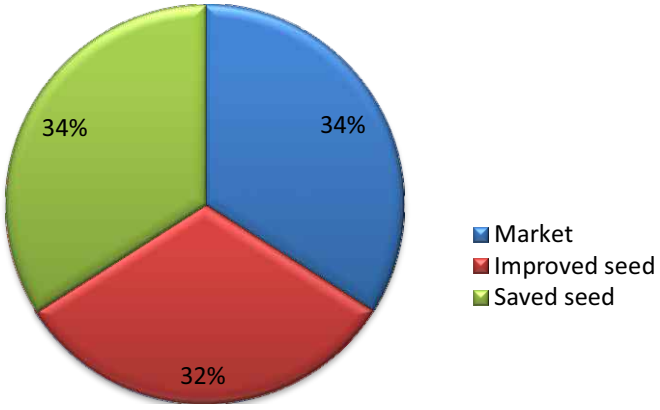

Fig. 3: Source of maize seed planted by farmers in the study area

Cropping systems practiced by farmers in the states surveyed

The majority of the farmers (66%) planted sole maize, while 34% planted maize in combination with other crops like: cassava, tomato, watermelon, melon, soybean, groundnut and yam. The majority of the farmers in Oyo, Ekiti and Osun planted sole maize (Table 4). Both mono-cropping and mixed cropping systems were practised by the farmers. However, there is need for detailed study on the level of FAW infestation under different cropping systems. Continuous cropping of single plant species (monoculture) with its typical low diversity is often faced with an array of problems, such as 'pest and disease outbreak (Altieri and Nicholls, 2004). Besides the fact that monocropping makes crops more visible to insects, they also make food resources available on a continuous basis for the insect. This agrees with Root's source concentration hypothesis (1973) which predicts that specialized species (herbivores) tend to attain higher numbers in large patches of host plants, because the insects are more likely to locate and colonize hosts that are growing in nearly pure or dense stands. This was also supported by Grez and Gonzalez (1995). This will invariably encourage an insect population build up as a result of high reproduction rates (Waage and Making, 1993). The expansion of a monoculture at the expense of crop diversity decreases insect habitat diversity, which eventually affects the abundance and efficiency of natural enemies (Altieri *et al*., 1984). Complex landscapes often have a greater abundance and more diversity of natural enemies, than the ones already simplified by intensive agriculture (Virues *et al*., 2012).

Table 4: Cropping Systems employed in maize farms visited for fall armyworm (n=74)

States	Mono-cropping	Mixed-cropping
Ogun	3	10
Oyo	15	8
Osun	14	2
Ondo	6	2
Ekiti	10	2
Kwara	1	1

***n-number of farms visited**

Control measures adopted by farmers

Some of the insecticides used by the farmers were; Sepadinforce, Tihan, DDforce, Caterpillarforce, Laraforce, Cypermethrin, Scorpion, Perfect Killer, Furadan, Snipper, Combat and herbicide (Atrazine). Many farmers left their fields unattended (not weeded) while some resorted to irrational use of array of insecticides and herbicides to tackle the menace of fall armyworms. Since this was a sudden outbreak, the first line of control action employed by the farmers was the use of chemical insecticides. However, several insecticides used were reported to be ineffective, possibly because the majority of the farmers were not aware of the biology and ecology of the pest in question. Also, the insecticide application method used by the farmers was inappropriate. Presently, efforts are being made by IAR&T to develop eco-friendly strategies for effective control of the pest.

Economic implications of pest outbreak

The implications of the devastation effects of fall army worm on the household economy and and the country at large are enormous. First, a farmer's income would be reduced or totally lost as in the case of a farmer who has 12ha totally ravaged at Ile - Ogbo via Iwo in Osun State (Fig. 4). In addition, there would be low yield and farmers could become discouraged and stop investing in maize farming activities since no one is paying for the loss. Lastly, if a farmer had borrowed money, it would negatively affect repayment and basic household needs would be unaffordable e.g. children's education, food, health etc. The economic effect on the nation at large would be greatly felt in the agro industry that produces livestock feed. The industry accounts for over 60% utilization of maize produced in the South-West. The implication is that there will be a reduction in the size of livestock farms, and prices of livestock products will be high and unaffordable for the common man.

Figure 4: Maize field (12 hectares) damaged by fall armyworm at Ile-Ogbo via Iwo in Osun State

Conclusion

Fall armyworm is a serious pest of maize with great potential to cause economic loss. Routine pest surveys and prompt intervention should always be put in place to forestall sudden epidemics. Therefore, farmers are advised to work in close collaboration with relevant research institutes and agencies in order to keep abreast with appropriate control strategies. However, there are other control methods which could help to alleviate the menace of fall armyworm, such as: host plant resistance, biological control, use of botanicals, cultural practices, mechanical control (hand picking and crushing) and chemical control (Hardke *et al.,* 2011; Figueroa-Brito *et al.,* 2011; Belay *et al.,* 2014; Silva *et al.,* 2014). The rational use of all these methods through Integrated Pest Management will reduce insect pest damage (Bosque-Perez and Buddenhagen, 1992). While other eco-friendly methods are being investigated by a team of scientists at IAR&T, farmers need to be made aware of the biology and ecology of the pest, be able to identify the pest and know the appropriate fall armyworm management strategy and proper application method. It is therefore suggested that Integrated Pest Management should be focused, with technology transfer from countries that have tackled fall armyworm problems in the past.

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