# **BIOECOLOGY OF THE FALL ARMYWORM, *Spodoptera frugiperda* J.E. SMITH ON MAIZE, *Zea mays* L. IN THE SOUTH-WEST, NIGERIA**

By

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# CERTIFICATION

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## DEDICATION

This work is dedicated to my mother, Mrs. Faustina Iyabo Ojumoola, for her inspirational love and strength.

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ABSTRACT

Fall Armyworm (FAW), *Spodoptera frugiperda*, is an invasive insect pest that causes severe damage and yield loss to maize. Synthetic insecticides applied for FAW control are environmentally unsustainable and ineffective due to development of resistance. Information on life-cycle and seasonal occurrence of FAW is necessary for its effective management. Reports on appropriate management strategies for FAW are limited. Therefore, FAW biology and ecology on maize in the South-West, Nigeria (SWN) were investigated.

A four-stage sampling procedure was used. In the first stage, three major Maize-Growing-Agroecologies (MGA): Humid-Forest (HF), Derived-Savanna (DS) and Southern-Guinea-Savanna (SGS) were purposively sampled in the SWN. In the second stage, one Agricultural Development Programme Zone (ADPZ) was purposively selected in each MGA. In the third stage, 50% of Agricultural Development Programme Blocks (ADPB) per ADPZ was randomly selected. In the fourth stage, Maize Farmers– MF (n = 212) were randomly sampled proportionate to size in each ADPB. Data were collected on MF knowledge of FAW attack period, damage severity, larva description, and control practices using structured questionnaire. Twenty early-whorl plants were assessed on-farm in each MGA for FAW infestation (%) and Foliar Damage Severity– FDS (0=immune to 5=highly susceptible). Life-cycle characteristics were assessed in the laboratory on Development Duration– DD (days), morphometrics of immature stages (mm), longevity of fed and unfed moths (days) and FAW oviposition. Twenty-five maize varieties were evaluated on the field for response to FAW during two consecutive early and late seasons; plots were laid-out in a randomised complete block design with four replicates. Egg-mass abundance, larva abundance and FDS at three, five, and seven Weeks-After-Sowing (WAS) were determined. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05.}$

Maize farmers (88.7%) observed FAW attack within two months-after-sowing but only 30.8% reported total damage. Most MF (75.9%) could describe FAW larva correctly. Also, 58.5% MF exclusively applied synthetic insecticides for FAW control. Insecticides commonly used by respondents were organophosphates (37.2%) >pyrethroids (29.0%)

>avermectins (18.2%). Percentage FAW infestation and FDS were significantly higher in HF (86.25±3.90%; 2.63±0.14) than in SGS (56.88±3.90%; 1.66±0.12), respectively. Total DD for egg, larva and pupa was 2–3, 11–12 and 7–10, respectively. Egg was spherical (0.24±0.01); larva comprised six-instars with 1.64±0.03 to 26.45±0.44 body-length, 0.18±0.01 to 3.45±0.07 body-width and 0.12±0.01 to 2.45±0.02 head-capsule-width. Pupa body-length and body-width were 14.38±0.14 and 4.21±0.04, respectively. Fed moths (7.25±0.47) significantly lived longer than unfed moths (4.13±0.17). Eggs laid by FAW paired at 1♂:1♀ (1354.00±168.16) were significantly higher than those paired at 3♂:1♀ (599.89±210.31). Also, eggs laid on abaxial (56.30±7.29) were significantly higher than on adaxial (13.00±0.00) leaf surface. Egg-mass abundance in early-season was 0.47±0.04 (3WAS) >0.18±0.02 (5WAS) >0.00±0.00 (7WAS). Larva-abundance in early-season was 0.38±0.03 (3WAS) >0.10±0.02 (5WAS) >0.03±0.01 (7WAS). Seasonal FDS of maize varieties ranged from 2.0 to 4.0.

Fall armyworm infestation was more severe in the humid forest and early planting season and development from egg to adult occurred within 20–25 days. Field-scouting within three weeks-after-sowing for eggs and larvae could guide appropriate timing for pest management interventions.

**Keywords:** Armyworm egg abundance, Head capsule width, Moth mating, Maize leaf surface, Whorl damage

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# CHAPTER ONE

## INTRODUCTION

Maize (*Zea mays* L.) is a globally cultivated and important staple food (Ranum *et al.*, 2014). It is the worlds' most produced cereal crop with an average global production of 853.13 million tonnes between 2000 and 2018 compared to rice paddy (682.48 million tonnes) and wheat (663.68 million tonnes) (Food and Agriculture Organisation Corporate Statistical Database-FAOSTAT, 2018). In terms of production, the United States, mainland China and Brazil are the world's top three producers of maize with an average output of 313.56, 179.84 and 58.52 million tonnes, respectively between 2000 and 2018 (FAOSTAT, 2018). However, Nigeria is the second largest producer of maize in Africa with an average production of 7.65 million tonnes produced between 2000 and 2018 (FAOSTAT, 2018). In sub-Saharan Africa (SSA), maize is consumed and relied upon for sustenance by more than 300 million people from different cultural and socio-economic backgrounds (United Nations Economic Commission for Africa-UNECA, 2015; FAOSTAT, 2018).

In Nigeria, maize is known by a number of local names which vary from one ethnic group to the other. It is called *agbado*, *Igbado* or *yangan* by the Yoruba tribes in southwestern Nigeria (Abdulrahman and Kolawole, 2006). In the northern part of the country, the Hausas call it *masara*, while the Ibo-speaking tribes in southeast Nigeria refer to it as *ogbado* or *oka*. It is also known as *apaapa*, *Ibokpot* or *Igumapa* by the Ebira, Efik and Yala tribes of the country, respectively (Abdulrahman and Kolawole, 2006; Olaniyan, 2015). Just as maize is known by different traditional names in Nigeria, it is also prepared and consumed as food in various forms. Probably the commonest, fresh maize is eaten as boiled or roasted corn on the cob. Another widespread method of consuming maize in the country is as hot or cold pap. Hot pap (*eko gbona* in Yoruba and *akamu* in Ibo) and cold pap (*eko tutu* in Yoruba, *agidi* in Ibo and *kafa* in Hausa) is maize pudding made from a slurry of maize flour (Olaniyan, 2015). The Yorubas also process maize into *abari* which is basically the maize version of the popular moi-moi made from cowpea. When *abari* is prepared without the addition of local palm oil, the resultant delicacy is often referred to as *iro*. Other traditional forms into which maize is processed and eaten in Nigeria include *tuwo* (*tuwo-masara* in Hausa, *oka* in Yoruba or *inioka* in Ibo) which may be eaten with bean soup or vegetable soup; *donkunnu* which is a traditional food introduced to Nigeria by the Ghanaians; *egbo* which is maize grains cooked to a pulp and eaten with boiled beans, groundnut or coconut; *donkwa* which are small ball-shaped delicacies made from a mix of dried groundnut flour and maize; *aadun* and *kokoro* which are common delicacies in southwestern Nigeria made from ground roasted maize kernels (Abdulrahman and Kolawole, 2006; Olaniyan, 2015).

Apart from being consumed as food (United States Agency for International Development-USAID and Dutch States Mine-DSM, 2002), maize may also be processed into several important industrial products like starch, flour, chips and ethanol (Farrell and O'Keeffe, 2007; Ranum *et al.,* 2014; Shah *et al.,* 2016). It may also be used as livestock feed in the form of green chop, dry foliage, silage or grain (Moran, 2006). The leaves, stem, husk and cob also serve domestic purposes as wood fuel and building materials (Ofor *et al.,* 2009). Nutritionally, maize kernels contain about 72% starch, 10% protein, 4% fat and 365 Kcal/100 g of energy (Nuss and Tanumihardjo, 2010). In addition, maize kernel contains 45 – 50% of oil that can be used for cooking (Orthoefer *et al.,* 2003). The refined oil is rich in linoleic acid (54–60%), oleic acid (25–31%), palmitic acid (11–13%), stearic acid (2–3%) and about 1% linolenic acid (Corn Refiners Association-CRA, 2006). Furthermore, maize contains important phytochemicals such as carotenoids, phenolic compounds, and phytosterols that provide numerous health benefits (Lopez-Martinez *et al.,* 2009; Shah *et al.,* 2016).

Despite its nutritional, industrial and domestic importance, maize production is constrained by a number of socio-economic, abiotic and biotic factors. Socio-economic factors including lack of agro-credits; lack of access to farm inputs such as improved seed varieties, fertilizers and pesticides; absence of small-scale farm mechanization; persistent use of inefficient traditional cultivation; storage technique etc. have greatly limited increased maize production in Africa (Agyare *et al.,* 2014; UNECA 2015). Maize cultivation in the developing countries, including those in SSA is mostly rainfed and as such, heavily dependent on rainfall. Consequently, about 25% of maize production in these regions is limited by insufficient rainfall and drought (Agyare *et al.,* 2014). Indeed, the drop in average global production of maize from 1164.40 million tonnes in 2017 to 1147.62 million tonnes in 2018 has been attributed to poor rains in the latter year (FAOSTAT, 2018). Apart from rainfall problems, other abiotic factors that contribute to low yields and thus limit maize production in the SSA region include high temperatures, extreme relative humidity, high wind speeds, low soil fertility, poor soil structure, soil erosion and degradation as well as extreme levels of soil pH (Ofor *et al.,* 2009; Agyare *et al.,* 2014; UNECA, 2015).

In addition, a number of biotic factors including disease causing pathogens, weed, vertebrate pests and insect pest damage have been reported to cause serious constraints to optimal maize production in SSA (Agyare *et al*., 2014). On-farm maize may be attacked by fungal pathogens which cause diseases such as rust, blight, leaf spot etc. and by viral pathogens especially Maize Streak Virus (MSV) in West Africa and Maize Lethal Virus in East Africa all of which are capable of causing significant yield losses (UNECA 2015, Ofor *et al.,* 2009). Weed infestation and competition if uncontrolled within three weeks after sowing can lead to significant maize yield losses on the field (James *et al.,* 2000). Weed species like *Eleusine indica*, *Pennisetum* spp., *Digitaria* spp., *Tribulus terrestris*, *Senna obtusifolia*, *Cyperus rotundus*, *Portulaca* spp. (Hughes, 2006b; O'Gara, 2007) and *Striga hermonthica*, which is capable of causing 10 to 100% maize yield losses especially in the guinea savanna agro-ecologies of Nigeria, have been implicated in maize yield losses (Ogunbodede and Olakojo, 2001; Ofor *et al.,* 2009; Agyare *et al.,* 2014). Also, plant nematode species like those in the genera *Meloidogyne* spp., *Pratylenchus* spp., *Helicotylenchus* spp. etc. are known to infect the roots of maize plants, hinder proper growth and consequently reduce yield (Ofor *et al.,* 2009). Furthermore, vertebrate pests especially monkeys, quelea birds and rodents like rats, grasscutters and squirrels inflict heavy damages to on-farm maize especially at the post vegetative stages of development resulting to often irreparable losses to farmers (Ofor *et al.,* 2009).

Up to 20 percent of maize yield is lost due to poor postharvest handling of maize grains in Africa (UNECA, 2015). The maize weevil, *Sitophilus zeamais* and its congenerics are notorious primary insect pests of maize in storage (Ojo and Omoloye, 2015). They are capable of causing significant postharvest losses by damaging whole stored grains thereby making them more susceptible to further decimation by secondary storage insect pests such as the red rust flour beetles, *Tribolium castaneum and T. confuscium* (Ofor *et al.,* 2009; Ojo and Omoloye, 2015). Other primary insect pests of maize kernels that contribute to postharvest losses in storage include the Angoumois grain moth, *Sitotroga cerealella*, the larger grain borer, *Prostephanus truncatus* and the lesser grain borer *Rhizopertha dominica* (Adedire, 2001; Ofuya and Lale, 2001).

Similarly, several insect pest species attack field-cultivated maize from the early vegetative stage to physiological maturity. In Nigeria, yield losses result when plants are attacked by stem borer species including *Busseola fusca* (African maize stem borer) and *Sesamia calamistis* (Pink stem borer) (Balogun and Tanimola, 2001). Stem borer larvae generally attack the maize plant, creating window pane effects on leaves and 'dead hearts' when they feed within the plant whorl (Ofor *et al.,* 2009). In addition, stem borers create long characteristic tunnels in the matured stems which in severe situations may lead to stem lodging (Ofor *et al.,* 2009). Other common important field insect pests of maize apart from stem borers in Nigeria include the variegated grasshopper, *Zonocerus variegatus*, and the African armyworm, *Spodoptera exempta* – a *Spodoptera* species with a larval stage that occasionally swarms maize farms causing serious destruction as they 'march' across. The recent addition of *Spodoptera frugiperda*, a new and more destructive insect pest, to the already heavy field pest complex have further constrained maize production in Nigeria and on the entire African continent.

The fall armyworm, *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae), is a transboundary and invasive moth native to the American continents where it is regarded as a highly destructive cosmopolitan insect pest of maize (Murúa *et al.,* 2009). In 2016, it was reported for the first time in Africa when the larvae were found damaging maize fields in Nigeria (Goergen *et al.,* 2016). Fall armyworm (FAW) has a high adult dispersal rate and had spread to over 30 countries on African mainland and islands by December

2017 (Huesing *et al.*, 2018). By 2018, its presence had been officially confirmed in 44 sub-Saharan African countries and several Asian countries including India, Yemen, Thailand, Myanmar and Sri Lanka (Rwomushana *et al.,* 2018; Ganiger *et al.,* 2018; Sharanabasappa *et al.*, 2018; Centre for Agriculture and Bioscience International-CABI, 2020). The fall armyworm was reported for the first time in mainland China in 2019 (International Plant Protection Convention-IPPC, 2019) and in Australia in 2020 (Department of Primary Industries and Regional Development-DPIRD, 2020).

Fall armyworm exhibits a number of biological traits such as an immense proliferation ability (Liu *et al.*, 2020); a high dispersal rate of adult moths that greatly constrain eradication on the continent (Huesing *et al.*, 2018); ability of female moths to oviposit directly on host plants unlike other common armyworm species (Rose *et al.,* 2000; Goergen *et al.,* 2016); and the presence of stronger mandibles and cannibalistic behaviours in older larvae (Brown and Dewhurst, 1975; Pogue, 2002; Sarmento *et al.*, 2002) which help them out-compete other lepidopterous species. These combine to make FAW the most damaging pest of maize in the genus *Spodoptera* present in Africa (Goergen *et al.*, 2016). In addition, the suitable agro-ecological conditions in many parts of SSA favour FAW development all year round, making it a serious and perpetual threat to food security in the region (Day *et al.*, 2017; Huesing *et al.,* 2018).

Fall armyworm is polyphagous and is able to attack maize, which is its primary host, as well as other cereal and non-cereal crops including rice, wheat, sorghum, millet, sugarcane, cowpea, potato, okra, orange, onion, soybean, sweet pepper, sunflower, sweet potato, groundnut, cotton etc. (Pogue, 2002; CABI, 2020; Food and Agriculture Organisation-FAO, 2018a; Huesing *et al.,* 2018; Montezano *et al.,* 2018). Feeding by young FAW larvae create different sizes of holes and a characteristic window pane on leaves while older larvae create ragged leaves, sectioned stems and badly damaged whorls soiled with wet yellowish-brown frass that become saw dust-like when dry (Goergen *et al.,* 2016; Abrahams *et al.*, 2017; McGrath *et al.,* 2018). Larvae may also cause extensive damage to reproductive organs such as the tassels and ears (Midega *et al.,* 2018; Prasanna *et al.,* 2018). According to the International Centre of Insect Physiology and Ecology-ICIPE (2020), maize damage by the fall armyworm has caused yield losses of between 8

– 20 million tonnes in Africa. Also, Day *et al.* (2017) estimated that FAW would cause annual yield losses valued at between US$2,481M and US$6,187M on the African continent if adequate control interventions were not initiated.

Being a new invasive insect pest on the continent, most of the information available on FAW biology, ecology and management was obtained from studies conducted in the Americas where it originated. In Africa, however, there currently exists a wide information gap on FAW that needs to be bridged through empirical studies. Though a few researches have been conducted on the genetic characteristics, dispersal, and management options of FAW in East and South Africa (Cock *et al.*, 2017; Day *et al.*, 2017; Bateman *et al.*, 2018; Midega *et al.*, 2018), and on its identification (Goergen *et al.*, 2016), field infestation and damage (Odeyemi *et al.*, 2020) in Nigeria, field- and laboratory-based studies on FAW development, seasonal occurrence and abundance and varietal resistance or tolerance of commonly cultivated maize varieties in African agroecologies are still scanty. Insect development is known to be influenced by climatic and geographical factors (Patel *et al.*, 2017) while information on seasonal occurrence and abundance of pests often enhances successful IPM program development (Phillips *et al.*, 2017).

In the laboratory, high rates of cannibalism in larval populations preclude cohort-based rearing (da Silva and Parra, 2013) and thus increasing research costs. Information that enables the optimization of cohort-based rearing methods would greatly enhance FAW research studies in the SSA. Furthermore, host plant resistance is a sustainable pest management approach (Luginbill, 1928) but the susceptibility of preferred maize varieties in SSA remains largely unknown (Abrahams *et al.*, 2017). The foregoing, therefore, underscores the need for more studies especially on the biology and ecology of FAW life stages and the resistance of maize varieties in African cropping systems and agro-ecologies.

Adoption of research technologies and solutions to typical maize production problems by smallholder farmers in SSA have been historically low (Kamara *et al.*, 2019). However, by adopting a participatory approach, which amongst other steps involves experiencesharing between stakeholders (Hagmann *et al.*, 1999), research technologies stand a better chance of been utilized by smallholder farmers in SSA. Some information have been provided in some parts of SSA on farmer's knowledge of FAW and their perception of its damage to field maize (Chimweta *et al.*, 2019; Kansiime *et al.*, 2019; Kumela *et al.*, 2018; Baudron *et al.*, 2019). These authors generally reported low knowledge of the pest, varying severity of damage to field maize, confusion about appropriate management strategies, and a preponderance of conventional insecticide spraying. Despite these few laudable efforts, there still exists a dearth of studies on farmers' knowledge of FAW and their perception on its damage in many parts of SSA including Nigeria. Such studies would enhance the dissemination and utilization of the sustainable technologies, strategies and interventions developed for FAW in African agro-ecosystems. Consequently, this study was used to investigate the biology and ecology of FAW in the south-west, Nigeria. The specific objectives of the study were to:

i. determine farmers' knowledge of FAW, control practices employed and their perception of FAW damage to maize in three maize-growing agro-ecological zones of southwestern Nigeria

ii. assess FAW infestation and damage to maize on selected farms in three maize-growing agro-ecological zones of southwestern Nigeria

iii. describe the developmental, reproductive and behavioural biology of FAW in the laboratory

iv. evaluate resistance in selected maize varieties to natural field infestation and damage by FAW at Ibadan, southwestern Nigeria.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1. Taxonomy, distribution and migration of the fall armyworm

### 2.1.1. Taxonomy

*Spodoptera frugiperda* J.E. Smith belongs to the Class Insecta, Order Lepidoptera, Family Noctuidae and Genus *Spodoptera* Guenée (Schmidt-Durán *et al.,* 2014). It is commonly known as the fall armyworm or corn leafworm or southern grassworm (CABI, 2020). The genus *Spodoptera* is made up of 30 species, half of which are important economic pests that include the Egyptian cotton leafworm, *S. littoralis* Boisduval, the African armyworm, *S. exempta* Walker, the tobacco caterpillar, *S. litura* Fabricius, the beet armyworm, *S. exigua* Hubner and the yellow-stripped armyworm, *S. ornithogalli* Guenée (Pogue, 2002).

### 2.1.2. Distribution

The existence of the fall armyworm (FAW) as a common pest of many crops in the tropical parts of North, South and Central America including the West Indian islands suggests that the pest originated from the tropics and sub tropics of the Western hemisphere (Sparks, 1979; Kamara *et al.,* 2020; Liu *et al*., 2020). From its native America origin, the pest has spread to other parts of the world (CABI, 2020) and more recently, to Africa and Asia (Goergen *et al*. 2016; Rwomushana *et al.,* 2018). Before 2016, only the armyworm species – *S. exigua* Hubner, *S. exempta* Walker, *S. littoralis* Boisduval, *S. cilium* Guenée and *S. triturita* Walker had been reported in Africa (Pogue, 2002). Fall armyworm however invaded the continent in 2016 and had been officially confirmed in 44 SSA countries by 2018 (Rwomushana *et al.,* 2018; Assefa and Ayalew, 2019) as well as in India, Yemen, Thailand, Myanmar, Sri Lanka, China and Australia (Ganiger *et al.*, 2018; Shylesha *et al.,* 2018; IPPC, 2019; DPIRD, 2020). Today, the fall armyworm occurs globally on all inhabited continents except Europe (CABI, 2020).

### 2.1.3. Migration

In the Northern states of the USA where the winter is extreme, FAW is known to be unable to survive. Fall armyworm is however a strong flier and is believed to migrate to the Southern Gulf coasts of the United States where the winter is mild or to other areas in the tropics whose climate permits their survival (Sparks, 1979; Ganiger *et al*., 2018). The extent to which adult FAW can migrate is believed to be strongly influenced by prevailing winds and frontal systems with their converging air masses during the spring (Rainey, 1979). In just a night, FAW moths can cover hundreds of kilometers by maintaining flight at heights of several hundred meters from where they are transported in a directional manner by winds (Westbrook *et al.,* 2016; Zhou *et al*., 2020).

Molecular studies from the minimal genetic variability of the pest in the Western hemisphere including northern and southern states of United States, have also confirmed the presence of migration in the fall armyworm (Clark *et al.,* 2007). The ability of FAW to migrate over very long distances has enabled the pest to become widely distributed in the Western hemisphere (Nagoshi *et al.,* 2007). It is unlikely that FAW was already present in Africa before 2016 because it does not need to build-up to high population levels like other common armyworm species before causing visible foliar damage to maize (Assefa and Ayalew, 2019; Kasoma *et al.,* 2020). Based on existing evidence, there is reason to believe that African FAW haplotypes have their origin in Florida or the Caribbean (Huesing *et al.,* 2018) and had probably reached the continent by wind-assisted flight or as contaminants of traded commodities, or as stowaways in aircrafts (Cock *et al*., 2017).

## 2.2. Biology of the fall armyworm

Eggs, which are dome shaped with flattened bases, are usually deposited on the abaxial side of leaves or occasionally on other parts of the host plant (Capinera, 1999). A typical FAW egg has a diameter of 0.4 mm and a height of 0.3 mm (Capinera, 1999). Eggs are laid in masses of 100 to 200, with a single female capable of laying up to 1500 to 2000 eggs during her lifetime (Capinera 1999). After oviposition, females usually cover eggs with scales from their abdomen that makes the mass appear mouldy (Capinera 1999; Prasanna *et al*., 2018).

Eclosion of the neonate larvae was reported to occur between 2-3 days (Vickery, 1929, Capinera, 2001). Based on the width of their head capsule, FAW larvae have been distinguished into 6 instar stages (Capinera, 2000). The actual number may however vary between 5 and 9 larval instars depending on rearing temperature and diet (Ali *et al.,* 1990; Rojas *et al.,* 2018). The first, second, third, fourth, fifth and sixth larval instars respectively have head capsule width of about 0.35, 0.45, 0.75, 1.3, 2.0, and 2.6 mm (Vickery 1929; Prasanna *et al.,* 2018; Ganiger *et al*., 2018). While neonate larvae are about 1.7 mm in length, matured larvae may be up to 34.2 mm (Vickery 1929; Prasanna *et al.,* 2018; Sharanabasappa *et al.,* 2018). Fall armyworm larvae are distinguished by the presence of a white inverted "Y" mark on their head and four black tubercles arranged to form a square on the second to last abdominal segment. The larval stage is known to last for about 14 days during summer in the western hemisphere (Capinera, 2001).

Larval cannibalism has been reported in field and laboratory populations of FAW (Sarmento *et al.,* 2002; Zennerde-Polania *et al.,* 2009). Laboratory rearing of FAW larvae is essential for behavioural studies or as food host for parasitoids, parasites or predators (Mihm, 1983; da Silva and Parra, 2013). Unfortunately, high rates of cannibalism in larval populations remain the chief limiting factor to the rearing of FAW larvae on artificial or natural diet (da Silva and Parra, 2013). Consequently, laboratory culturing of FAW populations is usually done using an individual-based method, where each larva is reared in individual vials or cups. While this method achieves the primary goal of reducing larval mortality caused by cannibalism, its use is greatly constrained by the large amounts of time and labour required (da Silva and Parra, 2013). Cohort-based rearing has been reported by da Silva and Para (2013) as a more efficient method of rearing FAW on a small- or mass-scale. The method involves rearing FAW larvae in groups or cohorts of about 40 larvae on a suitable diet in transparent plastic containers (da Silva and Para, 2013). Larvae such reared were reported to experience only about 10 percent mortalities (da Silva and Para, 2013). This is in sharp contrast to the 43 – 80% mortalities previously reported by Chapman *et al.* (1999b) for group rearing. Similarly, the influence of food availability on FAW larval cannibalism has been somewhat unclear. When FAW larvae were the same instar, cannibalism was reported to occur in response to low food availability or food scarcity (Chapman *et al.,* 1999a). In contrast, the same authors showed that the occurrence of cannibalism was not influenced by food availability or quantity when the larval population was composed of conspecifics of different ages (Chapman *et al.,* 1999b). The foregoing thus necessitates further studies on the influence of population, food quantity, larval age and other similar factors on larval cannibalism in FAW.

When matured larvae are ready to pupate, they seek a suitable pupation site where they form a cocoon. Just before pupation, larvae become inactive and shrink in size and are often referred to as pre-pupa larvae. In the wild, pupation occurs in the soil at a depth of 2 – 8 cm (Capinera, 2001). But when the soil is too hard to penetrate, the larva makes its cocoon out of leaf debris and other materials and then pupates on the soil surface (Vickery, 1929; FAO, 2018a). In captivity, however, remnants of food particles and frass are used to make pupation cocoons. Fall armyworm pupa is reddish brown in colour with a length and width of between 14 to 18 mm and 4.5 mm respectively. While pupation lasts for just 8 – 9 days in summer, it may last for up to 30 days or even 55 days in winter (Vickery, 1929; Capinera 2001). Pupation may also occur in between maize leaves or even within infested cobs.

The emergence of the adult moth marks the end of pupation. After emergence, females release sex pheromones which attract males and mating occurs several times during the night. Egg-laying takes place mainly at night though it may occur in the day to some extent (Vickery, 1929; Sparks, 1979; Ganiger *et al*., 2018). Oviposition occurs during the first four to five days after emergence of the female moth and may extend up to three weeks. Male FAW may be distinguished from their female counterparts by the presence of triangular white spots at the fringe and near the middle of their gray and brown colored forewings. Fore wings of female FAW moths lack this distinct coloration; they are usually duller and more uniform in appearance (Vickery, 1929; Sparks, 1979; Sharanabasappa *et al.,* 2018). Adult can live for an average of 10 days with a range of between 7 – 21 days (Vickery, 1929; Sparks, 1979; Ganiger *et al*., 2018).

## 2.3. Host preference and genetic variability in fall armyworm populations

### 2.3.1. Host preference

Fall armyworm is polyphagous and as such feeds on a wide range of crops species in different plant families (Rwomushana *et al.*, 2018). Montezano *et al.* (2018) reported that FAW has up to 353 host plant species belonging to 76 plant families with most of the species belonging to the Poaceae, Asteraceae and Fabaceae families. In Africa, maize is the preferred host of FAW and the most attacked and damaged. There are however reports of other cereal and non-cereal crops being attacked and damaged by the pest. For example, sorghum, millet, tomato and Napier grass were reportedly attacked in Ghana and Zambia (Rwomushana *et al.*, 2018). It has been reported that FAW infests non-cereal crops like the African eggplant, beans, cabbage, cashew nut, cassava, chillies, cocoa, cotton, groundnut, mango, okra, onion, orange, pearl millet, pigeon pea, rice, sesame, soybean, sugarcane, sunflower, sweet pepper, sweet potato, wheat, yam etc. but there are very few confirmed cases of damage on these (Rwomushana *et al.*, 2018).

### 2.3.2. Genetic differentiation in fall armyworm populations

Genetic differences amongst different populations of the same agricultural insect pest species have been attributed to their ability to adapt to local conditions (Krumm, 2005). Fall armyworm is known to occur in two host strains (the corn and rice strains) which are genetically unique but the same morphologically. The corn strain (C-strain) is thought to prefer large grasses like maize and sorghum while the rice strain (R-strain) prefers small grasses like rice, Bermuda grasses etc. (Pashley, 1986; Rwomushana *et al.*, 2018).

In 2016, Goergen *et al.* (2016) reported that the DNA sequences of FAW specimens collected in Nigeria were 100 percent identical to voucher specimens in public databases. Cock *et al.* (2017) further analyzed the DNA sequences of specimens collected from Nigeria and reported the presence of only the corn strain. The presence of both the rice and corn strains in other countries like Ghana (Cock *et al.*, 2017), South Africa (Jacobs *et al.*, 2018) and Uganda (Otim *et al.*, 2018) suggests that both strains are more or less spreading across Africa together (Rwomushana *et al.*, 2018). It is thus surprising that only the corn strain was reported from Nigeria especially when both are present in Ghana which is believed to have been invaded from Nigeria through Togo (Cock *et al.,* 2017). Goergen and his colleagues collected and barcoded just four specimens from Nigeria with two collected from only two locations in the southwestern, that is, Ibadan (Oyo State) and Ikenne (Ogun State). In addition, there is no record that the specimens were collected from multiple maize farms in the two locations. The very few locations from which FAW specimens were collected might have reduced the possibility of identifying the rice strain in field populations of FAW in Nigeria.

The presence of both strains in FAW populations is believed to hold significant consequences for FAW management. For example, the two strains differed in their survival, susceptibility to Bt, mating compatibility, physiology and sex pheromone composition (Lopez-Edwards *et al.*, 1999; Busato *et al.,* 2005; Groot *et al.,* 2008). Indeed, mortality studies on both strains gave quite different results even when the same chemicals were used (Kuate *et al.,* 2019).

### 2.4. Fall armyworm damage and economic importance

The Fall Armyworm (FAW) is regarded as one of the most destructive cosmopolitan pests in the Americas largely because of its ability to feed voraciously on several crop plants (Murúa *et al.,* 2009), its high rate of dispersion and its ability to form large swarming populations (Murúa *et al.,* 2003). The female moth initiates the process of damage, long before damage is seen, by laying her eggs mostly on young plants of not more than two feet high. Most FAW larvae will remain and continue feeding on the host plant where the eggs from which they eclosed was laid (CABI, 2020). The larvae cause varying degrees of damage to the plants as they feed on the leaves, stem and whorl. Young larvae usually scrape leaf surfaces during feeding while older ones may feed through the stems and whorl of maize plants (CABI, 2020). They may also bore through the kernels on older plants with cobs (CABI, 2020). Typically, maize plants attacked by FAW have their leaves and whorl riddled with holes, with ragged edges and filled with larval frass (CABI, 2020). In addition, larvae may also cause extensive damage to reproductive organs such as the tassels and kernels (Midega *et al.,* 2018; Prasanna *et al.,* 2018).

In Brazil, FAW is the most damaging and economically important insect pest of field maize (Sena *et al.,* 2003; Dal Pogetto *et al.,* 2012) where it has caused significant losses that range between 19 and 100% (Sarmento *et al.,* 2002). In Africa, it has been estimated that an annual yield loss valued at between US$2,481M and US$6,187M would be incurred in the absence of adequate control (Day *et al.,* 2017). Using estimates that were based on socio-economic surveys focused on farmers' perception of maize damage by FAW, Kumela *et al.* (2018) reported an impact of 32% and 47% on yield in Ethiopia and Kenya respectively. In contrast, Baudron *et al.* (2019) employed rigorous field scouting methods and reported a much lower estimate (9.14%) of FAW's impact on yield. Variability exists in yield losses caused by FAW because they are influenced by such factors as time or season of planting, maize cultivar planted, cultural practices employed etc. (Dal Pogetto *et al.,* 2012). Baudron *et al.* (2019) also noted that plant population impacted grain yield more than FAW infestation in African maize systems and that the higher yield losses attributed to FAW in previous studies from the continent may be due to other pests, drought, poor weeding or simply a case of over-estimation.

## 2.5. Control of Fall Armyworm

### 2.5.1. Monitoring

Monitoring has been defined as an active effort to track the occurrence, abundance and distribution of pests within a specified geography. It may occur at a regional or community level using the Universal Bucket and Heliothis-style pheromone traps respectively (McGrath *et al.,* 2018). Sex pheromones produced by female *S. frugiperda* moths have been shown to be useful for the monitoring of male FAW populations (Mitchell *et al.,* 1989). Pheromone traps contain lures used to trap adult male moths which are periodically collected, counted, recorded and used to make informed FAW management decisions. Scouting on the other hand, refers to any activity carried out using science-based procedures to keep track of pests within a field (Prasanna *et al.,* 2018). During scouting, a farmer or scout walks through his farm following a zigzag pattern. He stops periodically at five different locations and assesses 10 to 20 plants for signs of FAW feeding (Capinera, 2005; McGrath *et al.,* 2018). Record is taken on the percentage of damaged plants at each point and the entire data is then used to determine the percentage field infestation and damage. This informs the next course of action as it relates to FAW control on the field (McGrath *et al.*, 2018). According to Sibanda (2017) prompt insecticide spray application is recommended when 5% and 25% of field maize stands bear FAW eggs and symptoms of foliar damage respectively.

Information and Communication Technology (ICT) tools are increasingly being employed for insect pest monitoring. In 2018, the Food and Agriculture Organization (FAO) of the United Nations (UN) launched the FAW Monitoring and Early Warning System (FAMEWS) mobile application and the FAMEWS global platform (FAO, 2018c). The application was designed to collect field scouting and pheromone trap data on FAW. The global platform, on the other hand, is an online resource that uses data submitted from the mobile application to create maps that facilitate analysis of FAW infestation and spread across the globe in real-time (FAO, 2018c).

### 2.5.2. Polycropping systems

Polyculture cropping systems have been reported to be more effective in reducing the severity of FAW attack compared to monoculture systems (Andrews, 1980). Such polycropping systems are believed to interfere with FAW's ability to detect maize plants for feeding and oviposition while also increasing the diversity and abundance of natural enemies (FAO, 2018a). Midega *et al.* (2018), who worked in East Africa, recorded 82.7% reduction in the average number of FAW larvae per plant and 86.7% in plant damage per plot using a climate-adapted push-pull system that consisted of maize intercropped with the legume, *Desmodium intortum* (Mill.) Urb., and surrounded by Brachiaria cv Mulato II planted as a border crop. The intercrop is believed to produce semiochemicals that repel (push) moths while semiochemicals from the border crop attract (pulls) them away from the maize plants. This observation was validated by Hailu *et al.* (2018) who reported that the climate-smart and conventional push-pull technologies both reduced FAW infestation in Uganda. The authors also reported significantly lower FAW infestation in maize intercropped with common beans, soybeans or groundnuts compared with sole maize especially in the early and late whorl stages of growth. Baudron *et al.* (2019) in contrast did not observe any reduction in FAW infestation when maize was intercropped with cowpea, groundnut, and common beans in Eastern Zimbabwe.

### 2.5.3. Biological Control

According to Ashley (1979), there exist up to 53 species of parasitoids that attack FAW in different parts of the world. The wasp parasitoids – *Cotesia marginiventris* (Cresson) and *Chelonus texanus* (Cresson) and the fly parasitoid, *Archytas marmoratus* (Townsend) (Diptera: Tachinidae) are wasp parasitoids commonly reared in the United States from FAW larvae (Capinera, 2005). Species in the genus *Apanteles* have also been used to effectively control FAW in fig (*Ficus carica*) (Schmidt-Durán *et al.,* 2014). In 2020, after comprehensive assessments of performance, the International Centre of Insect Physiology and Ecology (ICIPE) conducted mass releases of native fall armyworm parasitoids in Kenya including the egg parasitoids, *Telelomus remus* and *Trichogramma chilonis*, and *Cotesia icipe*, a parasitoid of early instar fall armyworm larvae (ICIPE, 2020). In Nigeria, Ogunfunmilayo *et al.* (2021) identified the egg parasitoid, *Telelomus remus* and the larval parasitoid, *Euplectrus laphygmae* as natural enemies of FAW. Similarly, FAW larvae and pupae are attacked on the field by numerous insect and vertebrate predators. The insect predators include several generalist predators of lepidopteran larvae such as ground beetles (Coleoptera: Carabidae); the striped earwig, *Labidura riparia* (Pallas) (Dermaptera: Labiduridae); the spined soldier bug, *Podisus maculiventris* (Say) (Hemiptera: Pentatomidae); and the insidious flower bug, *Orius insidiosus* (Say) (Hemiptera: Anthocoridae) (Capinera, 2005).

The bacterium, *Bacillus thuringiensis* (All *et al.*, 1996) is an effective entomopathogen of FAW. According to Monnerat *et al.,* (2006), FAW samples collected from Mexico, Colombia, and Brazil displayed different susceptibility to pure preparation of the Cry 1B, Cry 1C, and Cry 1D toxins from selected Bt strains. Similarly, various nucleopolyhedrovirus (NPV) (Garrdner and Fuxa, 1980) strains isolated from FAW sampled from Nicaragua and the USA showed high infectivity level against the pest (Escribano *et al.,* 1999). The entomopathogenic fungi, *Metarhizium anisopliae* and *Beauveria bassiana*, were also isolated from soil samples during the survey. The entomopathogenic nematode species *Steinernema carpocapsae* Weiser and *S. riobravis* Cabanillas, Raulston and Poinar have also been used against FAW larvae with significant mortality effects (Molina-Ochoa *et al.*, 1999).

### 2.5.4. Host plant resistance

Host plant resistance offers a sustainable way to manage pests of agricultural importance including FAW (Luginbill, 1928). Morphological defenses in the maize inbred lines – Mp496, Mp701, Mp704, Mp706, and Mp708 have been related to their resistance to FAW (Brooks *et al.,* 2007). Other maize germplasms that have been selected for resistance to FAW in the North America include GT-FAWCC (C5), FAW0617 and FAW7111 (Wiseman *et al.,* 1996). Host plant resistance is a sustainable management tactic that is also compatible with biological control method (Omoloye, 2009). For example, Riggin *et al.* (1994) showed that FAW-resistant maize varieties did not reduce FAW parasitism rate under laboratory and field conditions.

In Africa, the susceptibility of preferred maize varieties to FAW is currently not known (Abrahams *et al.,* 2017). Maize breeding for resistance to insect pests including fall armyworm may be done under natural or artificial infestation depending on the availability and scale of manpower, funding, materials and equipment needed, uniformity, timing and speed of infestation, the type of resistance being evaluated as well as the objective of evaluation – to identify tentative resistance or to improve existing levels of resistance in maize germplasms (Ortega *et al.,* 1980; Prasanna *et al.,* 2018). Whether by natural or artificial infestations, maize plants' response to insect attack needs to be measured at the appropriate growth stage. Owing to the often-large numbers of germplasms at the beginning of resistance screening, visual rating scales are usually used and several of these have been developed for fall armyworm damage to maize under artificial or natural infestations (Ortega *et al.,* 1980; Wiseman *et al.,* 1966; Hormchong, 1967; Dal Pogetto *et al.,* 2012; Prasanna *et al.,* 2018).

The plants' response to damage may also be measured by determining the direct effects of the insect on the plants or of the plants on the insects, that is, through the identification of the mechanism (s) of resistance at play (Ortega *et al.,* 1980). According to Painter (1951), the mechanisms of host plant resistance could be antixenosis (non-preference), antibiosis or tolerance. Antixenotic studies measures the non-preference of the insect for the plants as food or oviposition site as a result of certain inherent morphological or biochemical constituents in the plant. Antibiosis measures the inhibition to growth, development, reproduction and other biological processes in insects hosted by the plants. Tolerance, on the other hand, is a measure of the plants ability to withstand infestation and attack by the insect pest. Mechanism of resistance studies maybe conducted under natural or artificial infestations depending on the particular measurements to be made on the insect or plants (Ortega *et al*., 1980).

Transgenic crops, also known as genetically modified crops, kill insect pests or inhibit their growth through the production of insecticidal proteins or toxins from the bacterium *Bacillus thuringiensis* (Sanchis, 2011). *Spodoptera frugiperda* larvae is however, known to be tolerant to the Cry1Ab Bt toxins in some transgenic maize events like MON810 and Bt11 (Omoto *et al.,* 2016). In 2006, the first documented case of field resistance in *S. frugiperda* to Bt (Cry1F) maize was reported in Puerto Rico (Storer *et al.,* 2010). The observed resistance in the Puerto Rican FAW population has been attributed to an autosomal gene with recessive inheritance (Storer *et al.,* 2010).

Breeding for FAW resistance has only just recently begun in Africa and as such there is no maize cultivar, adapted to the African agro-ecology, with experimentally proven resistance response to FAW (Prasanna *et al.,* 2018). Nevertheless, three fall armyworm tolerant elite maize hybrids namely FAWTH2001, FAWTH2002 and FAWTH2003 were derived by the International maize and Wheat Improvement Centre (CIMMYT, 2020).

### 2.5.5. Conventional insecticides

Conventional insecticides have been used exclusively for the control of the fall armyworm (Yu *et al.*, 2003). In Ghana and Zambia, 72% and 60% of farmers respectively employed insecticides for FAW control on maize (Day *et al.,* 2017). Similarly, Kumela *et al*. (2018) also reported that chemical spray application was the main method employed by most farmers in Ethiopia and Kenya. In countries like the USA, Mexico and Brazil where FAW is a major insect pest, insecticides belonging to the organophosphates, carbamates and pyrethroids class have been applied to prevent crop losses (Capinera, 2001; Tomquelski and Martins, 2007). Recently in southern Africa, two conventional insecticides– Fortenza duo and Lumivia formulated as seed treatments are commonly used to protect maize early-whorl maize plants from several underground and above ground insect pests of maize including FAW (Kasoma *et al.,* 2020). In Nigeria, Togola *et al.* (2018) found cypermethrin, deltamethrin, lambda-cyhalothrin, permethrin, and chlorpyrifos as common insecticide active ingredients used against FAW in Mokwa, north central Nigeria.

Insecticide application against FAW in Africa has been accompanied by reports of little or no effectiveness (Kumela *et al.,* 2018; Baudron *et al.,* 2019). The use of fake or adulterated insecticides, incorrect application rates or techniques, and wrong timing of spray application may be responsible for the low effectiveness of insecticides against FAW in Africa (Goergen *et al.,* 2016; Day *et al.,* 2017; FAO, 2018b; Kumela *et al.,* 2018; Rwomushana *et al.,* 2018). Furthermore, conventional insecticides are attended by several problems like toxicity to natural enemies (Berta *et al.,* 2000), environmental pollution, pest resurgence and the development of resistance in insects (Shazali *et al.,* 2003). Indeed, Togola *et al.* (2018) found residues of cypermethrin, deltamethrin, lambda-cyhalothrin, permethrin, and chlorpyrifos in soil samples taken from sprayed maize fields, though none was found in maize stem and seeds. Indeed, FAW strains have developed resistance to carbamates, organophosphates and pyrethroid groups of insecticide rendering them largely ineffective for its control (Abrahams *et al*., 2017; Fatoretto *et al.,* 2017; Kasoma *et al.,* 2020). It is therefore necessary to employ environmentally safe insecticides in the management of FAW in Africa.

### 2.5.6. Botanical insecticides

Insecticides of plant origin may be employed as eco-friendly alternatives to conventional insecticides. According to Salinas-Sanchez *et al.,* (2012), leaf extracts of *T. erecta* caused substantial mortalities to *S. frugiperda* larval and pupal stages. Similarly, D'Incao *et al.,* (2012) reported 58.5% mortality in *S. frugiperda* populations fed with leaf discs of perennial soybean, *Neonotonia wightii*, treated with cold water extracts of *E. pulcherrima.* Furthermore, González-López (2017) reported a significant decrease in the consumption and growth indices of FAW larvae as well as their food utilization index after treatment with aqueous leaf extracts combinations of *Azadirachta indica* and *Leucaena leucocephala* or *A. indica* and *Gliricidia sepium*. The use of plants secondary metabolites therefore serves as a promising alternative to conventional insecticides for FAW control (Tavares *et al.,* 2009; Alves *et al.,* 2014).

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1. Study sites

Survey of maize farmers and on-farm assessment of FAW damage was conducted in three major maize producing agro-ecological zones (AEZ) in southwestern Nigeria namely: the humid forest (Ikenne zone in Ogun State), the derived savanna (Ekiti North Zone in Ekiti State) and the southern guinea savanna (Saki zone in Oyo State). Experiments on the developmental, reproductive, and behavioural biology of FAW were conducted in the Entomology Laboratory, Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria. Biology of FAW was studied in the laboratory under ambient conditions (temperature: 29.0±3 $^{o}$C, relative humidity: 65.0±15% photoperiod: 12 h light: 12 h dark) from September 2019 to December 2019. Daily reading of ambient conditions within the laboratory was done using the digital hygro-thermometer (HTC-2 Model with 1% RH and 0.1$^{o}$C resolutions).Maize varietal trials were conducted under natural infestation of FAW on experimental plots at the National Horticultural Research Institute – NIHORT (7° 22' 36.2" N 3° 53' 44.9" E), Idi-Ishin, Ibadan in Ibadan, Nigeria.

## 3.2. Determination of farmers’ knowledge of FAW, control practices employed and their perception of FAW damage to maize in three maize-growing agro-ecological zones of southwestern Nigeria

This study was carried out to obtain information on maize farmers’ knowledge of FAW, control practices employed to tackle the pest problem on maize and their perception of maize damage by the pest in three maize-growing agroecological zones of southwestern Nigeria.

### 3.2.1. Sampling procedure

In the three agro-ecological zones (AEZ), maize farmers were selected through a four-stage sampling procedure with the help of agricultural extension officers. In the first stage, three states – Ogun, Ekiti and Oyo – representing AEZs of interest were purposively sampled. In other words, Ogun State is representative of the humid forest; Ekiti State the derived savanna and Oyo State of the southern guinea savanna (Figure 3.1). An Agricultural Development Programme (ADP) zone located within the selected AEZ in each state was purposively sampled in the second stage. Fifty percent of ADP blocks or Local Government Area (LGA) with high maize cultivation was randomly selected from each ADP zone in the third stage (Table 3.1). In the fourth stage, maize farmers, who had planted maize in 2016 and or 2017, were random sampled proportionate to size in each ADP block.

### 3.2.2. Questionnaire preparation and administration

Survey of maize farmers was carried out before the early maize planting season in 2018 using a structured questionnaire (Appendix I) that was face-validated by an agricultural extension expert in the Department of Agricultural Extension and Rural Development, University of Ibadan, Nigeria. Potential respondents in each ADP zone were identified with the help of Agricultural Extension. Just before administering the questionnaires, the study objectives were explained to the farmers and their consent to participate in the study obtained. Farmers were interviewed in their local Yoruba language and, where the farmer could comprehend, in English language. Table 3.2 presents an overview of the questions in the administered questionnaires. Questions were mainly close-ended in a multiple-choice format. Open ended questions were used to obtain information on the specific type of insecticides and cultural methods used for FAW control. A total of 212 questionnaires (with at least 70 questionnaires per AEZ) were administered.

## 3.3. Assessment of fall armyworm infestation and damage on selected farms in three maize-growing agro-ecological zones of southwestern Nigeria

On-farm survey of maize farms was conducted in the early planting season of 2019 to validate information on infestation and damage provided by maize farmers interviewed in the three maize-growing agro-ecological zones of southwestern Nigeria.

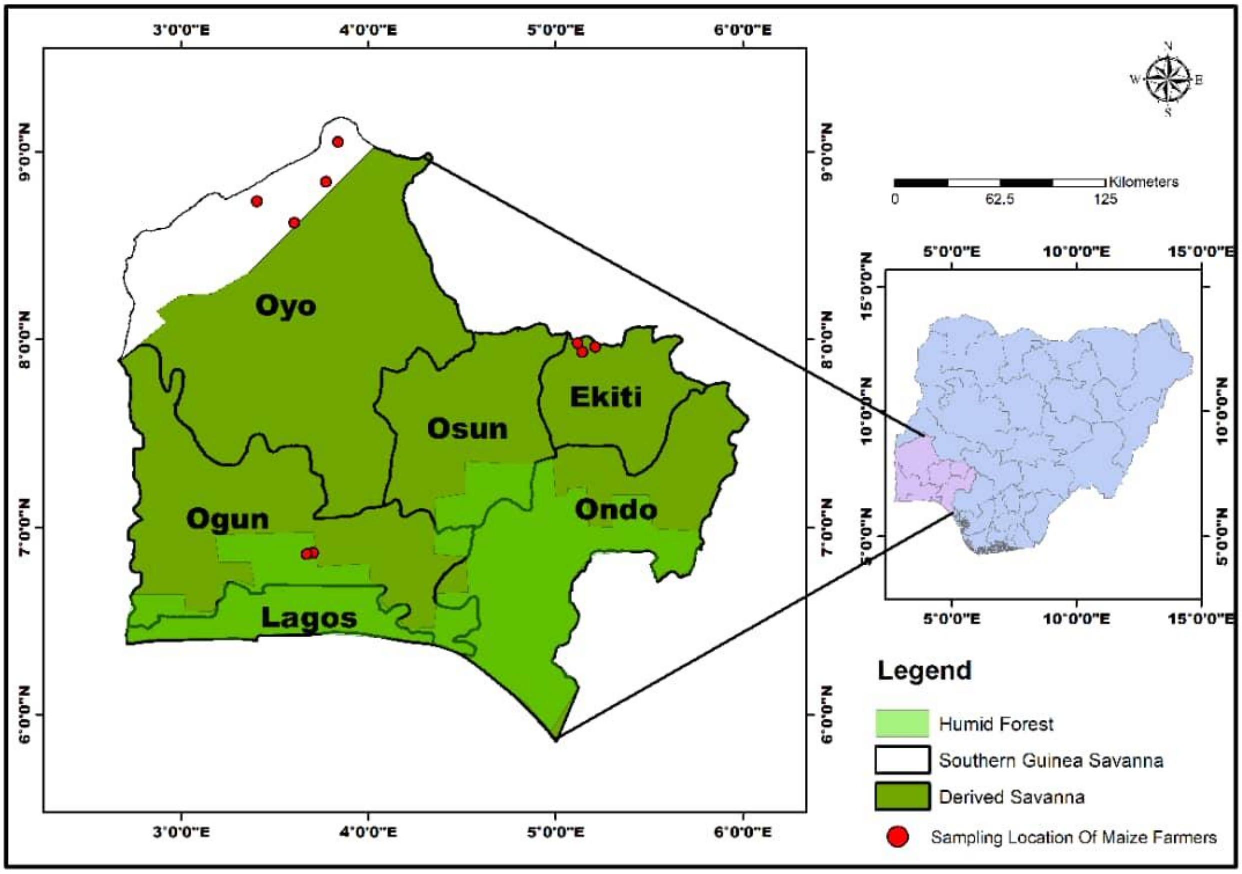


**Figure 3.1. Map of southwestern Nigeria showing agro-ecological zones and locations where maize farmers were sampled**

**Table 3.1. Sampling procedure for survey of maize farmers in southwestern Nigeria**

| **State**<br>**[GPS Coordinates]** | **ADP* Zone**<br>**(corresponding AEZ**)** | **ADP Block (LGA***)** |
|---|---|---|
| Ogun<br>[6° 58' 40.1" N<br>3° 26' 14.9" E] | Ikenne Zone<br>(Humid forest) | Ikenne<br>Sagamu |
| Ekiti<br>[7° 44' 9.2" N<br>5° 16' 20.6" E] | Ekiti North Zone 3<br>(Derived savanna) | Ido/Osi<br>Moba<br>Ilejemeje |
| Oyo<br>[8° 12' 51.0" N<br>3° 33' 46.2" E] | Saki Zone<br>(Southern guinea savanna) | Saki West<br>Saki East<br>Irepo<br>Orelope |

*ADP – Agricultural Development Programme

**AEZ – Agro-ecological Zone

***LGA – Local Government Areas (LGA)

**Table 3.2. Overview of questions in questionnaire administered to maize farmers in southwestern Nigeria to assess their experience with fall armyworm (FAW), control methods used and their perception of its damage to on-farm maize**

| Data Section | Description |
|---|---|
| 1. Farmers' demographics and maize farming practices | Gender; age (years); marital status (married, single); highest level of education (primary, secondary, tertiary, none); household size; size of land cultivated to maize; years of cultivating maize; maize farming system (rainfed, irrigation, wetland); purpose of maize cultivation (consumption, sales, both). |
| 2. Farmers' experience with fall armyworm | Which of these years did you cultivate maize (2016, 2017, 2016 and 2017); when was your maize attacked by FAW (2016, 2017, 2016 and 2017); what variety of maize attacked by FAW[+]; method of maize cultivation during attack (as sole maize; intercropped with legume; intercropped with tuber; intercropped with other crop types; age of maize plants during attack (< 1 month, 1 - 2 months, > 2 months); severity of maize damage (few leaves damaged, few plants damaged, more than half of plants damaged, all plants damaged); what does the FAW look like (small green grasshopper, small brown butterfly, small crawling worm); How did you identify the pest as FAW larvae and not stem borer larvae (color is different, size is different, eating pattern is different, fecal excretion on leaves; cannot tell difference); main source of information on FAW (farmers, agricultural extension officers, media) |
| 3. FAW control methods | Method employed for FAW control (insecticide sprays, non-chemical methods, both); name of insecticide used[+]; specific non-chemical methods used[+]; Number of insecticide sprays (1-2, 3-4, 5-6, 7-10); effectiveness of insecticide spray (excellent, moderate, poor). |
| 4. Farmers' perception of damage to maize by FAW[++] | Maize damage by FAW is a problem to be worried about; FAW damage reduces the quantity of maize harvested; FAW damage decreases profit from maize production; damage by FAW is more severe in early maize than in late maize; damage is more severe FAW on maize when intercropped than when planted sole; sufficient education is available to maize farmers on FAW damage. |

[+] Open ended questions

[++] Measured on a 5-point Likert scale

### 3.3.1. Farm scouting and assessment procedure

Two farms with maize plants between two and four weeks old, which had not been sprayed with insecticides, were selected in each of the nine representative LGA where survey of farmers was conducted (Table 3.3). The method of McGrath *et al.* (2018) was employed for scouting the maize farms visited. On each farm, an imaginary W-shaped scouting path was drawn and followed. Border row effect was avoided by ensuring that the end points of the scouting path were some distance (2 m to 5 m) away from the farm borders. The size of a scouting path and its distance from the farm border was determined by the size of the farm on which scouting was done. At each end of the imaginary W-shaped path, four randomly selected maize plants were visually assessed for larval infestation and thereafter scored for foliar damage. Consequently, on each farm, twenty (20) maize plants (four at each of the five ends) were assessed per farm. Maize plants were assessed for presence or absence of FAW larval infestation by gently turning the leaves and carefully unfurling whorls. Plants with one or more actively feeding larva were tagged infested (larva present) while those without any larval infestation were tagged not infested (larva absent). Characteristic FAW foliar feeding damage symptoms on plants (whether or not infested with larvae) was visually assessed and scored using the five-point rating scale described by Dal Pogetto *et al.* (2012) for fall armyworm damage to field maize (Table 3.4)**.**

## 3.4. Developmental, reproductive and behavioural biology of FAW in the laboratory

The development of fall armyworm egg, larva, pupa and moth was studied in the laboratory and described. Moth oviposition preference, their actual fecundity under different pairing ratio, and the cannibalistic behavior of larval populations were also investigated.

### 3.4.1. Experimental units and instrumentation

Experimental units used in this study include a wooden sleeve cage (45 cm x 45 cm x 60 cm) with netted sides and a glass top for moth mating and egg laying; rectangular transparent plastic containers (25 cm x 16.5 cm x 12.5 cm) with meshed plastic lids for

**Table 3.3. Agro-ecological zones and location of on-farm assessment of infestation and damage to maize by the fall armyworm in southwestern Nigeria**

| Agro-ecological zone | Agricultural Development Programme (ADP) Block | Town | Geolocation Information |
|---|---|---|---|
| Humid Forest | Sagamu | Sagamu | 6°51'16"N 3°40'13"E |
| | | Sagamu | 6°51'19"N 3°40'17"E |
| | Ikenne | Ikenne | 6°51'43"N 3°42'10"E |
| | | Ikenne | 6°51'46"N 3°42'13"E |
| Derived Savanna | Ilejemeje | Ewu Ekiti | 7°55'49"N 5°11'16"E |
| | | Ijesamodu Ekiti | 7°57'39"N 5°12'40"E |
| | Moba | Osun Ekiti | 7°58'15"N 5°05'12"E |
| | | Otun Ekiti | 7°58'49"N 5°07'02"E |
| | Ido/Osi | Aiyetoro Ekiti | 7°56'01"N 5°08'32"E |
| | | Usi Ekiti | 7°53'55"N 5°10'07"E |
| Southern Guinea Savanna | Saki West | Saki | 8°44'12"N 3°24'11"E |
| | | Saki | 8°41'19"N 3°22'11"E |
| | Saki East | Ago-Amodu | 8°38'16"N 3°39'26"E |
| | | Sepeteri | 8°37'24"N 3°36'13"E |
| | Irepo | Igboho | 8°50'29"N 3°46'21"E |
| | | Igboho | 8°48'37"N 3°45'33"E |
| | Orelope | Kisi | 9°03'12"N 3°50'11"E |
| | | Kisi | 9°03'12"N 3°50'03"E |

**Table 3.4. Rating for foliar damage to on-farm maize plants by the fall armyworm, *Spodoptera frugiperda* J. E. Smith**

| SCALE | RATING |
|---|---|
| 0 | Plants without damage |
| 1 | Plants with erasure leaves |
| 2 | Plants showing holes in the leaves |
| 3 | Plants with holes in the leaves and some damage on whorl |
| 4 | Plants with whorl destroyed |
| 5 | Dead plants |

Source: Dal Pogetto *et al.*, 2012

larval eclosion and cohort rearing; transparent disposable plastic cups (200 mL) covered with muslin cloth and used for individual rearing of older larvae or pupae; individual moth rearing cups made from similar 200 mL cups earlier mentioned but equipped with cotton absorbent rolls for delivering the moth food; moth mating and oviposition plastic container (500 mL) equipped with cotton absorbent rolls for moth feeding and brown paper strips for oviposition during experiments (Plate 3.1). Instruments used during the study include a digital sensitive balance (OHAUS Explorer Pro; 0.001g precision) for weighing pupae, a hand tally counter for counting eggs, a hand lens for magnifying eggs during counting, a carbon fibre composite digital caliper (0.1 mm precision) for measurements of diameter, length and width; and a digital hygro-thermometer (HTC-2 Model with 1% RH and 0.1$^{o}$C resolutions) for measuring both temperature and relative humidty.

### 3.4.2. Fall armyworm culture

Fall armyworm culture used in this study was started using matured larvae collected from infested maize plots in Ibadan, Nigeria. The field-collected larvae were reared individually on fresh leaves of SAMMAZ-32 maize variety till pupation (Plate 3.2). Pupae were washed with distilled water, dried on a paper towel and placed individually in rearing-cups covered with muslin cloth. On emergence, moths at rest were sexed using the distinct morphological features of their wings (Vickery, 1929; Sparks, 1979; Prasanna *et al*., 2018). Thereafter, 10 to 20 pairs of moth were released in the sleeve cage containing a poly-pot (filled with 10 kg sterilized loam soil) with four maize seedlings of approximately two weeks old. Moths in the sleeve cage were fed daily with 10% sugar solution and all the egg masses deposited on the leaves were cut out daily. Egg masses were immediately pinned unto fresh leaves in cohort-rearing container and watched daily for hatching. Neonates were allowed to feed together for four days then they were reared individually, as earlier described, until pupation. The vigour and damaging potential of larvae was maintained by regularly introducing field collected larvae into the laboratory population.

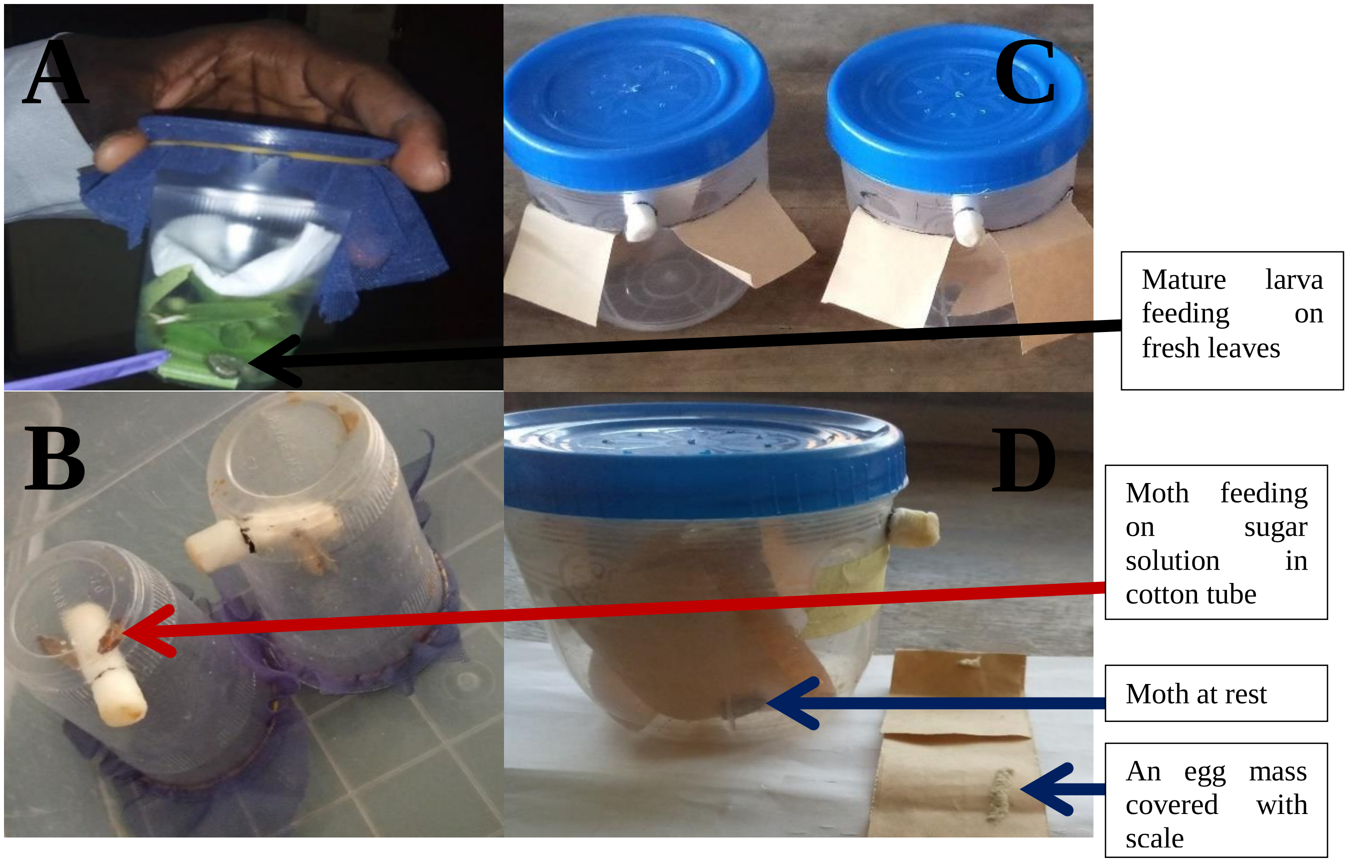


**Plate 3.1. Improvised experimental units for biological studies on (*Spodoptera frugiperda* J. E. Smith) in the laboratory**

**a = Container with fresh maize leaves and mature fall armyworm larva**
**b = Container with moths feeding on cotton-tubes laden with sugar solution**
**c = Containers for moth mating and with brown paper for oviposition**
**d = Mating and oviposition container with adult moth on brown paper strip and an egg-mass on a paper strip**

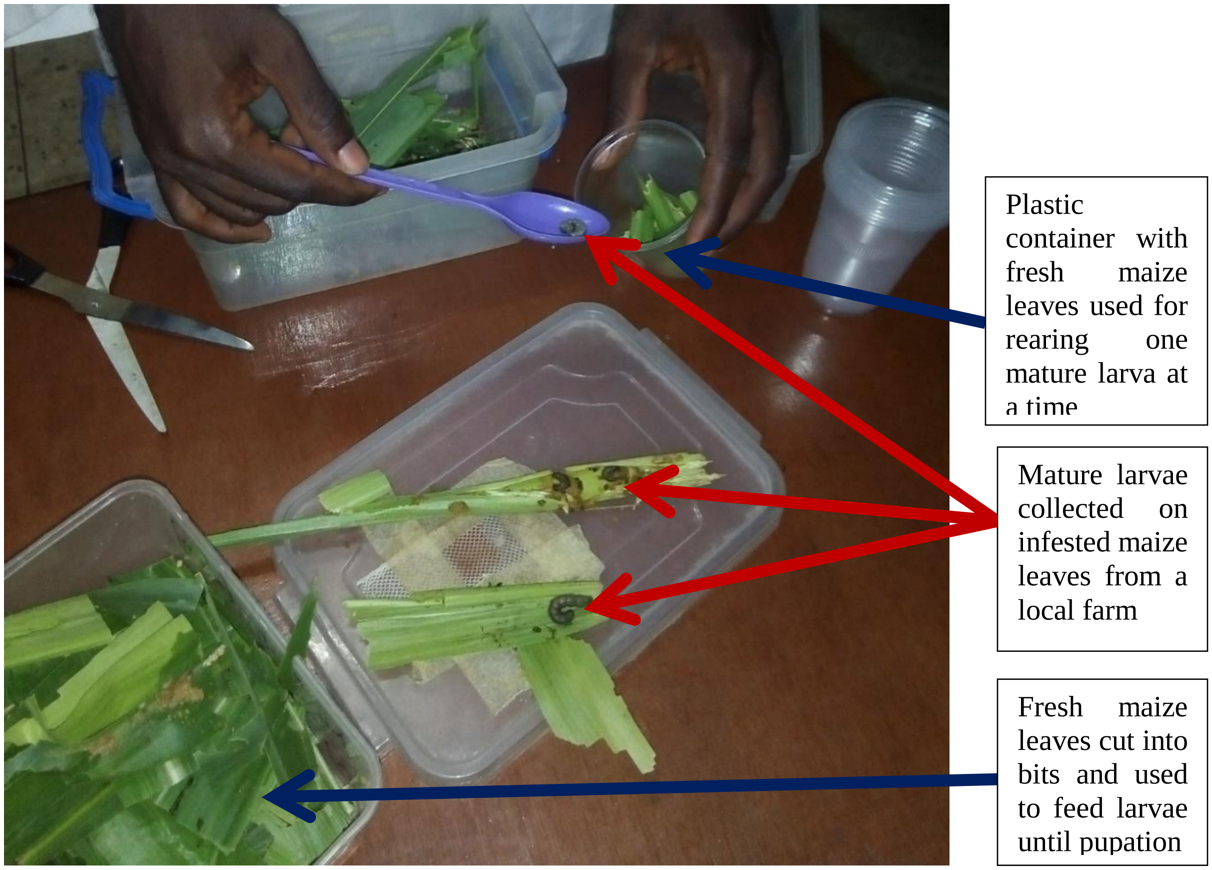


**Plate 3.2.** **Sorting of field-collected fall armyworm (*Spodoptera frugiperda* J. E. Smith) larvae**

### 3.4.3. Development and morphometrics of fall armyworm eggs

Four 2-week-old plants of SAMMAZ-32 maize variety grown in 10 kg soil-filled poly-pot were placed in the sleeve cage (45 cm x 45 cm x 60 cm). Five newly emerged pairs (five males and five females) of FAW moth were introduced into the sleeve cage to mate and oviposit. Egg masses deposited on leaves and paper in the cage were collected daily as described in 3.3.2. Thereafter, the eggs in each egg-mass were counted with the tally counter. Before counting, eggs in a mass were separated with a moist camel hair brush (0.4 mm hair size) on a wet brown paper sheet. Eggs were viewed with the unaided eyes (or hand lens when necessary) and counted using a hand tally counter. After counting, the eggs were placed in a 500 mL plastic jar (with firm unperforated lid) and observed daily for hatching. A total of 30 egg masses were randomly collected from the sleeve cage over a period of six days. The time taken for each mass of eggs to hatch was also recorded. Eclosed neonates were subsequently counted to determine percentage hatchability of eggs. The diameters of 30 randomly sampled eggs were also measured using the carbon fibre composite digital caliper.

### 3.4.4. Development and morphometrics of fall armyworm larvae

Neonate FAW larvae from a single egg mass were reared on fresh maize leaves of SAMMAZ-32 maize variety until pupation. Ten larvae were sampled daily. Sampled larvae were killed by placing them in a jar containing cotton wads soaked with 100 mL ethyl acetate for about three to five minutes, and thereafter larval body length, body width and head capsule width were measured using the carbon fibre composite digital caliper. Larval body length was measured from the head to the abdominal segment bearing the anal prolegs. Larval body width was measured at the mid-abdominal region. The distance between the lateral sides of the head was regarded as the head capsule width. Observations were also made on changes in larval body colouration and appearance and these were recorded at each sampling day. The number of larval instars was determined by plotting a frequency distribution of daily larval head capsule width measurements (Odebiyi, 1980; Debac *et al.*, 2010; Ojo and Omoloye, 2015). The number of instars determined by frequency distribution was further confirmed by testing the conformity of head-capsule-width measurements to Dyar’s law using independent sample t-test

(Odebiyi, 1980). A linear regression of the mean head capsule width of instars and their developmental period elapsing was constructed to confirm that all instars were accounted for during the measurements (Odebiyi, 1980; Alamu and Ewete, 2014).

### 3.4.5. Development and morphometrics of fall armyworm pupae

After pupation, 30 pupae were randomly sampled from the cohort of larvae that pupated in the larval morphometric studies. The body length, body width and body weight of each pupa was measured with a carbon fibre composite digital caliper (0.1 mm precision). Pupal body length was measured from the head to the tip of the abdomen bearing the cremaster. Pupal body width was measured at the mid-abdominal region. Each measured pupa was placed individually in appropriately-labeled transparent cups (200 mL), covered with muslin cloth and observed daily for adult emergence. Duration of pupal stage was determined by observing the time taken for individual pupa to completely develop into moths.

### 3.4.6. Morphometrics of fall armyworm moths

Twenty pairs of FAW moths that emerged from the pupae placed in individual cups (described in 3.3.6) were sexed and then killed with ethyl acetate fumes. The body length, body width and wing span of moths (male and female) were measured with a carbon fibre composite digital caliper (0.1 mm precision). Body length was measured from the frontoclypeal area of the head to the tip of the abdomen; body width was measured from the mid abdominal region while the wings were spread out; wing span was determined by detaching a wing and taking measurements from the axillary sclerite(s), where it articulates with the thorax, to the apical angle.

### 3.4.7. Oviposition site preference of female fall armyworm moths

Forty transparent cups (200 mL) were each filled with 200 g of moist-sterilized-loam-soils and three seeds of SAMMAZ-32 maize variety were then sown into each cup. After a week, the seedlings were thinned to two plants per cup. At two weeks after sowing, 25 cups with two seedlings each were placed in the sleeve cage. Five pairs of moths were released into the cage and allowed to mate and oviposit for 24 hours. The experiment was repeated on three consecutive days with different set of maize seedlings and moths on each day. In all replicates, males were a day old and unmated while females were two days and unmated. In addition, moths were fed 10% sugar solution immediately after emergence until they were used in the study. Moths were however, not fed during the 24-hour experiment. Data was collected on the number of eggs per egg mass laid on the leaves and stems. Eggs laid on leaves were categorized into those laid on the abaxial and adaxial surfaces. Each surface was further segmented into three distinct parts namely the distal, mid and proximal leaf portions.

### 3.4.8. Longevity of fed and unfed fall armyworm moths

Longevity of fed FAW moths was investigated in the laboratory by observing the life span of 15 randomly sampled pairs of newly emerged moths held in individual cups. The meshed transparent cups were equipped with absorbent cotton rolls to facilitate moth feeding as earlier described. Each isolated moth was fed daily with 10% sugar solution from emergence day until death. The longevity of unfed moths was also studied using 15 pairs of newly emerged moths with each isolated in each in a cup. Moths were, however, not provided with food for the duration of their life span in this latter experiment. In both experiments, the daily survival for each moth was recorded, and its lifespan determined by counting the total numbers of days alive.

### 3.4.9. Fecundity of female fall armyworm moths as influenced by pairing ratio

The influence of pairing ratio on the fecundity of female FAW moths was investigated in a laboratory experiment laid out in a Completely Randomized Design with seven replicates each. In the experiments, three different pairing ratios namely 0 male:1 female; 1 male:1 female; and 3 males:1 female, were evaluated. Moths were placed in 500 mL lidded plastic containers equipped with brown paper strips for oviposition and fed with 10% sugar solution in cotton absorbent rolls as earlier described. Each day, the cotton rolls were replenished with food and paper strips were checked for egg masses. When an egg mass was observed on a paper strip, the strip was removed and replaced with another one. The number of eggs laid per egg mass by females in each treatment was counted and recorded daily.

### 3.4.10. Influence of food quantity on cannibalism levels within fall armyworm populations

The cannibalism level, which was measured by percentage mortalities, within FAW larval populations fed with two- and five- grams of fresh maize leaves was studied in two separate experiments set up in a Completely Randomized Design. In both experiments, treatments were replicated five times and consisted of four different larval populations *viz:* 1, 2, 5 and 15 larvae per rearing container. Also, larvae used in both experiments were obtained from eggs that hatched on the same day. Immediately after hatching, the larvae were reared for four days on fresh leaves of SAMMAZ-32 after which they were used for experimentation. In the first experiment, each treatment was placed in a 500 mL container and then fed with two grams of fresh SAMMAZ-32 leaves. The container was then covered with perforated lids for ventilation. Thereafter, the same quantity of food was offered every other day to the different population of larvae (treatments) in each container. Before being fed new food, larvae were removed and counted while the containers were cleaned with dry paper towel. The experiment was concluded when matured last instar larvae entered prepupa stage. The second experiment was carried out in the same way as the first except that the larvae were fed 5 g of fresh maize leaves every two days. In both experiments, data were collected when larvae were six days old (early fifth instar stage), at eight days old (early sixth instar stage) and ten days old (late sixth instar stage and fully matured) on the number of surviving larvae per treatment.

### 3.4.11 Influence of rearing space on cannibalism levels within fall armyworm populations

Three transparent plastic containers of different volumes were used to evaluate the influence of rearing space on cannibalism levels in FAW populations. The first container (200 mL volume; 9.35 cm height; 64.4 mm internal top diameter and 43.8 mm base diameter) was tagged ‘small’ in the study. Similarly, the second container (500 mL volume; 9.95 cm height; 94.6 mm internal top diameter and 73.6 mm base diameter) was tagged ‘medium’. The last and biggest container (1000 mL volume; 11.8 cm height; 119.1 mm internal top diameter and 98.8 mm base diameter) was tagged ‘large’. Into each container, 15 four-day old FAW larvae obtained from eggs that hatched on the same day, were introduced. Also, 2 g of fresh maize leaves was put into each container as food source for the larvae. The containers were covered with muslin cloth to allow for ventilation. The same type and quantity of food was offered every other day to the larvae in each treatment. The experiment was replicated five times and set up in a Completely Randomized Design. Data was also collected on the number of surviving larvae per treatment when larvae were six, eight and ten days old.

## 3.5. Field evaluation of resistance in selected maize varieties to natural field infestation and damage by fall armyworm at Ibadan southwestern Nigeria

The field responses of selected open-pollinated varieties (OPVs) of maize to FAW infestation and damage were evaluated in the early (15 May to 25August) and late (14 September – 21 December) maize planting seasons of 2018 and 2019.

### 3.5.1 Source and selection of maize varieties

Thirty-six improved open-pollinated maize seeds, developed by national or international agricultural research institutes in Nigeria and cultivated by farmers in the country, were collected for the study. The seeds were sourced from the Institute for Agricultural Research and Training (IAR&T), Moor Plantation, Ibadan, Oyo State; the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State; and the Institute of Agricultural Research (IAR), Samaru, Zaria, Kaduna State. On receipt, identities of OPVs were cross-checked to prevent duplicity in case different research institutes had given the same variety different names. Thereafter, 25 OPVs were selected for field evaluation. The name, source, kernel colour and maturity group of each variety is presented in Table 3.5. Other important characteristics are also presented in Table 3.6.

**Table 3.5. Source, kernel colour and maturity group of Open Pollinated Varieties evaluated in the study**

| S/N | Open pollinated varieties | Source[+] | Colour | Maturity group[++] |
|---|---|---|---|---|
| 1 | SAMMAZ-14 | IAR | White | M |
| 2 | SAMMAZ-15 | IAR | White | M |
| 3 | SAMMAZ-16 | IAR | White | L |
| 4 | SAMMAZ-17 | IAR | White | M |
| 5 | SAMMAZ-19 | IAR | White | M |
| 6 | SAMMAZ-26 | IAR | White | M |
| 7 | SAMMAZ-29 | IAR | White | EE |
| 8 | SAMMAZ-31 | IAR | Yellow | L |
| 9 | SAMMAZ-32 | IAR | Yellow | M |
| 10 | SAMMAZ-37 | IAR | Yellow | M |
| 11 | SAMMAZ-38 | IAR | Yellow | EE |
| 12 | SAMMAZ-45 | IAR | Yellow | E |
| 13 | SAMMAZ-52 | IAR | Yellow | M |
| 14 | BR-9943-DMR-SR-W | IAR&T | White | E |
| 15 | BR-9928-DMR-SR-Y | IAR&T | Yellow | E |
| 16 | SUWAN-1-SR-Y | IAR&T | Yellow | E |
| 17 | DMR-LSR-Y | IAR&T | Yellow | M |
| 18 | TZEE-Pop-STR-QPM-Y | IITA | Yellow | EE |
| 19 | 2008-SYN-EE-W-DT-STR | IITA | White | EE |
| 20 | TZE-W-Pop-DT-STR-QPM$C_0$ | IITA | White | E |
| 21 | 2008-EVDT-STR-Y | IITA | Yellow | E |
| 22 | TZE-W-DT-STR-$C_4$ | IITA | White | E |
| 23 | TZE-Y-DT-STR-$C_4$ | IITA | Yellow | E |
| 24 | EVDT-W-99-STR | IITA | White | E |
| 25 | EVDT-Y-2000-STR | IITA | Yellow | E |

[+]Source: IAR – Institute for Agricultural Research, Samaru; IAR&T – Institute of Agricultural Research and Training, Moor Plantation, Ibadan; IITA – International Institute of Tropical Agriculture, Ibadan

[++]Maturity group: EE – Extra Early Maturing (<75 days); E – Early Maturing (75-85 days);M– Medium/Intermediate Maturing (90-110 days); L – Late Maturing (110-120 days)

**Table 3.6. Additional characteristics of maize varieties sourced from research institutes in Nigeria**

| Maize variety (Original name) | Characteristics |
|---|---|
| SAMMAZ-14 (Obatapa) | Medium maturing (106-110 days); quality protein maize (QPM); high yield, high lysine and typtophan content; resistant to maize streak virus and stem borers, tolerant to striga. Released in 2002 |
| SAMMAZ-15 (IWDC2SynF2) | Intermediate/medium maturity (100 – 110 days); yield potential of 6.9 tons/ha and 4.42 tons/ha under striga infestation; resistant to pest and highly tolerant to root and stalk lodging; as good ear and plant aspects and excellent husk cover. Released in 2008 |
| SAMMAZ-16 (TZLComplSynW-1) | Late maturing (110-120 days); synthetic variety with yield potential of 6.4 tons/ha; tolerant to maize streak virus and striga. Released in 2008 |
| SAMMAZ-17 (Acr Sakatifu C4) | Medium maturing variety (90-95 days); adapted to lowland tropics with a yield potential of 5 tons/ha; tolerant to striga and streak virus. Released in 2009 |
| SAMMAZ-19 (S.14 DKD DT) | Medium maturing variety (90-95 days); adapted to lowland tropics with a yield potential of 5 tons/ha; tolerant to striga and maize streak virus and drought. Released in 2009 |
| SAMMAZ-26 (DTSR-WC1) | Medium maturing (95-100 days), widely adaptable; tolerant to drought with resistance to maize streak, tolerant to low soil nitrogen. It as a potential yield of 3-4 tons/ha in drought prone areas. Released in 2009 |
| SAMMAZ-29 (2000 Syn EE-W-STR) | Very/extra early maturing (80-85 days); well adapted to lowland tropics with yield potential of 4.0 tons/ha. Escapes drought due to its extra early maturing; striga tolerant and resistant to maize streak virus. Released in: 2009 |

| | |
|---|---|
| SAMMAZ-31 (formerly LNTP-Y-C5) | Flint/dent with late maturity (100-110 days); yield potential of 3.5-4t/ha; tolerant to low soil nitrogen and resistant to maize streak virus. Released in 2009 |
| SAMMAZ-32 (99TZEE-Y Pop STR QPM Co) | Extra early maturing (85 days); quality protein maize Composite variety adapted to Sudan savannah and transition zones between Sudan and northern Guinea savannah; potential yield of 4.3 tons/ha. It is non-tillering and erect with good cob and seed size; Striga resistant, drought escaping, and tolerant to maize streak virus disease; |
| SAMMAZ-37 (Pop66, SR//AC 91 SUWAN-I-SR) | Medium maturing (115 days) synthetics, non-tillering, erect variety; adapted to the savannah; yield capacity of 5.9 tons/ha; tolerant to drought, maize streak virus and striga infestation. Released in 2011 |
| SAMMAZ-38 (PVA Syn2) | Extra early maturing variety adapted to the guinea and Sudan savannah; conventional variety with an intermediate level of Pro Vitamin A content; yield potential of high yield of 4-6 tons/ha and a Pro Vit A content of 5.7µg/g or 6-8ppm; striga resistant. Released in 2012 |
| SAMMAZ-45 (AFLATOXIN R SYN-Y2) | Aflatoxin resistant with a yield potential of 6.2 tons/ha; adapted to the northern and southern guinea savannah zones. Released in 2015 |
| SAMMAZ-52 (PVA SYN 13) | Medium maturing variety (110-120 days); vitamin A bio- fortified maize variety with intermediate level of Pro Vit A content of 9.3ppm; yield potential of 6.0tons/ha; tolerant to maize streak virus, rust, leaf blight and curcularia leaf spot. |
| BR-9928-DMR-SR-Y | Maturity of 75days; adapted to the forest AEZ and derived savannah; yield potential of 3-4 tons/ha; highly resistant to stem borers (both *Sesamia Calamistis* and *Eldana Saccharina*). Colour: Yellow; Released in 2009 |

| | |
|---|---|
| BR-9943-DMR-SR-W | It was developed by I.I.TA. It as maturity of 75days, highly resistant to stem borers (both *Sesamia Calamistis* and *Eldara Sacharina*). It as a yield potential of 3-4 tons/ha. Adapted to the forest AE2 and derived savannah. Colour: White; Released in 2009 |
| DMR-LSR-Y (NARZO 25) | Maturity of 90 days; adapted to the forest and savannah agro-ecology zone; resistant to downy mildew and sturdy vigorous plant. Released in 2009 |
| SUWAN-1-SR-Y | Resistant to downy mildew and maize streak virus. |

**Source: National Centre for Genetic Resources and Biotechnology-NACGRAB (2016)**

### 3.5.2 Land preparation, experimental design and field layout

At the study site, a long stretch of already cleared land (about 200 m x 100 m) was ploughed using a disc plough and thereafter beds or ridges were made using a ridger. Only a portion of the entire land was, however used for experimentation in the early and late seasons of both study years (Table 3.7). The same piece of land was however, not used twice during the study. In each season, experimental plots were laid out in a Randomized Complete Block Design with four replicates or blocks. Each block comprised all 25 OPVs with a variety allocated to a plot within a block. Plots sizes, inter plot and inter block spacing used in the early and late seasons of each study year are outlined in Table 3.6.

### 3.5.3. Maize planting and other agronomic practices

In both seasons of each study year, seeds were planted on double row plots with a between and within row spacing of 75 cm and 25 cm respectively. Three seeds were planted per hill and later thinned to one after two weeks, giving an optimum plant population density of 53,333 plants $ha^{-1}$ (Bello *et al.*, 2012). Weed control was done immediately after sowing with Xtraforce (active ingredients: atrazine/metoalachlor), a pre- and post-emergence chemical herbicide manufactured by Jubaili agrochemical company. Herbicide application was done according to the manufacturer's recommendations. At three weeks after sowing (WAS), the compound fertilizer, NPK 20:10:10 was applied at a recommended rate of 60 kg N, 60 kg P and 60 kg K per hectare (Bello *et al.*, 2012). Urea fertilizer (46% N) was applied as top dressing at the rate of 60 kg N per hectare (Bello *et al.*, 2012). Further weed control was subsequently carried out by hoe-weeding at four weeks after sowing and as at when needed. No insecticide was applied in both seasons of each study year.

### 3.5.4. Data collection

At three-, five- and seven- weeks after sowing (WAS), data were collected per plot on percentage infestation of FAW eggs and larvae; abundance of FAW eggs and larvae per five sampled maize stands; and foliar damage response per five sampled maize stands. Response of maize varieties to FAW foliar damage under natural infestation was

**Table 3.7. Dimension of experimental plots used for maize cultivation in 2018 and 2019**

| Maize planting season | Total land area allocated | Varietal plot size | Inter plot spacing | Inter block spacing | Plant population per plot (No. per row) |
|---|---|---|---|---|---|
| 2018 Early | 78 m by 11.5 m ($897\ m^2$) | 3 m by 1 m | 0.75 m | 1 m | 24 stands(12) |
| 2018 Late | 48 m by 16 m ($768\ m^2$) | 1.5 m by 1.0 m | 0.75 m | 1 m | 12 stands(6) |
| 2019 Early | 40 m by 18 m ($720\ m^2$) | 1.5 m by 1.0 m | 0.5 m | 1 m | 12 stands(6) |
| 2019 Late | 31.25 m by 10 m ($312.5\ m^2$) | 1m by 1m | 0.5 m | 0.75 m | 8 stands(4) |

measured using a five-point visual rating scale (Plate 3.3**).** The scale was a modification of the five-point scale developed by Hormchong (1967) for evaluating maize resistance to *Spodoptera* spp. under natural field infestation. At 11 WAS, destructive sampling of two maize stands per plot was done and data was collected on infestation and abundance of FAW and stem borer (SB) larvae in maize stems and cobs. Weather data at the experimental site was collected monthly from May to December in 2018 and 2019 (Appendix II)**.**

### 3.6. Data Analysis

Maize farmers' responses to each question were summarized with frequencies and percentages. Means and standard deviation were also determined for age, household size, land size and number years of maize cultivation. Where respondents did not answer a given question, such questions were taken as missing values and thus excluded from the analysis. Questions requiring multiple answers were analysed by calculating the quotient of percentage total responses per item and total respondents. Association between farming practices and FAW damage severity was investigated using the Chi-square test at 5% level of significance. The independence of FAW damage severity and AEZ as well as independence of farmers' perception of FAW damage and AEZ were also tested using the Chi-square test. Questionnaire data were analysed with the IBM SPSS software (version 20).

Furthermore, the number of plants infested with fall armyworm on each farm during the on-farm damage assessment survey was converted to percentages before statistical analysis. Thereafter, percentage infestation and foliar damage severity on farms in AEZs and LGAs were compared with one-way Analysis of Variance (ANOVA) test. Similarly, FAW morphometric and developmental data were analysed by calculating means, standard deviations and ranges in Microsoft Office Excel (v. 16). Data on FAW longevity was analysed using two-way ANOVA with feeding status and moth sex as factors. Similarly, laboratory experiment data on egg and egg-mass number, lifespan and percentage larval cannibalism were analysed with the one-way ANOVA test. To test for differences in egg-mass and larval abundance between seasons and between varieties in a year, ANOVA was done using the Linear Mixed Model procedure in GenStat Discovery


| SCALE | RATING | RESPONSE |
|---|---|---|
| 0 | No feeding damage to leaves, furl or whorl leaves | HR |
| 1 | Few pinholes or shot holes on leaves but none on furl/ whorl leaves | R |
| 2 | Several feeding holes on leaves with 1 – 20% damage to furl/whorl leaves | MR |
| 3 | Several feeding holes on leaves with 21 – 40% damage to furl/whorl leaves | MS |
| 4 | Many feeding holes on leaves with 41 – 80% damage to furl/whorl leaves | S |
| 5 | Many feeding holes on leaves with 81 – 100% damage to furl/whorl leaves | HS |

**HR: Highly Resistant; R: Resistant; MR: Moderately Resistant; Moderately Susceptible; S: Susceptible; HS: Highly Susceptible**

**Plate 3.3. Rating scale for maize resistance to foliar damage by the fall armyworm (*Spodoptera frugiperda* J. E. Smith)**

Edition 3 (2007) statistical package. In the model, fixed effects were maize planting season, maize variety, and the interaction of both. On the other hand, treatment blocks nested in season was taken as the random effect component of the model. Interaction effects were, however, not significant. Separate seasonal analysis of egg-mass and larval infestation and abundance for each study year was also done with GenStat Discovery Edition 3 (2007) statistical package using the one-way ANOVA in randomized blocks procedure. Furthermore, differences in varietal foliar damage scores in both seasons of each year of field evaluation were tested using the non-parametric Kruskal-Wallis test in the IBM SPSS (2011) software. Analysis of grain yield after harvest in the early and late seasons of both years was done with GenStat Discovery Edition 3 (2007) statistical package using analysis of covariance (ANCOVA) test, with percentage grain moisture as covariable.

Before each analysis, data were tested for homogeneity of variance using the Bartlett test and where significant, the data was subjected to transformation. Percentage data were transformed into arc sine percentages while abundance data with very low or zero values were square root ($\sqrt{x+0.5}$) transformed before analysis (Gomez and Gomez, 1984). Transformed data was subjected to analysis of variance while mean separation was done using Tukey's Honestly Significant Difference test at $\alpha_{0.05}$ Untransformed means were however presented in the result section. Relationships between abundance of FAW larvae and foliar damage on the varieties at each week of observation in the early and late planting seasons of 2018 and 2019 were investigated using correlation and linear regression in Microsoft Office Excel (2019).

# CHAPTER FOUR

# RESULTS

## 4.1. Farmers’ knowledge of FAW, control practices employed and their perception of FAW damage to maize in three maize-growing agro-ecological zones of southwestern Nigeria

Maize farmers’ knowledge, control practices and perception on FAW are outlined below.

### 4.1.1. Farmers' demographics and maize farming practices

The demographic characteristics and maize farming practices of 195 farmers in the three maize-growing agro-ecological zones surveyed in southwestern Nigeria shows that majority of the farmers were male (91.3%) while the average age of respondents was 47 years (Table 4.1). In addition, most (97.9%) were married, with more than half (73.3%) having at least a secondary school education and an average household size of 7 persons (Table 4.1). Average maize farming experience in the region was approximately 16 years with most farmers cultivating maize on a small-scale (67.7%), as rain-fed (87.7%) and for the dual-purpose of consumption and sales (87.2%).

### 4.1.2. Farmers’ experience with fall armyworm

About 85.6% of farmers planted maize in both 2016 and 2017 (Fig. 4.1). Also, only 43.1% experienced FAW damage in both years (Figure 4.2). Furthermore, 49.2% planted only maize, while 35.9% intercropped it with a tuber crop, mainly cassava (Figure 4.3). For 45.1% of farmers, maize of less than a month old were attacked, while 43.6% reported that their plants were attacked at 1-2 months of age (Figure 4.4). Also, 39.5% of farmers experienced FAW damage to half or more maize plants (Plate 4.1), while 30.8% experienced complete damage (Figure 4.5). There was an association between the method cultivation and severity of FAW damage to maize ($\chi^2 = 19.0$, $N = 187$, degrees of freedom (DF) = 9, $p < 0.05$). Similarly, there was a significant interaction between the age of maize at the time of FAW attack and the severity of maize damage experienced

**Table 4.1. Demographic characteristics and farming practices of 195 maize farmers in southwestern Nigeria**

| | Variable | Mean (± SD) | Total Respondents Number | % |
|---|---|---|---|---|
| **A.** | **Gender** | | | |
| | Male | | 178 | 91.3 |
| | Female | | 17 | 8.7 |
| **B.** | **Age (years)** | 47.1 (± 9.9) | | |
| **C.** | **Marital status** | | | |
| | Married | | 191 | 97.9 |
| | Single | | 4 | 2.1 |
| **D.** | **Highest level of education** | | | |
| | Tertiary | | 74 | 37.9 |
| | Secondary | | 69 | 35.4 |
| | Primary | | 42 | 21.5 |
| | No formal education | | 10 | 5.1 |
| **E.** | **Household size** | 6.9 (± 3.8) | | |
| **F.** | **Size of land cultivated to maize** | | | |
| | Subsistence (<0.5 ha) | | 11 | 5.6 |
| | Small scale (0.5 - 4.9 ha) | | 132 | 67.7 |
| | Medium scale (5 - 10 ha) | | 37 | 19 |
| | Large scale (> 10 ha) | | 15 | 7.7 |
| **G.** | **Total years of cultivating maize** | 15.9 (± 9.4) | | |
| **H.** | **Maize farming system** | | | |
| | Rainfed | | 171 | 87.7 |
| | Irrigation | | 3 | 1.5 |
| | Wetland | | 3 | 1.5 |
| | Rainfed and Irrigation | | 5 | 2.6 |
| | Rainfed and Wetland | | 13 | 6.7 |
| **I.** | **Purpose of maize cultivation** | | | |
| | Consumption | | 4 | 2.1 |
| | Sales | | 21 | 10.8 |
| | Consumption and Sales | | 170 | 87.2 |

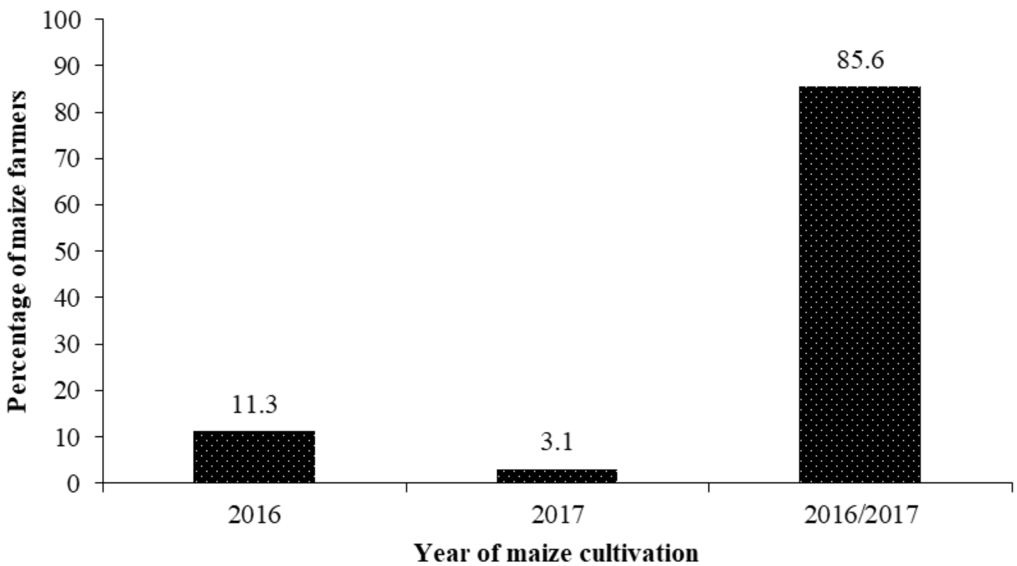


**Figure 4.1. Distribution of selected maize farmers in southwestern Nigeria by year of maize cultivation (N=195)**

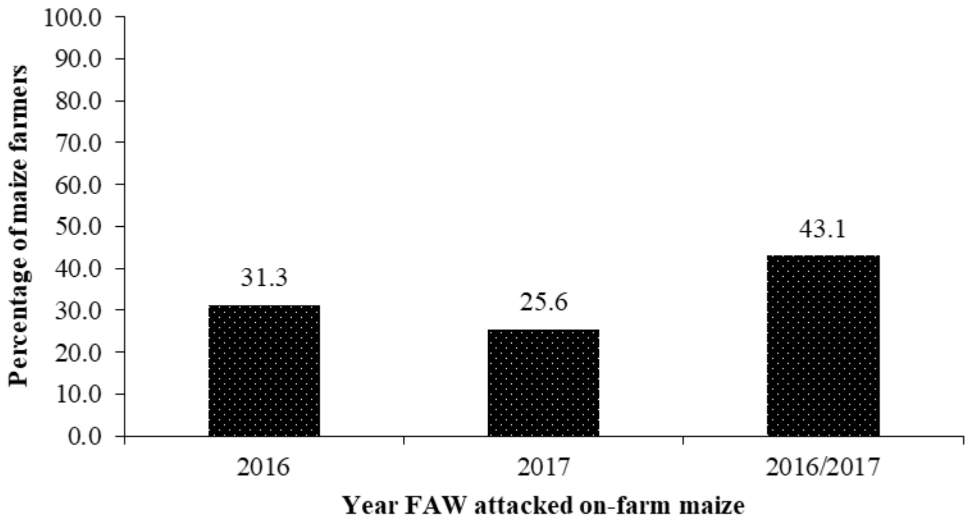


**Figure 4.2. Distribution of selected maize farmers in southwestern Nigeria by the year fall armyworm attacked to on-farm maize (N=195)**

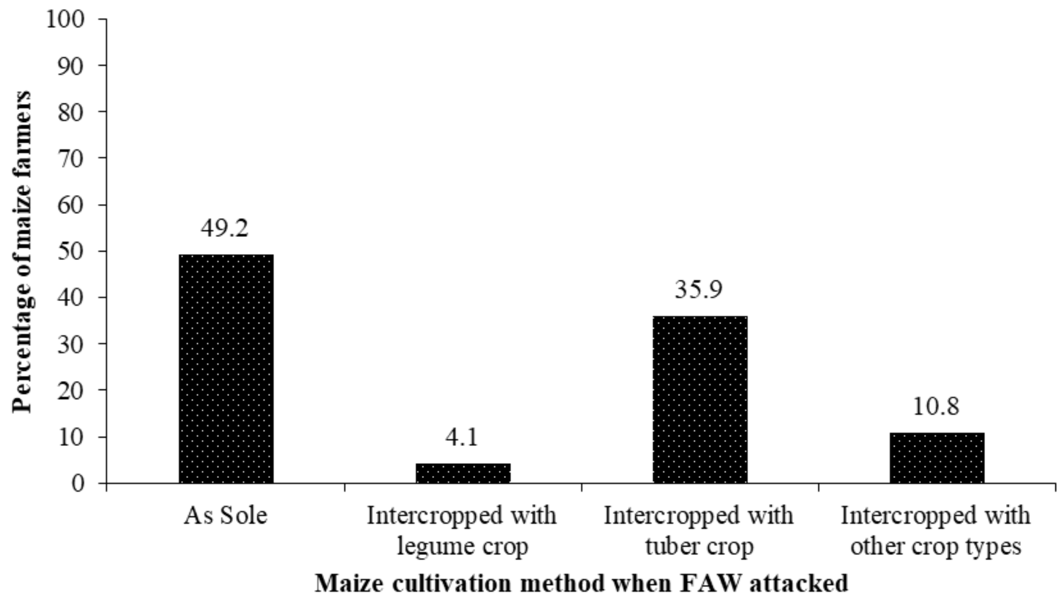


**Figure 4.3. Distribution of maize farmers in southwestern Nigeria by cultivation method used when on-farm maize was attacked by fall armyworm (N=195)**

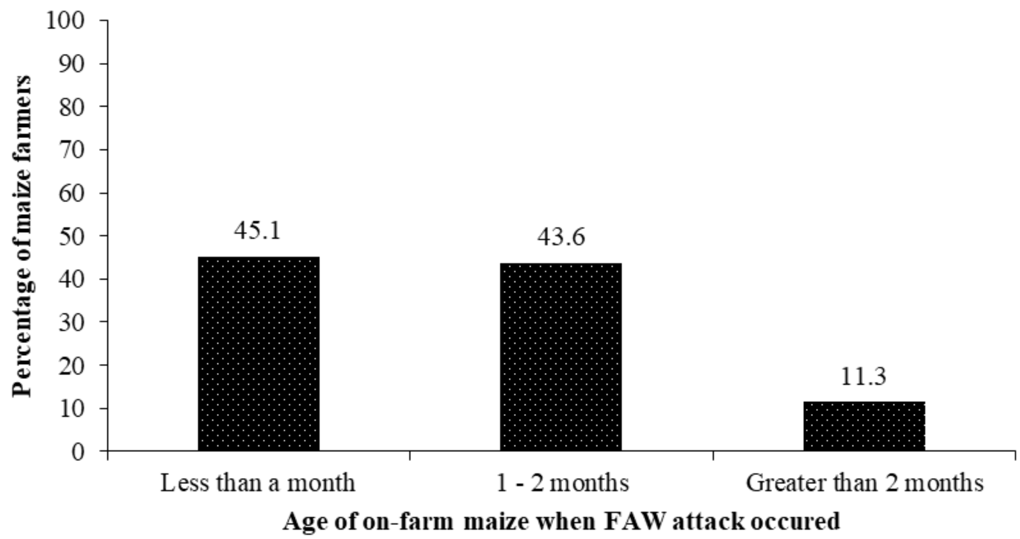


**Figure 4.4. Distribution of maize farmers in southwestern Nigeria by the age of on-farm maize when fall armyworm attacked (N=195)**


**Plate 4.1. On-farm maize plants with holes on leaves caused by fall armyworm larval feeding**

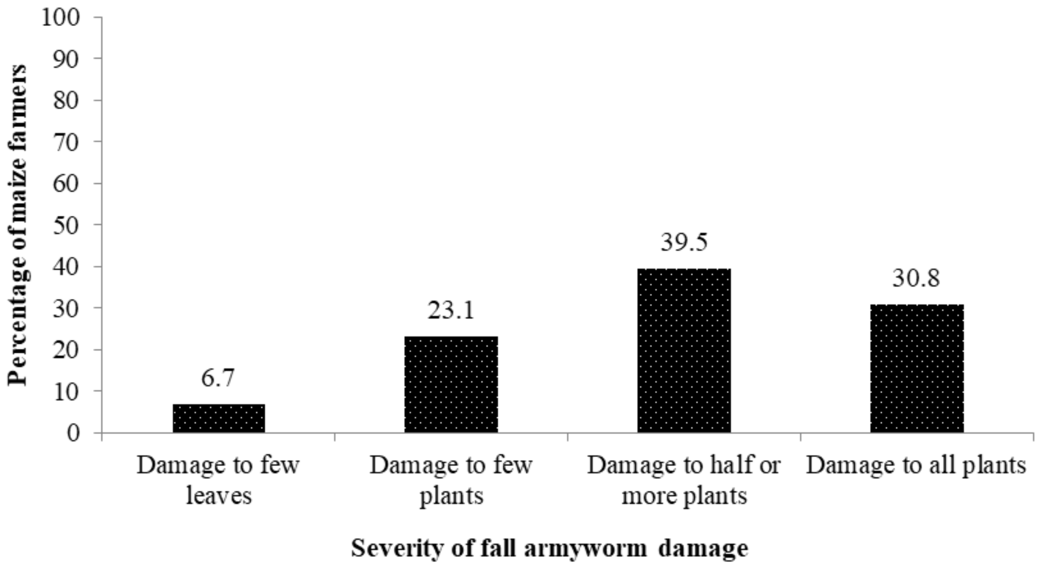


**Figure 4.5. Distribution of maize farmers by severity of fall armyworm damage to on-farm maize (N=195)**

($\chi^2$ = 25.6, $N$ = 187, DF = 6, $p$ < 0.001). Also, a strong association ($\chi^2$ = 41.3, $N$ = 195, DF = 6, $p$ < 0.001) was found between FAW damage severity and agro-ecological zone in this study.

### 4.1.3. Fall armyworm identification knowledge and information

Most maize farmers (75.9 %) described FAW as a small crawling worm (Table 4.2) and many (57.2 %) were able to distinguish it from stem borers by the unusual eating behaviour and fecal excretion on maize leaves (Table 4.2). In addition, 50.5 % of the farmers sourced information on FAW from agricultural extension agents, 40.9 % obtained it from other farmers while only 8.6 % recourse to radio and other media outlets.

### 4.1.4. Fall armyworm control methods

About 59.0 % of farmers sprayed only chemical insecticides for FAW control on maize (Table 4.2). In contrast, only 6.7 % strictly employed non-chemical control methods. An intermediate percentage number (31.8 %) however used both chemical and non-chemical methods. In terms of insecticide spray frequency, 71.6 % of the farmers sprayed once or twice; 22.2 % sprayed three or four times, while 6.3 % sprayed more than four times. Insecticide application was considered to be moderately effective against FAW by 57.4 % of the farmers; but 10.2 % reported that it was not effective against the pest. Nevertheless, no apparent association was observed between insecticide spray times and insecticide effectiveness ($\chi^2$ = 4.2, $N$ = 176, DF = 6, $p$ < 0.05).

Furthermore, seven different groups of insecticides were sprayed for FAW control by farmers in southwestern Nigeria (Figure 4.6). The insecticide groups were anthranilic diamides, avermectins, neonicotinoids, organochlorines, organophosphates, synthetic pyrethroids and oxadiazines. However, majority of the insecticide sprayed consisted of organophosphates (37.2 %) and synthetic pyrethroids (29.0 %). Similarly, non-chemical methods used for FAW control (Figure 4.7) include application of sand (22.2%) or botanical ash (14.4%), handpicking FAW larvae (20.9%), intercropping with other crops (17.0%), roguing and burning infected plants (18.9%), spraying neem extracts (3.0%) or pepper extracts (0.7%) or detergent solution (2.0%).

**Table 4.2. Fall armyworm identification knowledge and control practices of maize farmers in southwestern Nigeria (N=195)**

| Variable | | Total Respondents | |
|---|---|---|---|
| | | **Number** | **%** |
| A. | FALL ARMYWORM IDENTIFICATION | | |
| **i.** | **Fall armyworm attacking maize looks like** | | |
| | small green grasshopper | 10 | 5.1 |
| | small brown butterfly | 37 | 19 |
| | small crawling worm | 148 | 75.9 |
| | Total | 195 | 100 |
| **ii.** | **Fall armyworm and not stem borer larvae** | | |
| | Color is different | 61 | 18.9 |
| | Size is different | 62 | 19.3 |
| | Eating pattern is different | 109 | 33.9 |
| | Fecal excretion on maize leaves | 75 | 23.3 |
| | Cannot tell the difference | 15 | 4.7 |
| | Total | 322* | 100 |
| **iii** | **Main source of information on fall armyworm** | | |
| | Farmers | 114 | 40.9 |
| | Extension agents | 141 | 50.5 |
| | Media | 24 | 8.6 |
| | Total | 279* | 100 |
| B. | FALL ARMYWORM CONTROL PRACTICES | | |
| **i** | **Control methods employed** | | |
| | Insecticide spray | 114 | 58.5 |
| | Non-chemical method | 13 | 6.7 |
| | Both insecticide spray and non-chemical method | 62 | 31.8 |
| | No control applied | 6 | 3.1 |
| | Total | 195 | 100 |
| **ii** | **Number of times insecticide was sprayed** | | |
| | 1 - 2 times | 126 | 71.6 |
| | 3 - 4 times | 39 | 22.2 |
| | 5 - 6 times | 10 | 5.7 |
| | 7 - 10 times | 1 | 0.6 |
| | Total | 176 | 100 |
| **iii** | **Effectiveness of insecticide sprayed** | | |
| | Excellent | 57 | 32.4 |
| | Moderate | 101 | 57.4 |
| | Poor | 18 | 10.2 |
| | Total | 176 | 100 |

*Value is higher than 195 because respondents were allowed to select more than one option to the question

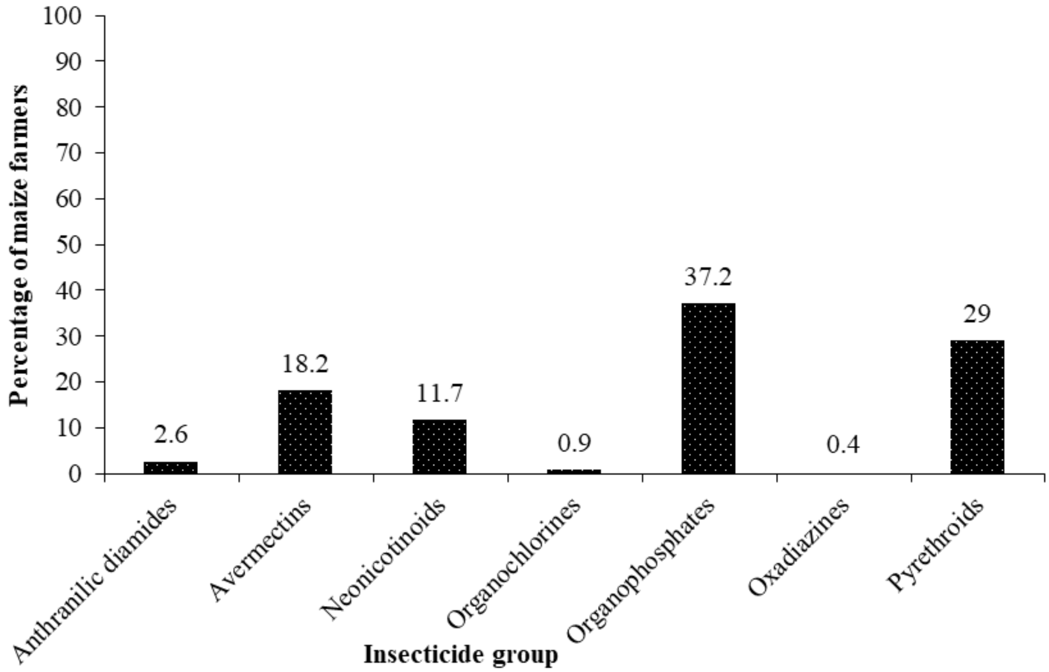


**Figure 4.6. Distribution of maize farmers in southwestern Nigeria by insecticide group applied for fall armyworm control on maize (N=187)**

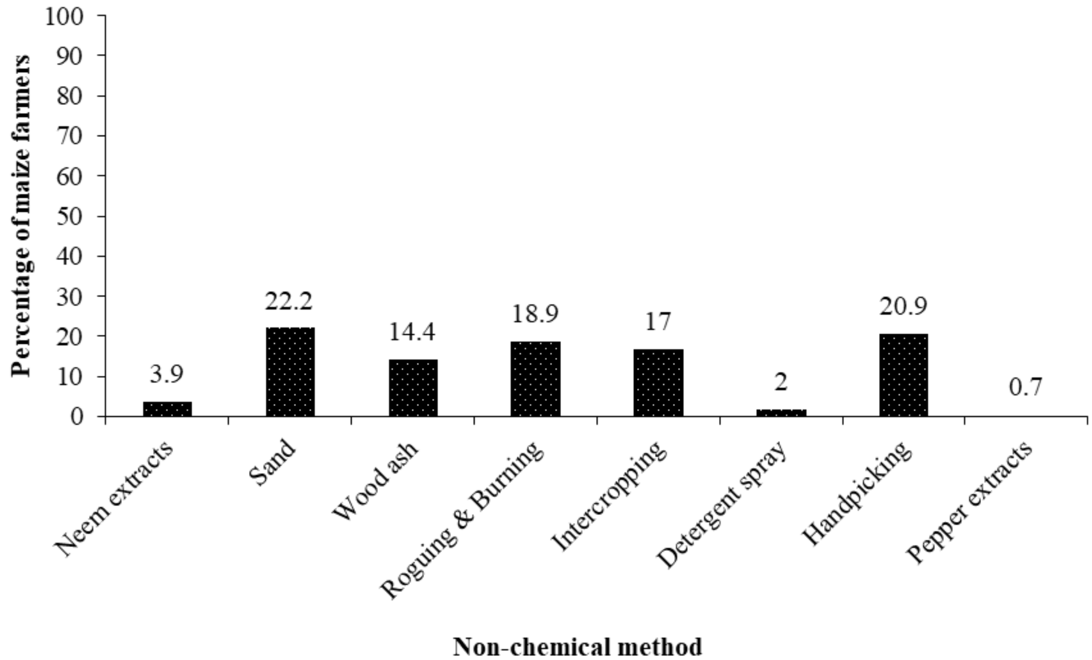


**Figure 4.7. Distribution of maize farmers in southwestern Nigeria by the non-chemical methods applied for fall armyworm control on maize (N=153)**

The seven insecticide groups sprayed against FAW by maize farmers in the present study consisted of 12 insecticide active ingredients. As shown in Table 4.3, three active ingredients – chlorpyriphos; dichlorvos and dimethoate were organophosphates while four – beta-cyfluthrin, cypermethrin, deltamethrin and lambda-cyhalothrin were pyrethroids. Table 4.3 also presents the World Health Organization (WHO) and Globally Harmonized System of Classification and Labeling of Chemicals (GHS) hazard classifications for each insecticide compound. Based on both classification systems, beta – cyfluthrin and dichlorvos were the most hazardous active ingredients applied for FAW control in the study area. In contrast, chlorantraniliprole (an anthranilic diamide), was the most innocuous active ingredients sprayed by maize farmers according to both pesticide hazard classifications. All other insecticide active ingredients fall under class II or category 3 of the WHO and GHS pesticide hazard classification respectively, and were thus moderately hazardous. Lindane, the only organochlorine observed in this study, was applied by less than 1% of the respondents.

### 4.1.5. Farmers' perception of damage to maize by fall armyworm

Most farmers (82.4%) considered FAW damage to be a serious and worrisome problem (Table 4.4). Similarly, 72.5% and 75.6% farmers strongly agreed that FAW damage reduced their expected harvest and profit respectively. About 57.0% of farmers perceived damage to be more severe in the early maize season, about 27.0% felt it was more severe in the late season (Table 4.4). Farmers' perception of damage severity to sole maize as compared to intercropped maize varied greatly, with majority (33.2%) being undecided. Furthermore, 50.8% of famers perceived they had sufficient education on FAW damage while an equally high percentage (40.4%) felt they needed more education (Table 4.4). A strong association ($\chi^2 = 77.2$, $N = 193$, DF = 30, $p < 0.001$) was observed between farmer's perception of FAW damage to maize and agro-ecological zones.

**Table 4.3. Insecticide and hazard classification groupings of active ingredients applied by maize farmers for fall armyworm control in southwestern Nigeria**

| | Active Ingredient | Insecticide Group | WHO Hazard Class[a] | GHS Hazard Category[b] |
|---|---|---|---|---|
| 1 | Beta – cyfluthrin | Pyrethroid | Ib | 2 |
| 2 | Chlorpyriphos | Organophosphate | II | 3 |
| 3 | Chlorantraniloprole | Anthranilic diamide | U | 5 |
| 4 | Cypermethrin | Pyrethroid | II | 3 |
| 5 | Deltamethrin | Pyrethroid | II | 3 |
| 6 | Dichlorvos | Organophosphate | Ib | 3 |
| 7 | Dimethoate | Organophosphate | II | 3 |
| 8 | Emamectin benzoate | Avermectin | Not available | Not available |
| 9 | Imidacloprid | Neonicotinoid | II | 4 |
| 10 | Indoxacarb | Oxadiazine | II | 3 |
| 11 | Lambda – cyhalothrin | Pyrethroid | II | 3 |
| 12 | Lindane[cd] (Gamma-HCH) | Organochlorine | II | 3 |

[a] World Health Organization (WHO) Recommended Classification of Pesticides by Hazard: Ia = Extremely hazardous; Ib = Highly hazardous; II = Moderately hazardous; III = Slightly hazardous; U = Unlikely to present acute hazard. (World Health Organisation-WHO, 2010)

[b] Globally Harmonized System of Classification and Labeling of Chemicals (GHS): 1, 2 = fatal if swallowed/fatal in contact with skin; 3 = toxic if swallowed/Toxic in contact with skin; 4 = harmful if swallowed/harmful in contact with skin; 5 = may be harmful if swallowed/may be harmful in contact with skin. (United Nations-UN, 2015)

[c] Production and use of lindane are being eliminated internationally under the Stockholm Convention on Persistent Organic Pollutants (POP) of 17 May 2004.

[d] Subject to the Rotterdam Convention of 24 February 2004 which is based on the Prior Informed Consent (PIC) procedure initiated by the United Nations Environmental Programme (UNEP) and the Food and Agriculture Organization (FAO) in 1989.

**Table 4.4. Maize farmers' perception of damage by the fall armyworm in southwestern Nigeria (N= 193)**

| Perception Statements | Farmers' response+ | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Maize damage by the fall armyworm is a problem to be worried about | 0 (0%) | 0 (0%) | 1 (0.5%) | 33 (17.1%) | 159 (82.4%) |
| Fall armyworm damage reduces quantity of maize harvested | 1 (0.5%) | 3 (1.6%) | 2 (1.0%) | 47 (24.4%) | 140 (72.5%) |
| Fall armyworm decreases profit of maize production | 3 (1.6%) | 3 (1.6%) | 1 (0.5%) | 40 (20.7%) | 146 (75.6%) |
| Damage by fall armyworm is more severe in early maize than in late maize | 11 (5.7%) | 41 (21.2%) | 32 (16.6%) | 58 (30.1%) | 51 (26.4%) |
| Damage is more severe on maize when intercropped than when planted as sole | 15 (7.8%) | 60 (31.1%) | 64 (33.2%) | 33 (17.1%) | 21 (10.9%) |
| Sufficient education is available to maize farmers on fall armyworm damage | 32 (16.6%) | 46 (23.8%) | 17 (8.8%) | 65 (33.7%) | 33 (17.1%) |

+ Response: 1 = Strongly Disagree; 2 = Disagree; 3 = Undecided; 4 = Agree; 5 = Strongly Agree

## 4.2. Fall armyworm infestation and damage on selected farms in three maize-growing agro-ecological zones of southwestern Nigeria

With respect to agro-ecological zones (AEZ), percentage infestation of on-farm maize was highest (86.25±3.88%) in the humid forest AEZ and lowest (56.88±3.93%) in the southern guinea savanna AEZ (Figure 4.8). The derived savanna AEZ, however, had an intermediate percentage infestation value of 71.67±4.13%. Infestation level of FAW larva in the humid forest was significantly higher than in the southern guinea savanna. Similarly, FAW infestation was observed, to varying degrees, in all LGA where maize farms (Figure 4.9). The top three locations with high FAW infestation were Ikenne LGA in Ogun State (92.5±4.22%) > Ido/Osi LGA in Ekiti State (85.0±5.72%) > Sagamu LGA in Ogun State (80.0±6.41%). In contrast, the three LGA with the lowest infestation were Oyo State namely – Orelope LGA (47.5±8.00%) < Saki West LGA (50.0±8.01%) < Irepo LGA (55.0±7.97%). Significant differences were observed between the percentage infestation levels of the top and bottom three locations.

The FAW foliar damage rating on maize farms across the sampled AEZ and LGA is presented in Figures 4.10 and 4.11 respectively. Mean foliar damage ratings were higher (2.63±0.14) in the humid forest AEZ, with most maize plants having FAW feeding holes in the leaves and whorl (Figure 4.10). On the other hand, mean foliar damage ratings of 2.24±0.14 and 1.66±0.12 were recorded in the derived and southern guinea savanna AEZ respectively, reflecting the presence of relatively less FAW damage to plants. Also, while maize plants on the average had severe whorl damage at Ikenne (3.05±0.18) and at Ido/Osi (2.78±0.21) LGA, whorl of plants at all other locations were mostly without serious damage (Figure 4.11).

## 4.3. Developmental, reproductive and behavioural biology of FAW in the laboratory

### 4.3.1. Developmental biology of the fall armyworm

Eggs with an average diameter of 0.24±0.01 mm were laid by females between 2 – 3 days after adult emergence (Table 4.5). The eggs were observed to hatch within 2.1±0.06 days at ambient temperature of 29.36±0.17$^{o}$C, 73.9±1.00% R.H and 12-hour photoperiod.

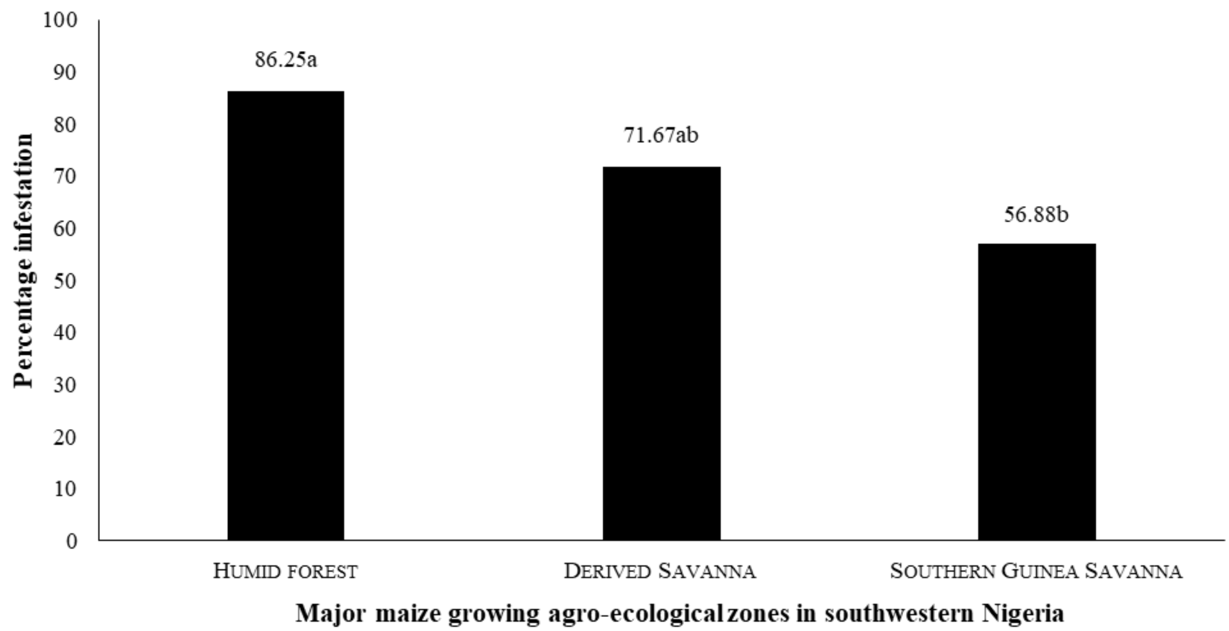


**Figure 4.8. Fall armyworm infestation on maize in selected farms in three maize-growing agro-ecological zones, southwestern Nigeria during the July 2019 survey**

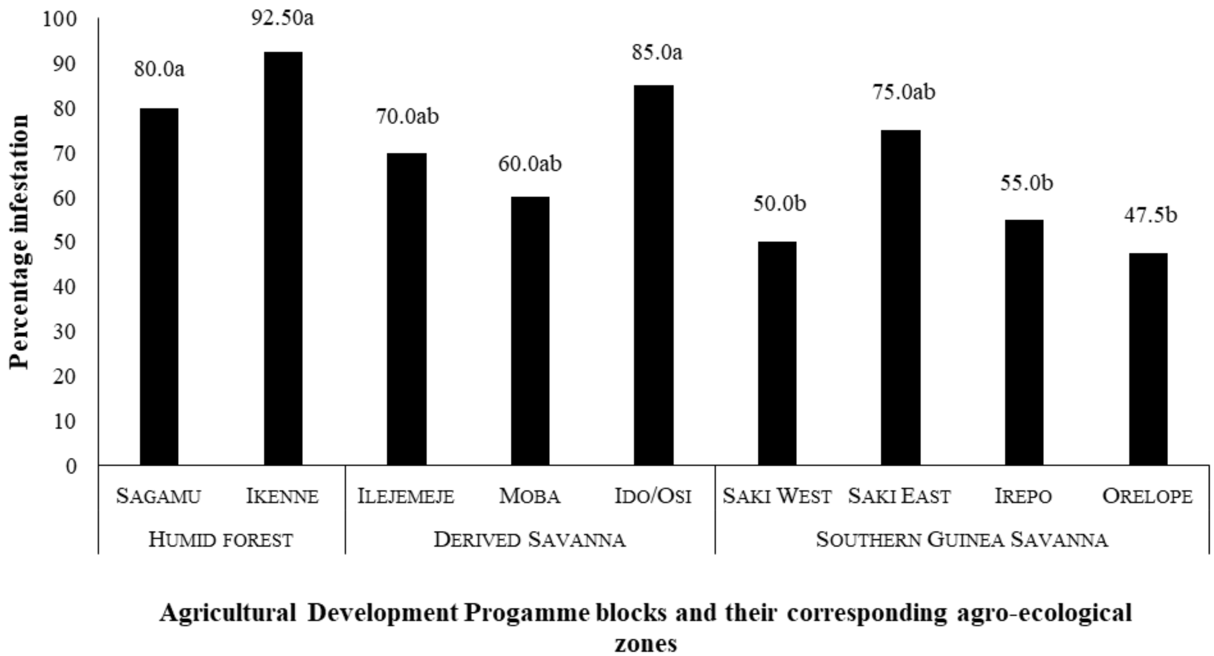


**Figure 4.9. Fall armyworm infestation in selected farms in Agricultural Development Progamme (ADP) blocks located in southwestern Nigeria during the July 2019 survey**

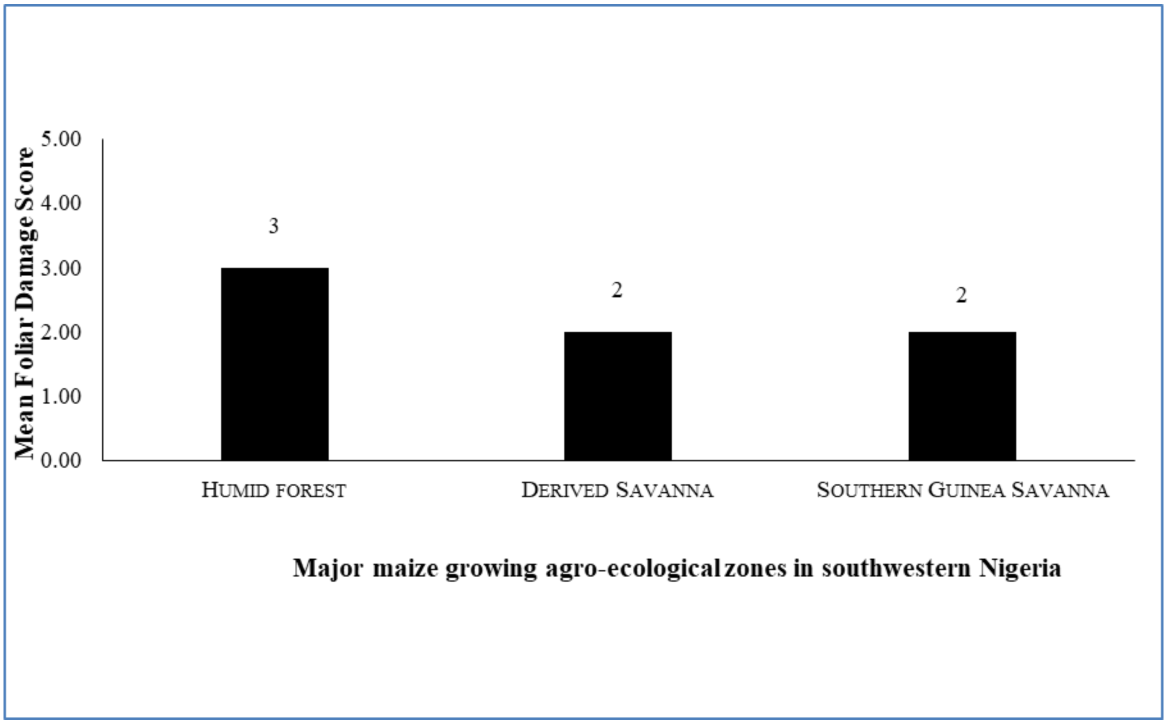


**Figure 4.10. Fall armyworm foliar damage ratings on maize in selected farms in three maize-growing agro-ecological zones, southwestern Nigeria during the July 2019 survey**

**Scale: Plants without damage (0); Plants with erasure leaves due to feeding by neonate and first instar larvae scored (1); plants with pin or shot holes in leaves alone scored (2); those with holes in leaves and some damage to whorl scored (3); plants with whorl destroyed scored (4) and completely decimated or dead plants scored (5).**

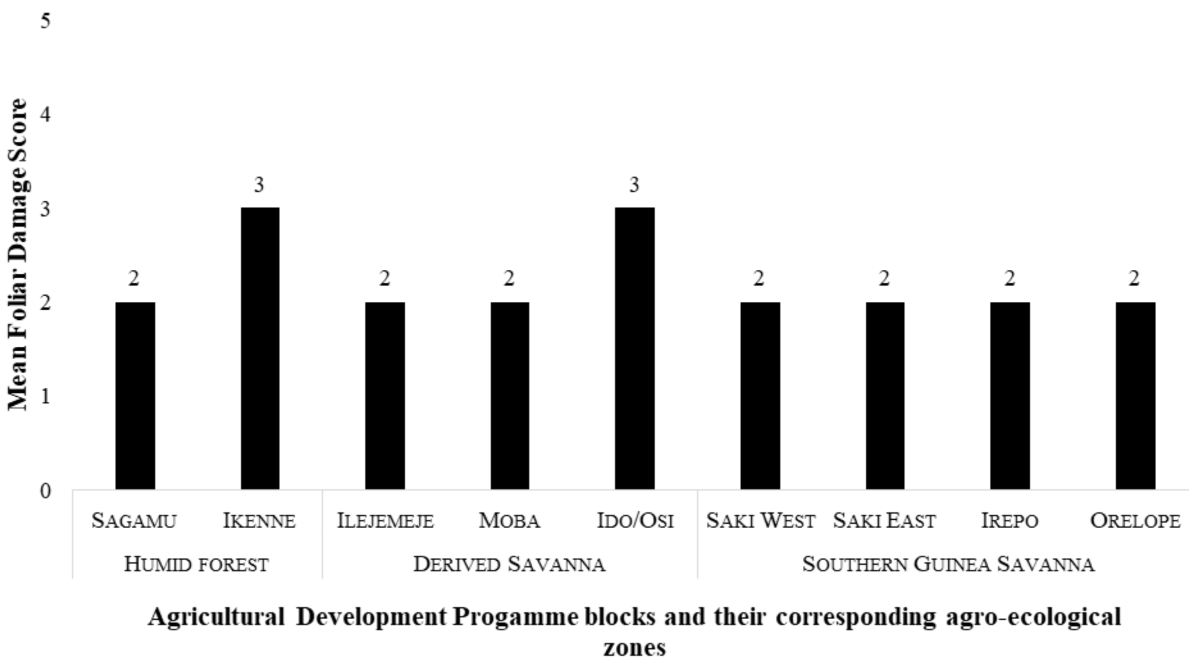


**Figure 4.11. Fall armyworm foliar damage ratings in selected maize farms in Agricultural Development Progamme (ADP) blocks located in southwestern Nigeria during the July 2019 survey**

**Scale: Plants without damage (0); Plants with erasure leaves due to feeding by neonate and first instar larvae scored (1); plants with pin or shot holes in leaves alone scored (2); those with holes in leaves and some damage to whorl scored (3); plants with whorl destroyed scored (4) and completely decimated or dead plants scored (5).**

**Table 4.5. Development and morphometric parameters of fall armyworm (*Spodoptera frugiperda*) eggs in Ibadan, Nigeria (N=30)**

| Parameters | Mean ± SE | Range |
|---|---|---|
| Incubation period (days)† | 2.10 ± 0.06 | 2.0 – 3.0 |
| Egg diameter (mm) | 0.24 ± 0.01 | 0.1 – 0.3 |
| Eggs per batch | 118.9 ± 17.92 | 15.0 - 340 |
| Hatchability (%) | 81.50 ± 2.28 | 52 - 100 |

† Incubation and hatching of eggs occurred in the laboratory at 29.36 ± 0.17 $^{o}$C, 73.90±1.00% relative humidity, 12 hours light and 12 hours dark photoperiods.
SE = Standard error of the mean

In addition, egg masses (Plate 4.2) consisted of an average of 118.9±17.92 eggs with an observed mean percentage egg hatchability of 81.50±2.28%.

Larval development, at an average temperature of 29.45±0.06 $^{o}$C, relative humidity of 69.77±0.54% and 12-hours photoperiod, consisted of six successive instar larvae (Table 4.6). Each instar was accompanied by changes in body length, body width, head capsule width and morphological features. Generally, measurements of body lengths and widths were observed to increase gradually from the neonate (1.64±0.03 mm and 0.18±0.01 mm) to the fully matured stage (26.45±0.44 mm and 3.45±0.07 mm) respectively. Neonates were observed to produce silks from their labial palps until the fourth instar stage. Also, body features that facilitate FAW larva identification, including the square-arranged body tubercles and inverted whitish Y mark on the head (Plate 4.2) were perceptible from the fourth instar larval. Generally, most larvae became prepupae and pupae (Plate 4.3) by the 11$^{th}$ and 12$^{th}$ day after eclosion respectively under the aforementioned rearing conditions. Total larval development therefore ranged between 11 and 12 days. Morphometrics of pre-pupa larvae could not be taken because they had shrunk in size.

Larvae were shown to develop through six instars with a mean head capsule width of 0.13±0.01, 0.31±0.01, 0.58±0.01, 1.15±0.02, 1.63±0.01 and 2.45±0.02 mm in the first, second, third, fourth, fifth and sixth respectively (Table 4.7). Growth rate in the successive instars was observed to range from 1.42 to 2.38. The sixth instar had the longest stadium duration and also had the highest increase (0.8 mm) in head capsule width. Cumulative developmental period for *S. frugiperda* larvae from neonate to matured larvae was 11-12 days. There was a significant difference in the mean head capsule width of the six larval instars. This shows to a 95% probability level, that head capsule width measurements within the range shown for an instar (Table 4.7) belongs to the instar. From the frequency distribution of daily head capsule width measurements (Figure 4.12) six peaks corresponding to the number of instar larval stages in the laboratory reared *S. frugiperda* were obtained. This number was further confirmed by determining the conformity of head capsule widths' measurements to Dyar's law using independent sample t-test (Table 4.8). A t-value of 0.97 calculated based on the difference ($d$) between

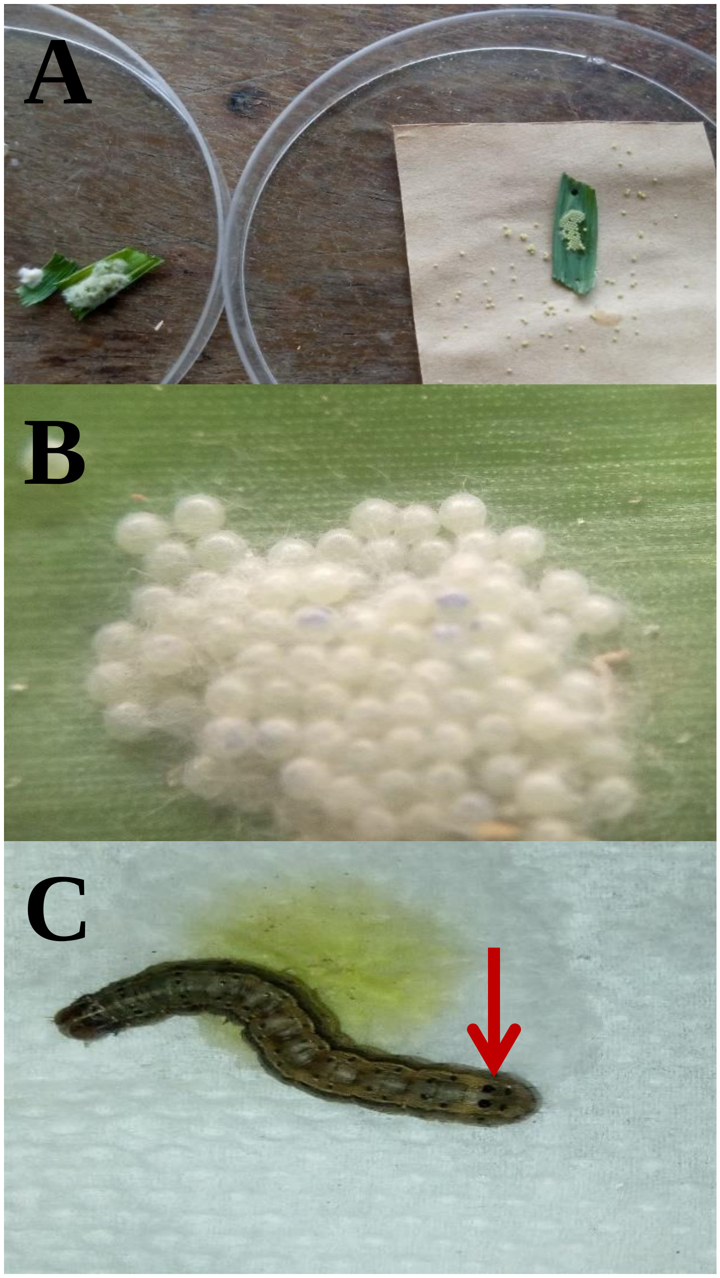


**Plate 4.2. Fall armyworm (*Spodoptera frugiperda*) egg mass and larvae**
**a = Egg mass laid on maize leaves: covered with scales (left) and without scales (right) leaf**
**b = Close up view of fall armyworm egg mass (x 40 magnification)**
**c = Mature fall armyworm larva with characteristic four black dots arranged in a square on second to last abdominal segment (red arrow)**

**Table 4.6. Daily Morphometrics of fall armyworm (*Spodoptera frugiperda*) larvae reared on maize leaves at Ibadan, Nigeria (N=10)**

| Days after larval eclosion | +Larval stage | Mean ± SE (Range) Body Length (mm) | Body Width (mm) | Head Capsule Width (mm) | Morphological Descriptions |
|---|---|---|---|---|---|
| 0 | 1 IL (Neonate) | 1.64 ± 0.03 (1.5 - 1.8) | 0.18 ± 0.01 (0.1 - 0.2) | 0.12± 0.01 (0.1 - 0.2) | Neonate larvae generally have a translucent body and actively produce silk from their labial palp |
| 1 | 1 IL | 2.91 ± 0.06 (2.6 - 3.1) | 0.31 ± 0.01 (0.3 -0.4) | 0.13 ± 0.02 (0.1 - 0.2) | Body appears green due to chlorophyll from ingested plants materials in the gut. Silking also persists. |
| 2 | 2 IL | 4.79 ± 0.12 (4.2 - 5.4) | 0.56 ± 0.02 (0.5 -0.6) | 0.31 ± 0.02 (0.2 - 0.4) | Larvae are visibly bigger but their bodies do not show any of the characteristic body markings distinctive of FAW |
| 3 | 3 IL | 5.15 ± 0.21 (4.0 -6.0) | 0.77 ± 0.02 (0.5 - 0.6) | 0.58 ± 0.01 (0.6 -0.8) | Larvae now has conspicuous body segmentation with the markings or turbercles (though tiny) but gradually becoming distinct |
| 4 | 4 IL | 7.55 ± 0.19 (6.5 - 8.5) | 1.14 ± 0.02 (1.0 - 1.2) | 1.15 ± 0.02 (1.1 - 1.2) | Body segmentation is obvious and tubercles are bigger and more distinct. |
| 5 | 4 IL | 11.65 ± 0.37 (10.0 -13.5) | 1.46 ± 0.04 (1.3 - 1.7) | 1.15 ± 0.04 (1.0 - 1.3) | Body color is partly brown at the last few abdominal segments and green towards the head. Spots and markings are quite visible. Silking is no longer observed |
| 6 | 5 IL | 13.9 ± 0.47 (12.0 - 16.0) | 1.82 ± 0.05 (1.5 - 2.0) | 1.63 ± 0.02 (1.6 -1.7) | All morphological body features for identification of FAW larvae, including the square-arranged body tubercles and inverted whitish Y mark on the head, are now clearly visible |
| 7 | 5 IL | 18.20 ± 0.38 (16.0 - 20.5) | 2.21 ± 0.05 (2.0 - 2.4) | 1.63 ± 0.02 (1.6 - 1.7) | Same as day six |

| | | | | | |
|---|---|---|---|---|---|
| 8 | 6 IL | 20.65 ± 0.30 (19.5 - 22.0) | 2.74 ± 0.07 (2.5 -3.1) | 2.41 ± 0.02 (2.3 - 2.6) | In addition to the features described at 4IL, larvae have a darker green color on the lateral sides and lighter green color bordered by yellowish lines on the dorsal sides. |
| 9 | 6 IL | 26.10 ± 0.39 (24.0 - 27.5) | 3.36 ± 0.05 (3.2 - 3.7) | 2.45 ± 0.02 (2.4 - 2.5) | In addition to the features described at 8DPE, larvae have abdominal segments that conspicuously bigger than the preceding body portion indicating the attainment of maturity |
| 10 | 6 IL | 26.45 ± 0.44 (25.0 - 28.5) | 3.45 ± 0.07 (3.2 - 3.8) | 2.44 ± 0.02 (2.4 - 2.5) | Same as day 9 |
| 11 | ++Pre-pupa larvae | | | | Larvae exhibited pre-pupation behaviours such a reduction in body length, formation of a cocoon with food debris and frass, termination of feeding activities and assumption of a quiescent state. |

IL = Instar larva; SE = Standard error of the mean

+Larval rearing was done at 29.45±0.06 $^{o}$C, 69.77±0.54% relative humidity, 12 hours light and 12 hours dark photoperiods.

++ By the 11$^{th}$ day after larval eclosion, about 90 percent of sampled larvae were at prepupal stage and by the 12$^{th}$ day, they had pupated.


**Plate 4.3.** **Fall armyworm (*Spodoptera frugiperda*) prepupae and pupa**
**a = Pre-pupa larvae of the fall armyworm**
**b = Fall armyworm pupa**

**Table 4.7. Head capsule width measurements of fall armyworm (*Spodoptera frugiperda*) larval instars**

| Instar | N | Range (mm) | Mean ± SE (mm) | Increase (mm) | †Growth ratio | Length of stadium (days) | Cumulative developmental period (days) |
|---|---|---|---|---|---|---|---|
| I | 10 | 0.1 - 0.2 | 0.13 ± 0.01 [a] | - | - | 2 | 0 |
| II | 10 | 0.3 - 0.4 | 0.31 ± 0.01 [b] | 0.18 | 2.38 | 1 | 3 |
| III | 10 | 0.5 - 0.6 | 0.58 ± 0.01 [c] | 0.27 | 1.87 | 1 | 4 |
| IV | 20 | 1.0 - 1.3 | 1.15 ± 0.02 [d] | 0.57 | 1.98 | 2 | 6 |
| V | 20 | 1.6 - 1.7 | 1.63 ± 0.01 [e] | 0.48 | 1.42 | 2 | 8 |
| VI | 30 | 2.3 - 2.6 | 2.43 ± 0.01 [f] | 0.8 | 1.49 | 3 | 11 |

N = Sample size; SE = Standard error of the mean
†Growth ratio was obtained by dividing the mean head capsule width of an instar by its preceding mean head capsule width
Mean in a column followed by different letters are significantly different at $\alpha_{0.05}$ according to the Tukey's Honestly Significant Difference test

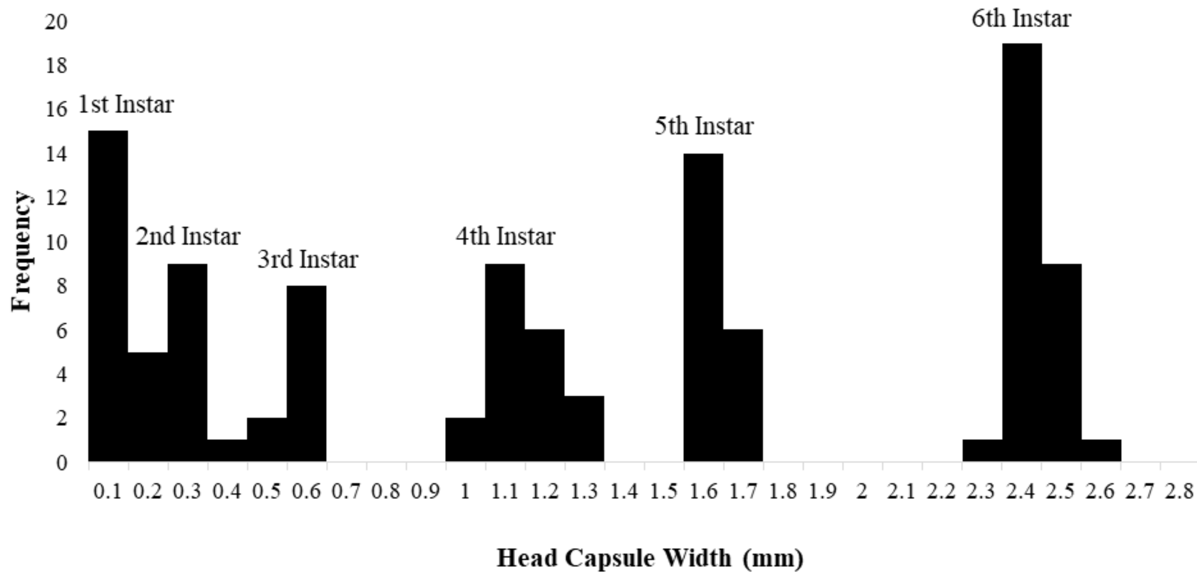


**Figure 4.12. Frequency distribution of daily head capsule width of fall armyworm (*Spodoptera frugiperda*) larval instars reared in the laboratory at Ibadan, Nigeria**

**Table 4.8. Conformity of fall armyworm (*Spodoptera frugiperda*) larval head capsule width measurements to Dyar's rule**

| Instar | Observed mean head capsule width (mm) | Ratio+ | Calculated mean head capsule width (mm)++ | Differences ($d$) |
|---|---|---|---|---|
| I | 0.13 | 0.42 | 0.18 | -0.05 |
| II | 0.31 | 0.53 | 0.33 | -0.02 |
| III | 0.58 | 0.50 | 0.65 | -0.07 |
| IV | 1.15 | 0.71 | 0.92 | 0.23 |
| V | 1.63 | 0.67 | 1.38 | 0.25 |
| VI | 2.43 | | | |
| Average ratio | | 0.57 | | |

Mean difference ( $\bar{d}$ ) = 0.07

Standard deviation of differences (s) = 0.16

Sample size (N) = 5

T calculated $(t) = \frac{\bar{d}}{S/\sqrt{N}}$ = 0.97

T tabulated (t tab) at 5% = 2.78

T tabulated (t tab) at 1% = 4.60

Reject Ho if T calculated > T tabulated

Decision: Do not reject $H_0$. Ratio is in conformity with Dyar's law

+Ratio was obtained by dividing the observed mean head capsule of an instar by the observed mean head capsule width of its succeeding instar

++Calculated mean head capsule width of an instar was obtained by multiplying its succeeding observed mean head capsule width by the average growth ratio observed and calculated mean head capsule widths. This calculated value was however less than the tabulated t-value at 5% (2.78) or at 1% (4.60) needed to show the presence of significant differences between the two mean head capsule widths. The relatively lower calculated t-value thus indicates the absence of any significant differences and the conformity of the measurements to Dyar's law (Dyar, 1890). The linear regression line (Figure 4.13) shows the relationship between the head capsule width and developmental period of laboratory reared *S. frugiperda* larva. The regression line has a high coefficient of determination ($R^2$ = 0.99; $p$<0.05) which shows that there is a strong correlation between both parameters and that the regression model sufficiently explains most of the variability in the mean observed head capsule widths.

Mean body length, body width, body weight and developmental duration of FAW pupae was 14.38±0.14 mm, 4.21±0.04 mm, 0.14±0.00 mg and 8.73±0.16 days respectively (Table 4.9). On the other hand, body length, body width and wing span of the *S. frugiperda* moths was 14.79±0.16 mm, 2.92 ± 0.06 mm and 13.91±0.15 mm respectively (Table 4.9). Furthermore, the morphometrics of male and female FAW pupae and moths (Table 4.10) show that pupa of both sexes did not differ significantly in their body length, body width and body weight. Similarly, no significant differences were observed in the body length and wing span of male and female FAW moths (Plate 4.4). In contrast, female moths generally had significantly wider mean body widths of 3.14±0.05 mm when compared to the 2.71±0.08 mm of their male counterparts. Also, in Table 4.10, development from pupa to adult is shown to occur at a significantly shorter duration of 8.27±0.11 days in females than in males (9.20 ± 0.16 days).

### 4.3.2. Oviposition site preference of female fall armyworm moths on maize plants

Figure 4.14 shows the number of eggs per egg mass laid by female FAW moths on different maize parts. Generally, lower numbers of eggs were laid on maize stems (35.3) than on the leaves. Also, more eggs (56.3±7.29) were deposited per egg mass on the abaxial side of leaves than on the adaxial surface, which had 13.0±0.00 eggs per egg mass (Figure 4.14). Furthermore, on the lower surface of leaves, higher numbers (68.4±10.91 eggs per egg mass) were laid on the distal portion compared to the mid- and proximal

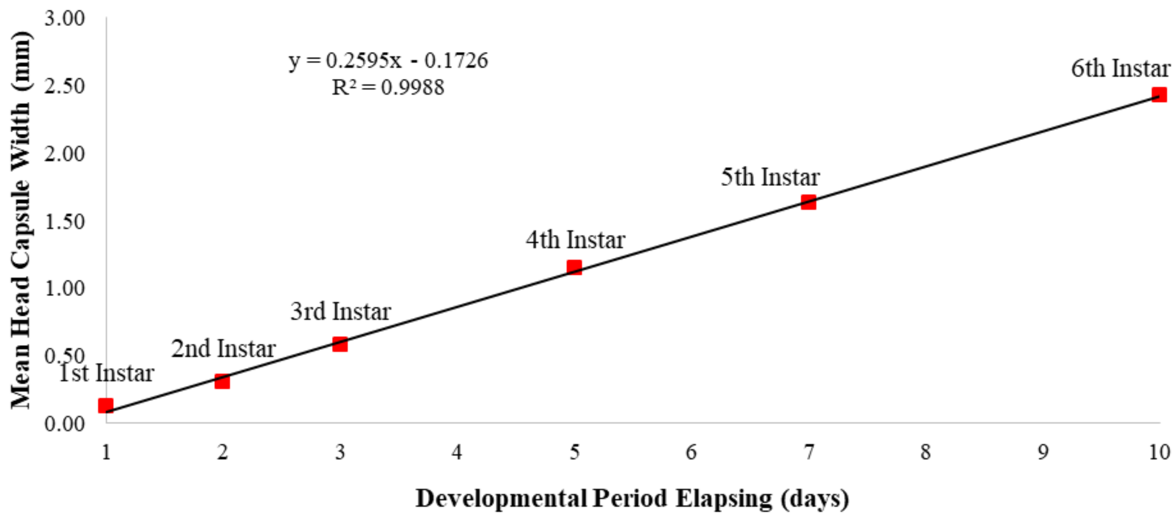


**Figure 4.13. Relationship between the head capsule width and developmental period elapsing of fall armyworm (*Spodoptera frugiperda*) larva reared in the laboratory at Ibadan, Nigeria**

**Table 4.9. Morphometrics of pupae and moths of fall armyworm (*Spodoptera frugiperda*)**

| Pupa (N=30) | | | | Adults (N=40) | | |
|---|---|---|---|---|---|---|
| **Body Length (mm)** | **Body Width (mm)** | **Body Weight (mg)** | **Duration of pupal developm ent (days)** | **Body Length (mm)** | **Body Width (mm)** | **Wing Span (mm)** |
| 14.38±0.14 (12.4 - 15.7) | 4.21±0.04 (3.7 - 4.6) | 0.14±0.00 (0.11 - 0.18) | 8.73±0.16 (7 - 10) | 14.79±0.16 (12.70 - 16.50) | 2.92±0.06 (1.80 - 3.50) | 13.91±0.15 (11.40 -15.20) |

Values are mean ± standard error (range)

**Table 4.10. Morphometrics and duration of development of male and female fall armyworm (*Spodoptera frugiperda*) pupa and moth**

| Sex | Mean ± SE (Range) | | | | | | Duration of Development from pupa to adult |
|---|---|---|---|---|---|---|---|
| | Pupa (N=15) | | | Adult Moth (N=20) | | | |
| | Body Length (mm) | Body Width (mm) | Body Weight (mg) | Body Length (mm) | Body Width (mm) | Wing Span (mm) | |
| Male | 14.43±0.17[a] (12.40 - 15.70) | 4.21±0.05[a] (3.70 - 4.60) | 0.14±0.00[a] (0.11 - 0.18) | 14.93±0.25[a] (12.70 - 16.50) | 2.71±0.08[b] (1.80 - 3.40) | 13.65±0.24[a] (11.40 -15.20) | 9.20±0.16[b] (8 - 10) |
| Female | 14.33±0.10[a] (13.40 - 15.30) | 4.21±0.03[a] (3.90 - 4.50) | 0.14±0.00[a] (0.11 - 0.17) | 14.66±0.19[a] (13.20 - 15.70) | 3.14±0.05[a] (2.60 - 3.50) | 14.17±0.14[a] (12.50 - 15.00) | 8.27±0.11[a] (7 -9) |

Means ± SE in a column values followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

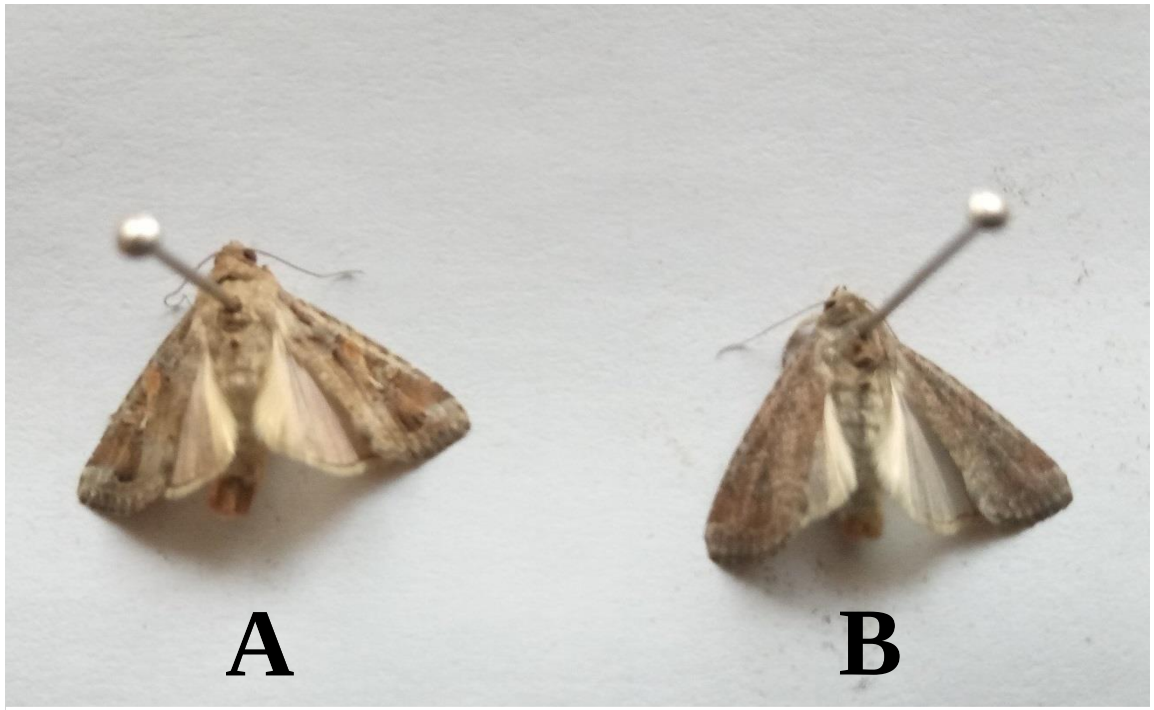


**Plate 4.4. Fall armyworm (*Spodoptera frugiperda*) moths**
**a = Male fall armyworm moth with white patches on the fringes of brown forewings**
**b = Female fall armyworm moth with more uniform brown forewings**

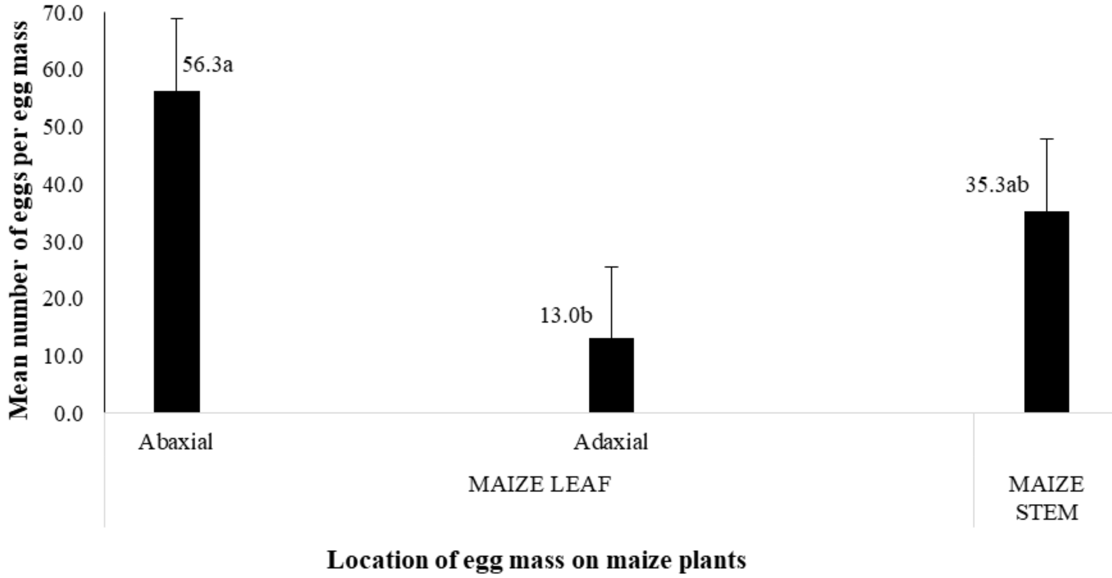


**Figure 4.14. Distribution of fall armyworm (*Spodoptera frugiperda*) eggs on maize plants**

portions with 50.0±13.61 and 35.3±9.91 eggs per egg mass respectively (Figure 4.15). On the upper surface of leaves, fewer numbers of eggs per egg mass were laid distally as opposed to the mid-and proximal portions where no eggs were deposited (Figure 4.15).

### 4.3.3. Longevity of fed and unfed fall armyworm moths

The effect of feeding on the longevity of fall armyworm moths was significant in the present study (Table 4.11). Moths that were fed had an average life span of 7.25±0.47 days, a period that was significantly longer than unfed moths which live for just 4.13±0.17 days. The sex of moths, on the other hand, did not significantly influence longevity (Table 4.12). The foregoing trend was further reflected in the interaction effects of feeding and moth sex (Table 4.13). The table showed that mean life span of fed males (8.07±0.69 days) and fed females (6.43±0.58 days) was significantly higher than those of their unfed male (3.8±0.14 days) and female (4.47±0.29 days) counterparts.

### 4.3.4. Fecundity of fall armyworm female moths as influenced by pairing ratio

The influence of pairing ratio on the fecundity of female FAW moths was significant in the present study (Table 4.14). Significantly higher mean number of egg mass (9.57±0.97) was laid when a female was paired with a male as opposed to when paired with three males (4.86±1.44 egg masses). Unpaired females laid the least number of egg mass (2.14±0.71) which was significantly lower than those laid by females paired with a male moth.

There was, however, no significant difference in the number of egg mass laid by unpaired females and those paired with three males. The number of eggs (1354.0 ± 168.16) laid by female moths paired with a male was significantly higher compared to the number (599.89 ± 210.31 eggs) laid by females paired with three males or the number (65.43 ± 25.89 eggs) laid by unpaired females. No significant differences were observed in the number of eggs laid by unpaired females and those paired with three males. Though unmated females had higher life span of 8.14±0.34 days compared to females paired with a male (7.00 ± 0.54 days) or three males (7.14±0.34 days), no significant difference was observed amongst the three pairing treatments.

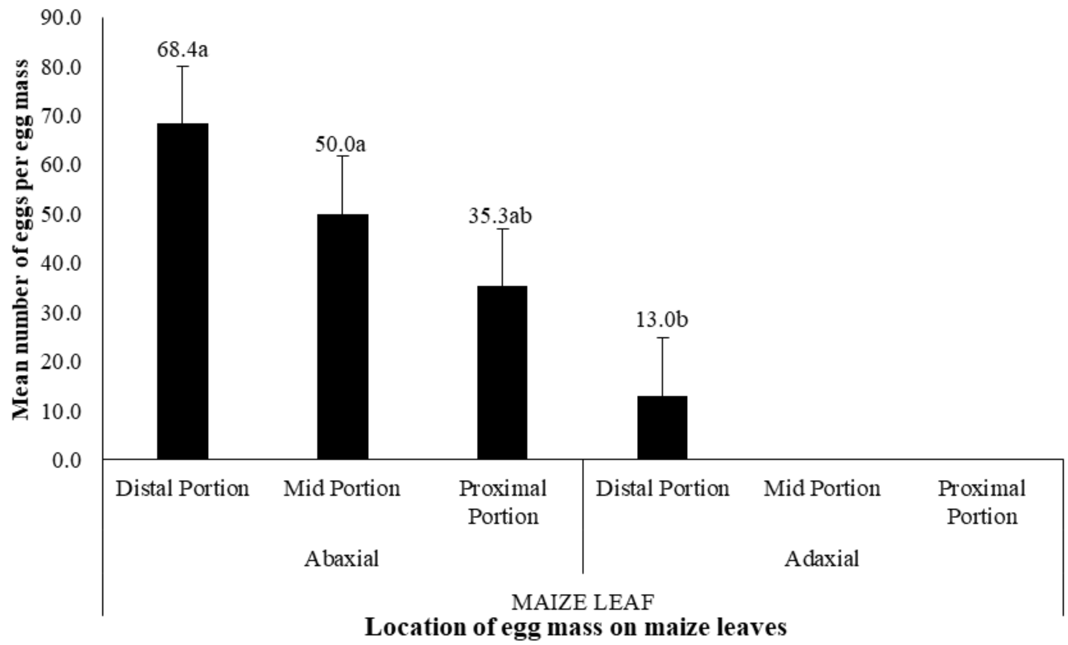


**Figure 4.15. Distribution of fall armyworm (*Spodoptera frugiperda*) eggs on maize leaves**

**Table 4.11. Effect of feeding on the longevity of fall armyworm (*Spodoptera frugiperda*) moths (N=30)**

| Feeding Status | Life Span (days) | |
|---|---|---|
| | Mean ± SE | Range |
| Fed | $7.25{\pm}0.47^{a}$ | 4 – 13 |
| Unfed | $4.13{\pm}0.17^{b}$ | 3 – 7 |

Means ± SE in a column values followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

**Table 4.12. Effect of sex on the longevity of fall armyworm (*Spodoptera frugiperda*) moths (N=30)**

| Sex of Moth | Life Span (days) | |
|---|---|---|
| | **Mean ± SE** | **Range** |
| Male | 5.86±0.52[a] | 3 – 13 |
| Female | 5.41±0.36[a] | 3 – 12 |

Means ± SE in a column values followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

**Table 4.13. Effect of feeding and sex on the longevity of fall armyworm (*Spodoptera frugiperda*) moths (N=15)**

| Feeding Status | Sex of Moth | Life Span (days) | |
|---|---|---|---|
| | | Mean ± SE | Range |
| Fed | Male | 8.07±0.69[a] | 5 – 13 |
| Fed | Female | 6.43±0.58[a] | 4 – 12 |
| Unfed | Male | 3.80±0.14[b] | 3 – 5 |
| Unfed | Female | 4.47±0.29[b] | 3 – 7 |

Means ± SE in a column values followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

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**Table 4.14. Fecundity of female fall armyworm (*Spodoptera frugiperda*) moths as influenced by pairing ratio**

| Pairing Ratio | Mean ± SE (Range) | | |
|---|---|---|---|
| | Number of egg mass per female moth | Number of eggs per female moth | Life span (days) |
| 0 Male: 1 Female | 2.14±0.71[a] (0 - 4) | 65.43±25.89[a] (0 - 181) | 8.14±0.34[a] (7 - 9) |
| 1 Male: 1 Female | 9.57±0.97[b] (6 - 13) | 1354±168.16[b] (855 - 2156) | 7.00±0.54[a] (5 - 9) |
| 3 Males: 1 Female | 4.86±1.44[a] (0 - 9) | 599.89±210.31[a] (0 - 1517) | 7.14 ±0.90[a] (6 - 8) |

Means ± SE values in a column followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

### 4.3.5. Influence of food quantity and volume of rearing space on cannibalism levels in fall armyworm population

At 6 days after emergence (DAE), percentage mortality in the 15-larvae-population treatment fed two grams and five grams of fresh maize leaves was 12.47±5.94% and 5.33±2.49%, respectively (Table 4.15). In contrast, no cannibalism occurred at 6 DAE in the 5-larvae, 2-larvae or 1-larva treatments fed with two grams and five grams of food. The percent mortality in the 15-larvae-population was not significantly higher than in other population treatments at 6 DAE. Similarly, when larvae were given two and five grams of food at 8 DAE, the highest percentage mortality of 52.0±5.33% and 42.7±4.51% respectively were observed in the 15-larvae-population treatment. These values were followed by the percentage mortality of 12.0±4.89% and 16.0±7.47% respectively in 5-larvae-population treatment. The percent mortality in the 15-larvae populations at 8 DAE was significantly higher than in the 2- and 5-larvae population when food was two grams but not when it was five grams.

At 10 DAE, the percentage mortality within populations of FAW larvae fed with two grams of food was highest in the fifteen- (74.4±5.26%) > two- (50.0±0.0%) > five- (48.0±7.99%) > one-(0.0±0.0%) larva populations (Table 4.15). The percent mortality of 74.4±5.26% in the 15-larvae population was not significantly higher than values recorded in the 2-larvae and 5-larvae when larvae were fed two grams of food. Feeding larvae with five grams of food at 10 DAE generally resulted in lower percent mortality of 30.0±12.25%, 20.0±8.93% and 52.0±3.88% in the 2-larvae, 5-larvae and 15-larvae-populations respectively. Percentage mortality value in the 15-larvae population fed five grams of food was significantly higher than in the 2-larvae population but not in the 5-larvae population. No cannibalism occurred in the 1-larva populations offered two or five grams at all periods after emergence.

Percentage mortality generally increased with increasing age irrespective of the rearing space volume (Figure 4.16). At the early fifth instar stage, percentage mortality due to larval cannibalism was 25.33±5.70%, 10.67±5.0% and 13.33±4.70% in the small, medium and large volume rearing containers respectively. On the other hand, at full maturity, percentage mortality had reached 70.67±4.0%, 64.00±7.8%, and 50.67±5.4% in

**Table 4.15. Influence of food quantity on percentage mortality due to larval cannibalism in fall armyworm (*Spodoptera frugiperda*) populations**

| Population of fall armyworm larvae $^{\phi}$ | Percentage mortality (Mean ± SE) | | | | | |
|---|---|---|---|---|---|---|
| | 6 DAE$^{+}$ | | 8 DAE$^{++}$ | | 10 DAE$^{+++}$ | |
| | Two grams of food | Five grams of food | Two grams of food | Five grams of food | Two grams of food | Five grams of food |
| 1 Larva | 0.0±0.0$^{a}$ | 0.0±0.0$^{a}$ | 0.0±0.0$^{a}$ | 0.0±0.0$^{a}$ | 0.0±0.0$^{a}$ | 0.0±0.0$^{a}$ |
| 2 Larvae | 0.0±0.0$^{a}$ | 0.0±0.0$^{a}$ | 0.0±0.0$^{a}$ | 20.0±12.25$^{abc}$ | 50.0±0.0$^{de}$ | 30.0±12.25$^{bcd}$ |
| 5 Larvae | 0.0±0.0$^{a}$ | 0.0±0.0$^{a}$ | 12.0±4.89$^{ab}$ | 16.00±7.47$^{abc}$ | 48.0±7.99$^{de}$ | 20.0±8.93$^{abc}$ |
| 15 Larvae | 12.47±5.94$^{ab}$ | 5.33±2.49$^{ab}$ | 52.0±5.33$^{cd}$ | 42.7±4.51$^{cd}$ | 74.4±5.26$^{e}$ | 52.0±3.88$^{de}$ |

Means ± SE values in column or rows followed by the same letter(s) are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

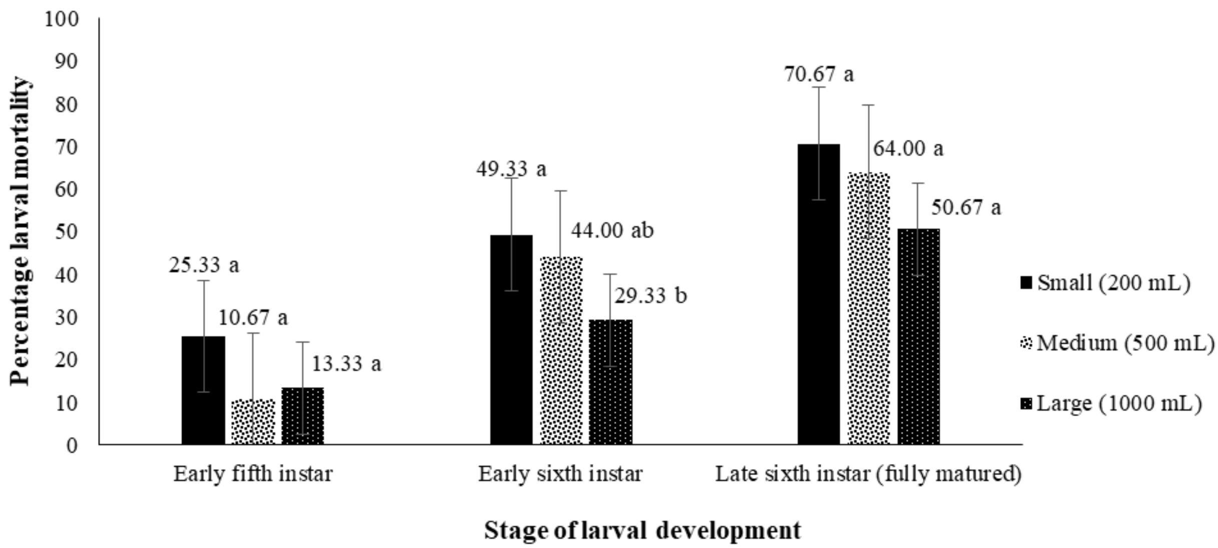
Food consisted of fresh maize leaves only and was offered to fourth instar larvae every two days

$^{+}$Six days after eclosion (early fifth larval instar)

$^{++}$Eight days after eclosion (early sixth larval instar)

$^{+++}$Ten days after eclosion (late sixth larval instar)

$^{\phi}$ Rearing was done at a mean temperature of 29.96±0.65 $^{o}$ C and relative humidity of 65.60±8.08% at which pupation commenced by the eleventh day after larval eclosion




*Bars at a given instar with the same letter are not significantly different are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference* test

**Figure 4.16. Larval mortality due to cannibalism in fall armyworm (*Spodoptera frugiperda*) populations reared in small, medium and large sized plastic containers**

the small, medium and large volume containers. No significant differences were however observed in the percentage mortality observed in all three containers at the early fifth and late sixth (fully matured) larval instar stages.

## 4.4. Field evaluation of resistance in selected maize varieties to natural field infestation and damage by fall armyworm at Ibadan southwestern Nigeria

### 4.4.1. Percentage infestation of fall armyworm in the early and late maize planting seasons of 2018

Percentage infestation of egg masses at 3-WAS in the early season (34.80±2.49) was significantly higher than in the late season (1.08±0.47) (Table 4.16). In contrast, no significant difference was observed in percentage egg-mass infestation on plants in the early season (14.13±1.80 and 0.20±0.2) and in the late season (1.56±0.65 and 0.00±0.0) at 5-WAS and 7-WAS respectively. Percentage infestation of FAW larvae in the early season (50.80±2.66 and 25.72±2.32) and late season (51.09±3.25 and 37.47±2.62) was not statistically different at 3-WAS and 5-WAS respectively (Table 4.16). There was also no significant difference in the percentage infestation of larvae on maize plants at 7-WAS in the early (3.20±0.89) and late (0.66±0.49) seasons of 2018.

### 4.4.2. Percentage infestation of fall armyworm in the early and late maize planting seasons of 2019

In 2019, percentage egg-mass infestation in the early season (18.50±2.69 and 6.86±1.66) was higher than in the late season (5.160±1.59 and 1.15±0.85) at 3-WAS and 5-WAS respectively (Table 4.17). While there was a significant difference in the percentage egg-mass infestation values at 3-WAS, no significant difference was observed in egg-mass infestation at 5-WAS. However, no plants were observed to be infested with egg masses at 7-WAS in both seasons of 2019. Percentage larval infestation of varieties at 3-WAS (36.33±3.34) in the early season of 2018 was significantly higher than in the late season (11.22±1.76). In contrast, no significant differences were observed in the percentage larval infestation in the early and late seasons at 5-WAS (11.45±2.20 and 21.54±3.29) and 7-WAS (3.41±1.06 and 0.68±0.49) respectively.

**Table 4.16. Seasonal percentage infestation (mean ± SE) of fall armyworm egg mass and larva in 2018 at Ibadan, Nigeria**

| Maize Planting Season | Egg mass (%) | | | Larva (%) | | |
|---|---|---|---|---|---|---|
| | **3-WAS** | **5-WAS** | **7-WAS** | **3-WAS** | **5-WAS** | **7-WAS** |
| Early | 34.80±2.49[b] | 14.13±1.80[a] | 0.20±0.2[a] | 50.80±2.66[a] | 25.72±2.32[a] | 3.20±0.89[a] |
| Late | 1.08±0.47[a] | 1.56±0.65[a] | 0.00±0.0[a] | 51.09±3.25[a] | 37.47±2.62[a] | 0.66±0.49[a] |

Mean values in a column followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

WAS: Weeks After Sowing

**Table 4.17. Seasonal percentage infestation (mean ± SE) of fall armyworm egg mass and larva in 2019 at Ibadan, Nigeria**

| Maize Planting Season | Egg mass (%) | | | Larva (%) | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| Early | 18.50±2.69$^{b}$ | 6.86±1.66$^{a}$ | 0.00±0.00$^{a}$ | 36.33±3.34$^{b}$ | 11.45±2.20$^{a}$ | 3.41±1.06$^{a}$ |
| Late | 5.160±1.59$^{a}$ | 1.15±0.85$^{a}$ | 0.00±0.00$^{a}$ | 11.22±1.76$^{a}$ | 21.54±3.29$^{a}$ | 0.68±0.49$^{a}$ |

Mean values in a column followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test
WAS: Weeks After Sowing

### 4.4.3. Abundance of fall armyworm in the early and late maize planting seasons of 2018

Significantly higher number of egg masses were observed on plants at 3-WAS in the early season (0.47±0.04) than in the late season (0.01±0.00) (Table 4.18). Egg mass number at in the early season (0.18±0.02) at 5-WAS was higher but not significantly different than in the late season (0.01±0.01). No eggs were observed at 7-WAS in the early and late seasons of 2018. Abundance of FAW larva at 3-WAS seasons in the early (0.66±0.04) and late seasons (0.63±0.03) was not significantly different (Table 4.18). At 5-WAS, also, larval abundance in the late season (0.39±0.03) was not significantly different from that of the early season (0.28±0.03). Larval abundance was very low and not significantly different in both seasons at 7-WAS.

### 4.4.4. Abundance of fall armyworm in the early and late maize planting seasons of 2019

More egg masses were observed in the early season (0.27±0.03 and 0.07±0.02) than in the late season (0.04±0.01 and 0.00±0.00) at 3-WAS and 5-WAS respectively (Table 4.19). No significant difference was found in the abundance of egg masses observed in both seasons at 3-, 5- and 7-WAS. In contrast, there was a significant difference in larval abundance observed at 3-WAS during the early (0.38±0.03) and late season (0.17±0.02) of 2019. At 5 and 7-WAS, however, no significant difference was found in the abundance of FAW larvae in both seasons.

### 4.4.5. Abundance of stem borer and fall armyworm larvae in the early and late maize planting seasons of 2018 and 2019

Higher numbers of stem borer species were observed in maize stems in the late (1.05±0.13) than in the early (0.28±0.07) seasons of 2018 (Table 4.20). Conversely, higher numbers of stem borer species were found in maize cobs in the early (1.04±0.13) than in the late (0.41±0.06) seasons. The abundance of FAW larvae in maize cobs during the late season (0.37±0.05) of 2018 was also higher than in the early season (0.01±0.00) of the same year. No FAW larvae were observed in maize stems in both seasons of 2018. Generally, no significant differences were found in the abundance of stem borer or fall

**Table 4.18. Seasonal abundance (mean ± SE) of fall armyworm egg-mass and larva in 2018 at Ibadan, Nigeria**

| Maize Planting Season | Egg mass | | | Larva | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| Early | 0.47±0.04[b] | 0.18±0.02[a] | 0.00±0.00[a] | 0.66±0.04[a] | 0.28±0.03[a] | 0.00±0.00[a] |
| Late | 0.01±0.00[a] | 0.01±0.01[a] | 0.00±0.00[a] | 0.63±0.03[a] | 0.39±0.03[a] | 0.01±0.01[a] |

Mean values in a column followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

WAS: Weeks After Sowing

**Table 4.19. Seasonal abundance (mean ± SE) of fall armyworm egg-mass and larva in 2019 at Ibadan, Nigeria**

| Maize Planting Season | Egg mass | | | Larva | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| Early | 0.27±0.03[a] | 0.07±0.02[a] | 0.00±0.00[a] | 0.38±0.03[b] | 0.10±0.02[a] | 0.03±0.01[a] |
| Late | 0.04±0.01[a] | 0.00±0.00[a] | 0.00±0.00[a] | 0.17±0.02[a] | 0.22±0.03[a] | 0.01±0.00[a] |

Mean values in a column followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

WAS: Weeks After Sowing

**Table 4.20. Seasonal abundance (mean ± SE) of stem borer and fall armyworm larva in 2018 and 2019 at Ibadan, Nigeria**

| Maize Planting Season | 2018 | | | | 2019 | | | |
|---|---|---|---|---|---|---|---|---|
| | Number in Stems | | Number in Cobs | | Number in Stems | | Number in Cobs | |
| | Stem borer | Fall armyworm | Stem borer | Fall armyworm | Stem borer | Fall armyworm | Stem borer | Fall armyworm |
| Early | 0.28±0.07[a] | 0.00±0.00[a] | 1.04±0.13[a] | 0.01±0.00[a] | 0.75±0.13[b] | 0.00±0.00[a] | 0.82±0.11[b] | 0.02±0.01[a] |
| Late | 1.05±0.13[a] | 0.00±0.00[a] | 0.41±0.06[a] | 0.37±0.05[a] | 0.02±0.01[a] | 0.00±0.00[a] | 0.07±0.03[a] | 0.00±0.00[a] |

Mean values in a column followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test armyworm larvae in stems and cobs during the early and late maize planting seasons of 2018.

In 2019, however, combined abundance of stem borer larvae in maize stems (Table 4.20) was significantly higher in the early season (0.75±0.13) than in the late season (0.02±0.01). Similarly, more stem borer larvae were found in maize cobs in the early season (0.82±0.11) compared to the late season (0.07±0.03). The numbers of FAW larvae observed in maize cobs were relatively very low in the early (0.02±0.01) and late (0.00±0.00) seasons. No FAW larvae were found in maize stems in both seasons of 2019.

### 4.4.6. Percentage infestation of fall armyworm on 25 open pollinated varieties of maize in 2018

Percentage infestation of egg mass at 3-WAS ranged from 5.00±3.27 on SAMMAZ-26 to 32.50±11.30 on TZE-W-Pop-DT-STR-QPM-$C_0$ (Table 4.21). At 5-WAS, egg-mass infestation ranged from 2.50±2.50 on both SAMMAZ-17 and SAMMAZ-29 to 17.50±7.96 on SAMMAZ-45. At 7-WAS, 3.33±3.33 egg mass were observed on EVDT-W 99 STR while no egg mass were found on the other varieties. Other varieties had intermediate percentage egg-mass infestations and were not significantly different from varieties with the highest and lowest value at 3-, 5- and 7-WAS. The lowest (28.57±12.23) and highest (60.10±9.26) percentage larval infestation at 3-WAS were observed on varieties TZE-Y DT-STR-C4 and SAMMAZ-38 respectively. On the other hand, varieties EVDT-Y 2000 STR and BR-9943DMR-SR-W had the lowest (17.50±7.01) and highest (46.88±9.68) percentage larval infestation values at 5-WAS. BR-9943-DMR-SR-W also had the highest larval infestation value of 7.50±3.66 at 7-WAS. No significant difference was however found in the percentage infestation of FAW larvae on all the varieties at 3-, 5- and 7-WAS.

### 4.4.7. Percentage infestation of fall armyworm on 25 open pollinated varieties of maize in 2019

Percentage infestation of egg mass at 3-WAS ranged from 0.00±0.00 on TZE-W-Pop-DT-STR-QPM-$C_0$ to 25.00±13.60 on SAMMAZ-16 (Table 4.22) At 5-WAS, the highest percentage egg-mass infestation (20.00±20.00) was observed on TZE-Y-DT-STR $C_4$. No egg mass was however found on all varieties at 7-WAS. There was no significant different in the percentage egg-mass infestation on all varieties at 3-, 5- and 7-WAS. The

**Table 4.21. Percentage infestations (mean ± SE) of fall armyworm egg mass and larva on 25 Open pollinated varieties of maize evaluated in 2018 at Ibadan, Nigeria**

| Maize Variety | Egg mass (%) | | | Larva (%) | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 8.57±4.04 | 5.71±3.69 | 0.00±0.00 | 28.57±12.23 | 27.14±8.92 | 2.86±2.86 |
| SAMMAZ-37 | 22.5±10.31 | 12.50±7.5 | 0.00±0.00 | 52.50±5.26 | 27.50±9.21 | 2.50±2.50 |
| EVDT-W 99 STR | 14.29±7.19 | 5.71±3.69 | 3.33±3.33 | 51.43±15.03 | 25.24±9.37 | 3.33±3.33 |
| SAMMAZ-14 | 12.50±6.48 | 10.00±6.55 | 0.00±0.00 | 55.0±9.82 | 30.00±10.69 | 2.50±2.50 |
| SAMMAZ-52 | 20.00±6.55 | 2.50±2.50 | 0.00±0.00 | 57.50±7.01 | 25.00±8.24 | 5.00±5.00 |
| TZEE-Pop-STR-QPM-Y | 13.33±8.43 | 6.67±4.22 | 0.00±0.00 | 46.67±16.87 | 30.0±16.12 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 27.50±9.96 | 7.50±7.50 | 0.00±0.00 | 55.0±12.39 | 32.50±9.96 | 0.00±0.00 |
| SAMMAZ-38 | 17.50±7.96 | 9.17±6.03 | 0.00±0.00 | 60.10±9.26 | 42.50±10.31 | 0.00±0.00 |
| SAMMAZ-16 | 12.50±5.26 | 7.50±3.66 | 0.00±0.00 | 57.50±8.80 | 33.33±7.02 | 0.00±0.00 |
| SAMMAZ-19 | 14.29±8.41 | 10.71±7.44 | 0.00±0.00 | 57.14±11.07 | 45.71±6.21 | 0.00±0.00 |
| DMR-LSR-Y | 27.50±13.59 | 12.50±6.48 | 0.00±0.00 | 50.00±13.09 | 35.00±6.27 | 2.50±2.50 |
| SAMMAZ-31 | 28.57±12.23 | 2.86±2.86 | 0.00±0.00 | 44.29±14.78 | 22.86±7.78 | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 28.57±12.23 | 9.29±4.42 | 0.00±0.00 | 48.57±9.37 | 21.90±8.93 | 2.86±2.86 |
| 2008-EVDTSTR-Y | 17.50±7.96 | 7.50±5.26 | 0.00±0.00 | 45.42±9.17 | 40.62±14.03 | 5.00±5.00 |
| SAMMAZ-15 | 15.0±6.27 | 7.50±3.66 | 0.00±0.00 | 36.67±10.31 | 21.88±9.06 | 5.00±5.00 |
| TZE-W-Pop-DT-STR-QPM-$C_0$ | 32.50±11.30 | 15.00±5.00 | 0.00±0.00 | 55.0±8.24 | 30.0±8.45 | 0.00±0.00 |
| BR-9928DMR-SR-Y | 20.00±11.34 | 5.00±5.00 | 0.00±0.00 | 50.00±10.00 | 22.50±5.90 | 0.00±0.00 |
| SAMMAZ-29 | 17.50±9.59 | 2.50±2.50 | 0.00±0.00 | 42.50±12.78 | 23.75±6.53 | 0.00±0.00 |
| SAMMAZ-17 | 25.0±11.18 | 2.50±2.50 | 0.00±0.00 | 57.50±12.78 | 23.90±8.45 | 5.00±5.00 |
| SAMMAZ-32 | 20.00±7.56 | 10.00±5.35 | 0.00±0.00 | 57.50±8.81 | 37.50±4.53 | 5.00±3.27 |
| SUWAN-1-SR | 7.50±3.66 | 12.50±7.50 | 0.00±0.00 | 58.12±9.26 | 35.0±10.52 | 0.00±0.00 |
| SAMMAZ-26 | 5.00±3.27 | 12.50±9.96 | 0.00±0.00 | 45.0±9.82 | 30.0±10.69 | 0.00±0.00 |
| EVDT-Y-2000-STR | 20.00±8.45 | 2.50±2.50 | 0.00±0.00 | 57.50±7.96 | 17.50±7.01 | 0.00±0.00 |
| BR-9943-DMR-SR-W | 15.00±6.27 | 3.13±3.13 | 0.00±0.00 | 45.0±9.82 | 46.88±9.68 | 7.50±3.66 |
| SAMMAZ-45 | 20.00±10.00 | 17.5±7.96 | 0.00±0.00 | 55.00±12.39 | 38.12±7.79 | 0.00±0.00 |
| | NS | NS | NS | NS | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

**Table 4.22. Percentage infestations (mean ± SE) of fall armyworm egg mass and larva on 25 open pollinated varieties of maize evaluated in 2019 at Ibadan, Nigeria**

| Maize Variety | Egg mass (%) | | | Larva (%) | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 22.50±13.33 | 20.00±20.00 | 0.00±0.00 | 12.50±6.48 | 24.0±19.39 | 0.00±0.00 |
| SAMMAZ-37 | 13.33±5.04 | 0.00±0.00 | 0.00±0.00 | 43.81±11.35 | 17.14±6.80 | 0.00±0.00 |
| EVDT-W-99-STR | 8.57±4.04 | 5.71±5.71 | 0.00±0.00 | 21.43±7.05 | 24.76±11.15 | 0.00±0.00 |
| SAMMAZ-14 | 11.43±5.95 | 0.00±0.00 | 0.00±0.00 | 25.71±5.70 | 17.14±14.09 | 0.00±0.00 |
| SAMMAZ-52 | 11.43±8.57 | 0.00±0.00 | 0.00±0.00 | 5.71±3.69 | 38.57±12.04 | 2.86±2.86 |
| TZEE-Pop-STR-QPM-Y | 18.10±9.17 | 4.00±4.00 | 0.00±0.00 | 16.19±8.83 | 4.00±4.00 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 9.17±4.70 | 3.13±3.13 | 0.00±0.00 | 12.50±3.66 | 19.79±5.00 | 5.00±3.27 |
| SAMMAZ-38 | 8.57±8.57 | 5.00±5.00 | 0.00±0.00 | 22.86±8.92 | 25.00±12.58 | 9.38±6.58 |
| SAMMAZ-16 | 25.0±13.60 | 0.00±0.00 | 0.00±0.00 | 46.67±21.08 | 15.00±9.57 | 9.00±5.57 |
| SAMMAZ-19 | 40.0±24.49 | 4.17±4.17 | 0.00±0.00 | 16.0±11.66 | 0.00±0.00 | 0.00±0.00 |
| DMR-LSR-Y | 17.50±7.20 | 5.00±5.00 | 0.00±0.00 | 20.62±8.26 | 10.00±6.83 | 2.50±2.50 |
| SAMMAZ-31 | 12.50±8.18 | 15.00±9.57 | 0.00±0.00 | 36.25±15.58 | 0.00±0.00 | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 20.0±8.17 | 0.00±0.00 | 0.00±0.00 | 30.0±5.77 | 15.00±9.57 | 2.86±2.86 |
| 2008-EVDT-STR-Y | 17.86±14.14 | 5.00±5.00 | 0.00±0.00 | 31.90±13.88 | 6.25±6.25 | 5.00±5.00 |
| SAMMAZ-15 | 7.50±7.50 | 0.00±0.00 | 0.00±0.00 | 10.62±5.55 | 5.00±5.00 | 0.00±0.00 |
| TZE-W-Pop-DT-STR | 0.00±0.00 | 5.00±5.00 | 0.00±0.00 | 25.00±25.00 | 25.00±14.43 | 0.00±0.00 |
| BR-9928-DMR-SR-Y | 3.33±3.33 | 5.00±5.00 | 0.00±0.00 | 21.67±8.33 | 12.50±12.50 | 0.00±0.00 |
| SAMMAZ-29 | 0.00±0.00 | 3.33±3.33 | 0.00±0.00 | 31.43±12.57 | 26.67±9.89 | 0.00±0.00 |
| SAMMAZ-17 | 2.50±2.50 | 7.50±5.26 | 0.00±0.00 | 17.50±8.81 | 12.50±6.48 | 0.00±0.00 |
| SAMMAZ-32 | 17.14±7.06 | 7.50±4.79 | 0.00±0.00 | 30.00±13.97 | 13.33±6.67 | 0.00±0.00 |
| SUWAN-1-SR | 18.89±9.95 | 15.0±9.57 | 0.00±0.00 | 26.67±10.47 | 13.33±8.17 | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 41.90±15.45 | 28.0±14.97 | 4.00±4.00 |
| EVDT-Y-2000-STR | 11.43±5.95 | 0.00±0.00 | 0.00±0.00 | 17.14±6.80 | 8.57±5.95 | 8.33±8.33 |
| BR-9943-DMR-SR-W | 6.67±4.54 | 9.38±6.58 | 0.00±0.00 | 21.67±12.65 | 2.50±2.50 | 0.00±0.00 |
| SAMMAZ-45 | 7.50±3.66 | 2.50±2.50 | 0.00±0.00 | 28.12±5.17 | 7.50±3.66 | 2.86±2.86 |
| | NS | NS | NS | NS | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

lowest (5.71±3.69) and highest (46.67±21.08) percentage larval infestation at 3-WAS were observed on SAMMAZ-52 and SAMMAZ-16 respectively (Table 4.22). At 5-WAS, however, SAMMAZ-19 and SAMMAZ-31 both had the lowest (0.00±0.00) larval infestation value while the highest (38.57±12.04) value was recorded on SAMMAZ-52. The highest percentage larval infestation at 7-WAS was on SAMMAZ-38 while no larvae were recorded on several varieties in the period. In 2019, no significant difference was found in the percentage infestation of FAW larvae on all varieties at 3-, 5- and 7-WAS.

### 4.4.8. Abundance of fall armyworm on 25 open pollinated varieties of maize in 2018

At 3-WAS, the lowest (0.05±0.04 and 0.09±0.05) egg mass numbers were observed on SUWAN-1-SR and TZE-Y-DT-STR-C4 varieties while the highest values (0.47±0.20 and 0.48±0.13) were recorded on SAMMAZ-45and TZE-W-DT-STR-C4 respectively (Table 4.23). A significant difference was observed in the number of egg mass on the varieties with the highest and lowest values at 3-WAS. Furthermore, the highest egg mass number at 5-WAS (0.15±0.07) and at 7-WAS (0.04±0.04) were observed on SAMMAZ-37 and EVDT-W-99-STR respectively. There was, however, no significant difference between the abundance of FAW egg mass observed on all varieties at 5 and 7-WAS in 2018.

Similarly, larval abundance on varieties at 3-WAS ranged from 0.35±0.10 on TZE-Y-DT-STR-C4 to 0.90±0.20 on SAMMAZ-37. At 5-WAS, larval abundance was lowest (0.13±0.10) on SAMMAZ-15 and highest (0.56±0.13) on BR-9943-DMR-SR-W. Variety BR-9943-DMR-SR-W also had the highest number (0.05±0.05) of FAW larvae at 7-WAS. Nevertheless, no significant differences were observed in the abundance of FAW larvae on all varieties at 3-, 5- and 7-WAS in 2018.

### 4.4.9. Abundance of fall armyworm on 25 open pollinated varieties of maize in 2019

At 3-WAS, egg-mass abundance was lowest (0.00) on SAMMAZ-26, SAMMAZ-29 and TZE-W-Pop-DT-STR-QPM-$C_0$ but highest (0.67±0.27) on SAMMAZ-19 (Table 4.24). At 5-WAS, no egg mass was found on several varieties and those that with egg mass had very few. At 7-WAS, all varieties were devoid of egg mass. At 3- and 5-WAS, larval abundance was highest on SAMMAZ-16 (0.60±0.13) and SAMMAZ-52 (0.34±0.09) respectively. At 7-WAS, however, several varieties had no egg mass laid (0.00±0.00) and

**Table 4.23. Abundance (mean ± SE) of fall armyworm egg-mass and larva on 25 open pollinated varieties of maize evaluated in 2018 at Ibadan, Nigeria**

| Maize Variety | Egg mass | | | Larva | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 0.09±0.05[a] | 0.09±0.07 | 0.00±0.00 | 0.35±0.10 | 0.27±0.08 | 0.00±0.00 |
| SAMMAZ-37 | 0.25±0.09[ab] | 0.15±0.07 | 0.00±0.00 | 0.90±0.20 | 0.30±0.10 | 0.00±0.00 |
| EVDT-W-99-STR | 0.20±0.08[ab] | 0.08±0.05 | 0.04±0.04 | 0.76±0.13 | 0.23±0.08 | 0.04±0.04 |
| SAMMAZ-14 | 0.20±0.08[ab] | 0.13±0.06 | 0.00±0.00 | 0.63±0.12 | 0.33±0.08 | 0.00±0.00 |
| SAMMAZ-52 | 0.18±0.07[ab] | 0.03±0.03 | 0.00±0.00 | 0.68±0.12 | 0.35±0.10 | 0.00±0.00 |
| TZEE-Pop-STR-QPM-Y | 0.27±0.14[ab] | 0.09±0.06 | 0.00±0.00 | 0.55±0.14 | 0.23±0.11 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 0.48±0.13[b] | 0.08±0.04 | 0.00±0.00 | 0.75±0.12 | 0.38±0.10 | 0.00±0.00 |
| SAMMAZ-38 | 0.23±0.08[ab] | 0.08±0.04 | 0.00±0.00 | 0.70±0.11 | 0.45±0.10 | 0.00±0.00 |
| SAMMAZ-16 | 0.13±0.05[ab] | 0.05±0.04 | 0.00±0.00 | 0.83±0.15 | 0.37±0.10 | 0.00±0.00 |
| SAMMAZ-19 | 0.20±0.08[ab] | 0.12±0.07 | 0.00±0.00 | 0.69±0.11 | 0.39±0.10 | 0.00±0.00 |
| DMR-LSR-Y | 0.35±0.10[ab] | 0.13±0.05 | 0.00±0.00 | 0.58±0.11 | 0.40±0.10 | 0.00±0.00 |
| SAMMAZ-31 | 0.30±0.20[ab] | 0.04±0.04 | 0.00±0.00 | 0.65±0.15 | 0.24±0.11 | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 0.39±0.12[ab] | 0.09±0.05 | 0.00±0.00 | 0.55±0.11 | 0.22±0.11 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 0.21±0.08[ab] | 0.09±0.05 | 0.00±0.00 | 0.42±0.10 | 0.24±0.10 | 0.00±0.00 |
| SAMMAZ-15 | 0.25±0.11[ab] | 0.08±0.04 | 0.00±0.00 | 0.44±0.10 | 0.13±0.10 | 0.05±0.04 |
| TZE-W-Pop-DT-STR-QPM-$C_0$ | 0.35±0.10[ab] | 0.10±0.06 | 0.00±0.00 | 0.70±0.11 | 0.38v0.11 | 0.00±0.00 |
| BR-9928-DMR-SR-Y | 0.33±0.10[ab] | 0.05±0.04 | 0.00±0.00 | 0.65±0.12 | 0.30±0.11 | 0.00±0.00 |
| SAMMAZ-29 | 0.25±0.10[ab] | 0.05±0.05 | 0.00±0.00 | 0.53±0.11 | 0.22±0.07 | 0.00±0.00 |
| SAMMAZ-17 | 0.35±0.13[ab] | 0.03±0.03 | 0.00±0.00 | 0.73±0.12 | 0.48±0.10 | 0.00±0.00 |
| SAMMAZ-32 | 0.30±0.11[ab] | 0.13±0.06 | 0.00±0.00 | 0.78±0.14 | 0.38±0.10 | 0.00±0.00 |
| SUWAN-1-SR | 0.05±0.04[a] | 0.20±0.10 | 0.00±0.00 | 0.72±0.10 | 0.35±0.10 | 0.00±0.00 |
| SAMMAZ-26 | 0.13±0.08[ab] | 0.15±0.06 | 0.00±0.00 | 0.63±0.18 | 0.30±0.10 | 0.00±0.00 |
| EVDT-Y-2000-STR | 0.33±0.12[ab] | 0.05±0.05 | 0.00±0.00 | 0.68±0.11 | 0.23±0.08 | 0.00±0.00 |
| BR-9943-DMR-SR-W | 0.20±0.09[ab] | 0.03±0.03 | 0.00±0.00 | 0.50±0.10 | 0.56±0.13 | 0.05±0.05 |
| SAMMAZ-45 | 0.47±0.20[b] | 0.33±0.15 | 0.00±0.00 | 0.63±0.11 | 0.46±0.11 | 0.00±0.00 |
| | | NS | NS | NS | NS | NS |

Mean values in a column followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test.
NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

**Table 4.24. Abundance (mean ± SE) of fall armyworm egg-mass and larva on 25 open pollinated varieties of maize evaluated in 2019 at Ibadan, Nigeria**

| Maize Variety | Egg mass | | | Larva | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 0.21±0.09 | 0.04±0.04 | 0.00±0.00 | 0.18±0.07 | 0.09±0.06 | 0.00±0.00 |
| SAMMAZ-37 | 0.09±0.05 | 0.00±0.00 | 0.00±0.00 | 0.42±0.11 | 0.18±0.07 | 0.00±0.00 |
| EVDT-W-99-STR | 0.09±0.07 | 0.10±0.07 | 0.00±0.00 | 0.34±0.12 | 0.30±0.09 | 0.00±0.00 |
| SAMMAZ-14 | 0.12±0.06 | 0.03±0.03 | 0.00±0.00 | 0.33±0.1 | 0.26±0.08 | 0.00±0.00 |
| SAMMAZ-52 | 0.16±0.08 | 0.00±0.00 | 0.00±0.00 | 0.10±0.05 | 0.34±0.09 | 0.03±0.03 |
| TZEE-Pop-STR-QPM-Y | 0.22±0.10 | 0.04±0.04 | 0.00±0.00 | 0.15±0.07 | 0.00±0.00 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 0.14±0.07 | 0.03±0.03 | 0.00±0.00 | 0.19±0.08 | 0.19±0.07 | 0.05±0.04 |
| SAMMAZ-38 | 0.16±0.10 | 0.03±0.03 | 0.00±0.00 | 0.23±0.08 | 0.20±0.07 | 0.06±0.04 |
| SAMMAZ-16 | 0.44±0.18 | 0.05±0.05 | 0.00±0.00 | 0.60±0.13 | 0.15±0.11 | 0.12±0.08 |
| SAMMAZ-19 | 0.67±0.27 | 0.00±0.00 | 0.00±0.00 | 0.33±0.13 | 0.00±0.00 | 0.00±0.00 |
| DMR-LSR-Y | 0.25±0.11 | 0.04±0.04 | 0.00±0.00 | 0.25±0.10 | 0.14±0.07 | 0.03±0.03 |
| SAMMAZ-31 | 0.18±0.13 | 0.00±0.00 | 0.00±0.00 | 0.53±0.17 | 0.06±0.06 | 0.06±0.06 |
| 2008-SYN-EE-W-DT-STR | 0.25±0.12 | 0.13±0.07 | 0.00±0.00 | 0.30±0.11 | 0.13±0.07 | 0.05±0.05 |
| 2008-EVDT-STR-Y | 0.21±0.12 | 0.00±0.00 | 0.00±0.00 | 0.26±0.10 | 0.05±0.05 | 0.00±0.00 |
| SAMMAZ-15 | 0.10±0.05 | 0.03±0.03 | 0.00±0.00 | 0.13±0.06 | 0.14±0.09 | 0.00±0.00 |
| TZE-W-Pop-DT-STR-QPM-$C_0$ | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.13±0.13 | 0.22±0.15 | 0.00±0.00 |
| BR-9928-DMR-SR-Y | 0.05±0.05 | 0.00±0.00 | 0.00±0.00 | 0.38±0.15 | 0.11±0.07 | 0.00±0.00 |
| SAMMAZ-29 | 0.00±0.00 | 0.04±0.04 | 0.00±0.00 | 0.36±0.11 | 0.30±0.09 | 0.00±0.00 |
| SAMMAZ-17 | 0.03±0.03 | 0.03±0.03 | 0.00±0.00 | 0.23±0.08 | 0.14±0.06 | 0.00±0.00 |
| SAMMAZ-32 | 0.16±0.07 | 0.06±0.04 | 0.00±0.00 | 0.28±0.08 | 0.16±0.08 | 0.00±0.00 |
| SUWAN-1-SR | 0.32±0.13 | 0.11±0.07 | 0.00±0.00 | 0.26±0.13 | 0.16±0.09 | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.31±0.11 | 0.30±0.10 | 0.03±0.03 |
| EVDT-Y-2000-STR | 0.16±0.08 | 0.00±0.00 | 0.00±0.00 | 0.19±0.07 | 0.16±0.07 | 0.04±0.04 |
| BR-9943DMR-SR-W | 0.13±0.09 | 0.09±0.07 | 0.00±0.00 | 0.16±0.07 | 0.03±0.03 | 0.00±0.00 |
| SAMMAZ-45 | 0.13±0.08 | 0.03±0.03 | 0.00±0.00 | 0.36±0.09 | 0.08±0.04 | 0.04±0.04 |
| | NS | NS | NS | NS | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

SAMMAZ-16 had the highest larval abundance (0.12±0.08). No significant difference was observed in the number of FAW larvae on all varieties at 3-, 5- and 7-WAS in 2019.

### 4.4.10. Abundance of stem borer and fall armyworm larvae in stems and cobs of 25 open pollinated varieties of maize in 2018 and 2019

In 2018, stem borer larval abundance in stems was observed to range from 0.00±0.00 on EVDT-W-99-STR and SAMMAZ-31 to 1.25±0.57 on TZE-W-Pop-DT-STR-QPM-$C_0$ (Table 4.25). Similarly, the lowest numbers (0.00±0.00) of stem borers in cobs was found in variety EVDT-W-99-STR and SAMMAZ-31 while TZE-Y-DT-STR-C4 had the highest (1.64±0.80) value. Fall armyworm abundance in maize cobs was highest (0.44±0.22) in SAMMAZ-45. No FAW larvae were, however, found in the stems of all the varieties in 2018.

In 2019, stems of SAMMAZ-19 and SAMMAZ-26 varieties had the lowest number (0.00±0.00) of stem borers while the highest number (1.79±0.60) was observed in the stems of SAMMAZ-16 (Table 4.26). As in 2018, no FAW larvae were found in stems of all varieties in 2019. With the exception of varieties TZEE-Pop-STR-QPM-Y, EVDT-Y 2000 STR and BR-9943-DMR-SR-W, which had FAW larval abundance of 0.08±0.08, 0.07±0.07 and 0.06±0.06 respectively, cobs of all other varieties had no FAW larvae in 2019.

### 4.4.11. Percentage infestation of fall armyworm on 25 open pollinated maize varieties in the early planting season of 2018

At 3-WAS and 5-WAS in the early planting season of 2018, percentage egg-mass infestation ranged from 10.00±5.77 to 60.00±8.17 and 5.00±5.00 to 30.00±12.91 respectively (Table 4.27). With the exception of SUWAN-1-SR-Y and SAMMAZ-26 varieties on which egg-mass infestation increased from 3- to 5-WAS, percentage egg-mass infestation on all other varieties generally decreased during the same period. The highest percentage egg-mass infestation at 3-WAS and 5-WAS were observed on TZE-W-Pop-DT-STR-QPM-$C_0$ (60.00±8.17) and SAMMAZ-45 (30.00±12.91) respectively. No eggs were, however, found on all varieties at 7-WAS. On the other hand, percentage larval infestation ranged from35.00±9.57 to70.00±10.00 at 3-WAS, 10.00±5.77 to 50.00±10.99 at 5-WAS and 0.00±0.00 to 10.00±10.00 at 7-WAS, with a general weekly

**Table 4.25. Abundance (mean ± SE) of stem borer and fall armyworm larva on 25 open pollinated maize varieties in 2018 at Ibadan, Nigeria**

| Variety | Abundance in stems | | Abundance in cobs | |
|---|---|---|---|---|
| | SB | FAW | SB | FAW |
| TZE-Y-DT-STR-C4 | 0.39±0.18 | 0.00±0.00 | 1.64±0.80 | 0.08±0.28 |
| SAMMAZ-37 | 0.19±0.10 | 0.00±0.00 | 1.07±0.33 | 0.19±0.10 |
| EVDT-W-99-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-14 | 0.60±0.41 | 0.00±0.00 | 0.33±0.16 | 0.38±0.13 |
| SAMMAZ-52 | 1.07±0.35 | 0.00±0.00 | 0.53±0.19 | 0.33±0.23 |
| TZEE-Pop-STR-QPM-Y | 0.25±0.16 | 0.00±0.00 | 1.40±0.75 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 1.20±0.45 | 0.00±0.00 | 1.00±0.50 | 0.13±0.09 |
| SAMMAZ-38 | 0.38±0.22 | 0.00±0.00 | 0.67±0.36 | 0.25±0.11 |
| SAMMAZ-16 | 0.50±0.30 | 0.00±0.00 | 0.69±0.34 | 0.13±0.09 |
| SAMMAZ-19 | 0.39±0.24 | 0.00±0.00 | 1.09±0.37 | 0.15±0.10 |
| DMR-LSR-Y | 0.38±0.18 | 0.00±0.00 | 0.73±0.28 | 0.13±0.09 |
| SAMMAZ-31 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 0.30±0.20 | 0.00±0.00 | 0.50±0.27 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 0.25±0.18 | 0.00±0.00 | 0.46±0.28 | 0.25±0.18 |
| SAMMAZ-15 | 0.85±0.77 | 0.00±0.00 | 0.46±0.22 | 0.08±0.08 |
| TZE-W-Pop-DT-STR-QPM-$C_0$ | 1.25±0.57 | 0.00±0.00 | 1.21±0.63 | 0.19±0.10 |
| BR-9928-DMR-SR-Y | 0.56±0.24 | 0.00±0.00 | 0.67±0.25 | 0.00±0.00 |
| SAMMAZ-29 | 0.62±0.24 | 0.00±0.00 | 1.58±0.84 | 0.00±0.00 |
| SAMMAZ-17 | 0.75±0.41 | 0.00±0.00 | 0.60±0.27 | 0.06±0.06 |
| SAMMAZ-32 | 0.73±0.46 | 0.00±0.00 | 0.64±0.20 | 0.00±0.00 |
| SUWAN-1-SR | 0.50±0.22 | 0.00±0.00 | 0.19±0.10 | 0.38±0.16 |
| SAMMAZ-26 | 1.00±0.35 | 0.00±0.00 | 0.75±0.21 | 0.31±0.15 |
| EVDT-Y-2000-STR | 0.69±0.30 | 0.00±0.00 | 0.73±0.27 | 0.13±0.09 |
| BR-9943-DMR-SR-W | 0.81±0.28 | 0.00±0.00 | 0.31±0.12 | 0.19±0.14 |
| SAMMAZ-45 | 0.75±0.32 | 0.00±0.00 | 0.81±0.37 | 0.44±0.22 |
| | NS | NS | NS | NS |

NS: Not Significant at $\alpha_{0.05}$
SB: Stem Borer species
FAW: Fall armyworm species

**Table 4.26. Abundance (mean ± SE) of stem borer and fall armyworm larva on 25 open pollinated varieties of maize in 2019 at Ibadan, Nigeria**

| Variety | Abundance per stems | | Abundance per cobs | |
|---|---|---|---|---|
| | SB | FAW | SB | FAW |
| TZE-Y-DT-STR-C4 | 0.50±0.50 | 0.00±0.00 | 0.25±0.16 | 0.00±0.00 |
| SAMMAZ-37 | 0.33±0.16 | 0.00±0.00 | 0.28±0.11 | 0.00±0.00 |
| EVDT-W-99-STR | 0.38±0.26 | 0.00±0.00 | 1.25±1.00 | 0.00±0.00 |
| SAMMAZ-14 | 0.33±0.23 | 0.00±0.00 | 0.17±0.11 | 0.00±0.00 |
| SAMMAZ-52 | 0.07±0.07 | 0.00±0.00 | 0.36±0.17 | 0.00±0.00 |
| TZEE-Pop-STR-QPM-Y | 0.09±0.09 | 0.00±0.00 | 0.46±0.25 | 0.08±0.08 |
| TZE-W-DT-STR-C4 | 1.00±0.78 | 0.00±0.00 | 0.46±0.27 | 0.00±0.00 |
| SAMMAZ-38 | 0.08±0.08 | 0.00±0.00 | 0.50±0.36 | 0.00±0.00 |
| SAMMAZ-16 | 1.79±0.60 | 0.00±0.00 | 0.78±0.32 | 0.00±0.00 |
| SAMMAZ-19 | 0.00±0.00 | 0.00±0.00 | 0.44±0.24 | 0.00±0.00 |
| DMR-LSR-Y | 0.43±0.23 | 0.00±0.00 | 0.64±0.27 | 0.00±0.00 |
| SAMMAZ-31 | 0.57±0.37 | 0.00±0.00 | 0.57±0.43 | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 0.63±0.26 | 0.00±0.00 | 1.25±0.25 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 1.00±1.00 | 0.00±0.00 | 0.11±0.11 | 0.00±0.00 |
| SAMMAZ-15 | 0.13±0.09 | 0.00±0.00 | 0.44±0.38 | 0.00±0.00 |
| TZE-W-Pop-DT-STR | 0.40±0.25 | 0.00±0.00 | 1.00±0.55 | 0.00±0.00 |
| BR-9928-DMR-SR-Y | 1.00±0.57 | 0.00±0.00 | 0.38±0.18 | 0.00±0.00 |
| SAMMAZ-29 | 0.07±0.07 | 0.00±0.00 | 0.71±0.44 | 0.00±0.00 |
| SAMMAZ-17 | 0.53±0.36 | 0.00±0.00 | 0.20±0.11 | 0.00±0.00 |
| SAMMAZ-32 | 0.36±0.29 | 0.00±0.00 | 0.86±0.59 | 0.00±0.00 |
| SUWAN-1-SR | 0.90±0.61 | 0.00±0.00 | 1.30±0.62 | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.25±0.13 | 0.00±0.00 |
| EVDT-Y-2000-STR | 0.07±0.07 | 0.00±0.00 | 0.14±0.10 | 0.07±0.07 |
| BR-9943-DMR-SR-W | 0.07±0.07 | 0.00±0.00 | 0.00±0.00 | 0.06±0.06 |
| SAMMAZ-45 | 0.56±0.38 | 0.00±0.00 | 0.31±0.15 | 0.00±0.00 |
| | NS | NS | NS | NS |

NS: Not Significant at $\alpha_{0.05}$
SB: Stem Borer species
FAW: Fall armyworm species

**Table 4.27. Percentage infestations (mean ± SE) of fall armyworm egg mass and larva on 25 open pollinated varieties of maize evaluated in the early planting season of 2018 at Ibadan, Nigeria (N=20)**

| Variety | Egg mass (%) | | | Larva (%) | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 15.00±5.00 | 10.00±5.77 | 0.00±0.00 | 35.00±17.08 | 30.00±12.91 | 5.00±5.00 |
| SAMMAZ-37 | 45.00±12.58 | 25.00±12.58 | 0.00±0.00 | 45.00±5.00 | 10.00±5.77 | 5.00±5.00 |
| EVDT-W-99-STR | 25.00±9.57 | 10.00±5.77 | 5.00±5.00 | 65.00±9.57 | 15.00±5.00 | 5.00±5.00 |
| SAMMAZ-14 | 25.00±9.57 | 20.00±11.55 | 0.00±0.00 | 55.00±9.57 | 10.00±10.00 | 5.00±5.00 |
| SAMMAZ-52 | 35.00±5.00 | 5.00±5.00 | 0.00±0.00 | 50.00±12.91 | 30.00±12.91 | 10.00±10.00 |
| TZEE-Pop-STR | 20.00±11.50 | 10.00±5.77 | 0.00±0.00 | 45.00±17.08 | 20.00±11.55 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 50.00±10.00 | 15.00±15.00 | 0.00±0.00 | 70.00±10.00 | 45.00±17.08 | 0.00±0.00 |
| SAMMAZ-38 | 35.00±9.57 | 18.33±10.67 | 0.00±0.00 | 55.00±9.57 | 30.00±12.91 | 0.00±0.00 |
| SAMMAZ-16 | 25.00±5.00 | 10.00±5.77 | 0.00±0.00 | 45.00±9.57 | 36.67±11.06 | 0.00±0.00 |
| SAMMAZ-19 | 25.00±12.58 | 18.75±11.97 | 0.00±0.00 | 60.00±16.33 | 50.00±10.99 | 0.00±0.00 |
| DMR-LSR-Y | 55.00±18.93 | 25.00±9.57 | 0.00±0.00 | 55.00±22.17 | 30.00±10.00 | 5.00±5.00 |
| SAMMAZ-31 | 50.00±28.87 | 5.00±5.00 | 0.00±0.00 | 40.00±18.26 | 27.50±7.50 | 0.00±0.00 |
| 2008-SYN-EE-W | 45.00±17.08 | 10.00±5.77 | 0.00±0.00 | 55.00±15.00 | 15.00±9.57 | 5.00±5.00 |
| 2008-EVDT-STR-Y | 35.00±9.57 | 15.00±9.57 | 0.00±0.00 | 35.00±9.57 | 15.00±9.57 | 10.00±10.00 |
| SAMMAZ-15 | 30.00±5.77 | 15.00±5.00 | 0.00±0.00 | 45.00±17.08 | 10.00±5.77 | 0.00±0.00 |
| TZE-W-Pop-DT | 60.00±8.17 | 15.00±5.00 | 0.00±0.00 | 50.00±10.00 | 20.00±14.14 | 0.00±0.00 |
| BR-9928-DMR-SR | 40.00±18.26 | 10.00±10.00 | 0.00±0.00 | 50.00±12.91 | 20.00±8.17 | 0.00±0.00 |
| SAMMAZ-29 | 35.00±15.00 | 5.00±5.00 | 0.00±0.00 | 60.00±14.14 | 15.00±9.57 | 0.00±0.00 |
| SAMMAZ-17 | 50.00±12.91 | 5.00±5.00 | 0.00±0.00 | 60.00±16.33 | 35.00±15.00 | 10.00±10.00 |
| SAMMAZ-32 | 35.00±9.57 | 20.00±8.17 | 0.00±0.00 | 65.00±5.00 | 40.00±8.17 | 10.00±5.77 |
| SUWAN-1-SR-Y | 15.00±5.00 | 20.00±14.14 | 0.00±0.00 | 50.00±12.91 | 15.00±9.57 | 0.00±0.00 |
| SAMMAZ-26 | 10.00±5.77 | 25.00±18.93 | 0.00±0.00 | 35.00±17.08 | 25.00±15.00 | 0.00±0.00 |
| EVDT-Y-2000-STR | 40.00±8.17 | 5.00±5.00 | 0.00±0.00 | 50.00±12.91 | 20.00±14.14 | 0.00±0.00 |
| BR-9943-DMR-SR | 30.00±5.77 | 6.25±6.25 | 0.00±0.00 | 50.00±19.15 | 43.75±16.25 | 10.00±5.77 |
| SAMMAZ-45 | 40.00±14.14 | 30.00±12.91 | 0.00±0.00 | 45.00±20.62 | 35.00±15.00 | 0.00±0.00 |
| | NS | NS | NS | NS | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

decrease in infestation observed on all varieties. The highest percentage larvae infestation at 3-WAS and at 5-WAS were recorded on TZE-W-DT-STR-$C_4$ (70.00±10.00) and SAMMAZ-19 (50.00±10.99) respectively. Generally, no significant difference was observed in the percentage egg-mass and larval infestation on all 25 varieties at 3-, 5- and 7-WAS in the early maize planting season of 2018.

### 4.4.12. Percentage infestation of fall armyworm on 25 open pollinated varieties of maize in the late planting seasons of 2018

In the late planting season of 2018, percentage egg-mass infestation ranged from 0.00±0.00 to 6.67±6.67 at 3-WAS (Table 4.28). Similarly, at 5-WAS a range of 0.00±0.00 to 15.00±9.57-WAS observed. At 7-WAS, however, no egg mass was found on any of the varieties. Percentage infestation of FAW larvae at 3-WAS during the late season was lowest (20.00±20.00) on TZE-Y-DT-STR-C4 and highest (70.00±12.91) on SAMMAZ-16. At 5-WAS, however, the highest (66.25±19.72) percentage larval infestation occurred on 2008-EVDT-STR-Y while the lowest value (15.00±5.00) was observed on EVDT-Y-2000-STR. At 7-WAS, only SAMMAZ-15 (10.00±10.00) and BR-9943-DMR-SR-W (5.00±5.00) were infested with FAW larvae. No significant difference was observed in the percentage egg-mass or larval infestation of all varieties at all weeks of evaluation in the late planting season of 2018.

### 4.4.13. Percentage infestation of fall armyworm egg mass and larva on 25 open pollinated varieties of maize in the early planting seasons of 2019

In the early maize planting season of 2019 (Table 4.29), percentage infestation of FAW egg masses ranged from 0.00±0.00 to 66.67±33.33 at 3-WAS. There was a further decrease in percentage egg-mass infestation (0.00±0.00 to 25.00±25.00) at 5-WAS and then at 7-WAS were no egg-mass infestation was observed. Percentage larval infestation at 3-WAS was lowest (6.67±6.67) in SAAMAZ 52 and highest (77.78±22.22) in SAMMAZ-26. Furthermore, the highest (30.00±23.80) percentage infestation of larvae at 5-WAS was observed on TZE-Y-DT-STR-C4 while EVDT-Y-2000-STR had the highest (25.00±25.00) percentage value at 7-WAS. Generally, no significant differences were observed in the percentage egg-mass and larval infestation at 3-, 5-, and 7-WAS in the early maize planting season of 2019.

**Table 4.28. Percentage infestation (mean ± SE) of fall armyworm egg mass and larva on 25 open pollinated varieties of maize evaluated in the late planting season of 2018 at Ibadan, Nigeria (N=20)**

| Variety | Egg mass (%) | | | Larva (%) | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 20.00±20.00 | 23.33±14.53 | 0.00±0.00 |
| SAMMAZ-37 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 60.00±8.17 | 45.00±12.58 | 0.00±0.00 |
| EVDT-W-99-STR | 0.00±0.00 | 5.00±5.00 | 0.00±0.00 | 33.33±33.33 | 38.89±20.03 | 0.00±0.00 |
| SAMMAZ-14 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 55.00±18.93 | 50.00±12.91 | 0.00±0.00 |
| SAMMAZ-52 | 5.00±5.00 | 0.00±0.00 | 0.00±0.00 | 65.00±5.00 | 20.00±11.55 | 0.00±0.00 |
| TZEE-Pop-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 50.00±50.00 | 50.00±50.00 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 5.00±5.00 | 0.00±0.00 | 0.00±0.00 | 40.00±21.60 | 20.00±8.17 | 0.00±0.00 |
| SAMMAZ-38 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 65.00±17.08 | 55.00±15.00 | 0.00±0.00 |
| SAMMAZ-16 | 0.00±0.00 | 5.00±5.00 | 0.00±0.00 | 70.00±12.91 | 30.00±10.00 | 0.00±0.00 |
| SAMMAZ-19 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 53.33±17.64 | 40.00±0.00 | 0.00±0.00 |
| DMR-LSR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 45.00±17.08 | 40.00±8.17 | 0.00±0.00 |
| SAMMAZ-31 | 6.67±6.67 | 0.00±0.00 | 0.00±0.00 | 50.00±28.87 | 16.67±16.67 | 0.00±0.00 |
| 2008-SYN-EE-W | 0.00±0.00 | 8.33±8.33 | 0.00±0.00 | 40.00±10.00 | 31.11±17.36 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 55.83±15.12 | 66.25±19.72 | 0.00±0.00 |
| SAMMAZ-15 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 28.33±12.58 | 33.75±15.99 | 10.00±10.00 |
| TZE-W-Pop-DT | 5.00±5.00 | 15.00±9.57 | 0.00±0.00 | 60.00±14.14 | 40.00±8.17 | 0.00±0.00 |
| BR-9928-DMR-SR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 50.00±17.32 | 25.00±9.57 | 0.00±0.00 |
| SAMMAZ-29 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 25.00±18.93 | 32.50±7.50 | 0.00±0.00 |
| SAMMAZ-17 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 55.00±22.17 | 45.00±9.57 | 0.00±0.00 |
| SAMMAZ-32 | 5.00±5.00 | 0.00±0.00 | 0.00±0.00 | 50.00±17.32 | 35.00±40.00 | 0.00±0.00 |
| SUWAN-1-SR-Y | 0.00±0.00 | 5.00±5.00 | 0.00±0.00 | 66.25±13.75 | 55.00±12.58 | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 55.00±9.57 | 35.00±17.08 | 0.00±0.00 |
| EVDT-Y-2000-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 65.00±9.57 | 15.00±5.00 | 0.00±0.00 |
| BR-9943-DMR-SR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 40.00±8.17 | 50.00±12.91 | 5.00±5.00 |
| SAMMAZ-45 | 0.00±0.00 | 5.00±5.00 | 0.00±0.00 | 65.00±15.00 | 41.25±7.18 | 0.00±0.00 |
| | NS | NS | NS | NS | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

**Table 4.29. Percentage infestations (mean ± SE) of fall armyworm egg mass and larva on 25 open pollinated varieties of maize evaluated in the early planting season of 2019 at Ibadan, Nigeria (N=20)**

| Variety | Egg mass (%) | | | Larva (%) | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 15.00±15.00 | 25.00±25.00 | 0.00±0.00 | 20.00±11.55 | 30.00±23.80 | 0.00±0.00 |
| SAMMAZ-37 | 17.78±9.69 | 0.00±0.00 | 0.00±0.00 | 68.89±5.88 | 6.67±6.67 | 0.00±0.00 |
| EVDT-W-99-STR | 6.67±6.67 | 13.33±13.33 | 0.00±0.00 | 30.00±10.00 | 11.11±11.11 | 0.00±0.00 |
| SAMMAZ-14 | 15.00±9.57 | 0.00±0.00 | 0.00±0.00 | 25.00±9.57 | 30.0±23.80 | 0.00±0.00 |
| SAMMAZ-52 | 20.00±20.00 | 0.00±0.00 | 0.00±0.00 | 6.67±6.67 | 23.33±14.53 | 6.67±6.67 |
| TZEE-Pop-STR | 31.11±17.36 | 6.67±6.67 | 0.00±0.00 | 37.78±11.76 | 6.67±6.67 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 18.33±6.87 | 6.25±6.25 | 0.00±0.00 | 10.00±5.77 | 19.58±7.08 | 10.00±5.77 |
| SAMMAZ-38 | 20.00±20.00 | 6.67±6.67 | 0.00±0.00 | 30.00±15.28 | 26.67±17.64 | 18.75±11.97 |
| SAMMAZ-16 | 37.50±17.50 | 5.00±5.00 | 0.00±0.00 | 70.00±23.80 | 15.0±9.57 | 11.25±6.58 |
| SAMMAZ-19 | 66.67±33.33 | 0.00±0.00 | 0.00±0.00 | 26.67±17.64 | 0.00±0.00 | 0.00±0.00 |
| DMR-LSR-Y | 25.00±10.21 | 6.25±6.25 | 0.00±0.00 | 31.25±11.97 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-31 | 12.50±12.50 | 5.00±5.00 | 0.00±0.00 | 72.50±16.01 | 0.00±0.00 | 5.00±5.00 |
| 2008-SYN-EE-W | 20.00±8.17 | 15.0±9.57 | 0.00±0.00 | 30.00±5.77 | 15.00±9.57 | 5.00±5.00 |
| 2008-EVDT-STR-Y | 31.25±23.66 | 0.00±0.00 | 0.00±0.00 | 35.00±23.63 | 6.25±6.25 | 0.00±0.00 |
| SAMMAZ-15 | 15.00±15.00 | 5.00±5.00 | 0.00±0.00 | 15.00±9.57 | 5.00±5.00 | 0.00±0.00 |
| TZE-W-Pop-DT | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 33.33±33.33 | 25.00±14.43 | 0.00±0.00 |
| BR-9928-DMR-SR | 5.00±5.00 | 5.00±5.00 | 0.00±0.00 | 32.50±7.50 | 12.50±12.50 | 0.00±0.00 |
| SAMMAZ-29 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 60.00±13.88 | 10.00±10.00 | 0.00±0.00 |
| SAMMAZ-17 | 0.00±0.00 | 5.00±5.00 | 0.00±0.00 | 25.00±15.00 | 10.00±10.00 | 0.00±0.00 |
| SAMMAZ-32 | 31.67±9.28 | 15.00±7.64 | 0.00±0.00 | 50.00±28.87 | 6.67±6.67 | 0.00±0.00 |
| SUWAN-1-SR-Y | 28.33±12.58 | 15.00±9.57 | 0.00±0.00 | 31.67±14.24 | 13.33±8.17 | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 77.78±22.22 | 0.00±0.00 | 10.00±0.00 |
| EVDT-Y-2000-STR | 20.00±11.55 | 0.00±0.00 | 0.00±0.00 | 20.00±11.55 | 0.00±0.00 | 25.00±25.00 |
| BR-9943-DMR-SR | 13.33±8.17 | 18.75±11.97 | 0.00±0.00 | 43.33±20.82 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-45 | 15.00±5.00 | 5.00±5.00 | 0.00±0.00 | 36.25±3.75 | 5.00±5.00 | 0.00±0.00 |
| | NS | NS | NS | NS | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

### 4.4.14. Percentage infestation of fall armyworm egg mass and larva on 25 open pollinated varieties of maize in the late planting seasons of 2019

In the late planting season of 2019, percentage egg-mass infestation ranged from 0.00±0.00 to 30.00±23.80 observed on TZE-Y-DT-STR-C4 at 3-WAS (Table 4.30). Percentage infestation of egg masses was lower at 5-WAS (0.00±0.00 to 10.00±10.00) and non-existent at 7-WAS. On the other hand, percentage infestation of FAW larvae at 3-WAS ranged from 00.00±00.00 in many varieties to 27.78±14.70 in 2008-EVDT-STR-Y. Similarly, larval infestation at 5-WAS ranged from 0.00±0.00 to 50.00±17.32 in SAMMAZ-52. With the exception of SAMMAZ-19 and BR-9943-DMR-SR-W with 8.33±8.33 and 5.00±5.00 respectively, all other varieties were not infested by FAW larvae at 7-WAS in the late planting season of 2019. No significant difference was observed in the percentage egg-mass or larval infestation of all varieties at all weeks of evaluation in the late planting season of 2018.

### 4.4.15. Abundance of fall armyworm egg mass and larva on 25 open pollinated varieties of maize in the early planting seasons of 2018

At 3-WAS in the early maize planting season of 2018, abundance of FAW egg mass was highest (0.90±0.36) on SAMMAZ-45 but lowest (0.10±0.07) on SUWAN-1-SR-Y (Table 4.31). SAMMAZ-45 also had the highest (0.60±0.28) abundance of egg mass at 5-WAS while the lowest (0.05±0.05) numbers was observed SAMMAZ-52, SAMMAZ-17 and BR-9943-DMR-SR-W. No egg mass was, however, found on all varieties at 7-WAS. On the other hand, abundance of FAW larvae was highest (0.95±0.45) on SAMMAZ-37 and lowest (0.40±0.13) on 2008-EVDT-STR-Y at 3-WAS in the early planting season of 2018. SAMMAZ-14 and SAMMAZ-15 both had the lowest (0.10±0.07) larval abundance value at 5-WAS while BR-9943-DMR-SR-W had the highest (0.63±0.23) number. Apart from EVDT-W-99-STR which had a value of (0.05±0.05), no larvae were collected on all other variety at 7-WAS in the early maize planting season of 2018. There was no significant difference in the abundance of FAW egg mass and larva on all varieties at 3-, 5- and 7-WAS in the early maize planting season of 2018.

**Table 4.30. Percentage infestation (mean ± SE) of fall armyworm egg mass and larva on 25 open pollinated varieties of maize evaluated in the late planting season of 2019 at Ibadan, Nigeria (N=20)**

| Variety | Percentage egg mass | | | Percentage larva | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 30.00±23.80 | 0.00±0.00 | 0.00±0.00 | 5.00±5.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-37 | 10.00±5.77 | 0.00±0.00 | 0.00±0.00 | 25.00±12.58 | 25.00±9.57 | 0.00±0.00 |
| EVDT-W-99-STR | 10.00±5.77 | 0.00±0.00 | 0.00±0.00 | 15.00±9.57 | 35.00±17.08 | 0.00±0.00 |
| SAMMAZ-14 | 6.67±6.67 | 0.00±0.00 | 0.00±0.00 | 26.67±6.67 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-52 | 5.00±5.00 | 0.00±0.00 | 0.00±0.00 | 5.00±5.00 | 50.00±17.32 | 0.00±0.00 |
| TZEE-Pop-STR- | 8.33±8.33 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 15.00±5.00 | 20.00±8.17 | 0.00±0.00 |
| SAMMAZ-38 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 17.50±11.81 | 20.00±0.00 | 0.00±0.00 |
| SAMMAZ-16 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-19 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 8.33±8.33 |
| DMR-LSR-Y | 10.00±10.00 | 0.00±0.00 | 0.00±0.00 | 10.00±10.00 | 30.00±10.00 | 0.00±0.00 |
| SAMMAZ-31 | 12.50±12.50 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| 2008-SYN-EE-W-DT | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 27.78±14.70 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-15 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 6.25±6.25 | 0.00±0.00 | 0.00±0.00 |
| TZE-W-Pop-DT-STR- | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| BR-9928-DMR-SR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-29 | 0.00±0.00 | 5.00±5.00 | 0.00±0.00 | 10.00±10.00 | 35.00±12.58 | 0.00±0.00 |
| SAMMAZ-17 | 5.00±5.00 | 10.00±10.00 | 0.00±0.00 | 10.00±10.00 | 15.00±9.57 | 0.00±0.00 |
| SAMMAZ-32 | 6.25±6.25 | 0.00±0.00 | 0.00±0.00 | 15.00±9.57 | 20.00±11.55 | 0.00±0.00 |
| SUWAN-1-SR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 16.67±16.67 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 15.00±5.00 | 35.00±17.08 | 0.00±0.00 |
| EVDT-Y-2000-STR | 5.00±5.00 | 0.00±0.00 | 0.00±0.00 | 15.00±9.57 | 15.00±9.57 | 0.00±0.00 |
| BR-9943-DMR-SR-W | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 5.00±5.00 | 5.00±5.00 |
| SAMMAZ-45 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 20.00±8.17 | 10.00±5.77 | 0.00±0.00 |
| | NS | NS | NS | NS | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

**Table 4.31. Abundance (mean ± SE) of fall armyworm egg mass and larva on 25 open pollinated varieties of maize evaluated in the early planting season of 2018 at Ibadan, Nigeria (N=20)**

| Variety | Egg mass | | | Larva | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 0.25±0.08 | 0.15±0.11 | 0.00±0.00 | 0.45±0.15 | 0.30±0.11 | 0.00±0.00 |
| SAMMAZ-37 | 0.50±0.14 | 0.30±0.13 | 0.00±0.00 | 0.95±0.45 | 0.20±0.16 | 0.00±0.00 |
| EVDT-W-99-STR | 0.25±0.10 | 0.10±0.07 | 0.05±0.05 | 0.80±0.16 | 0.15±0.08 | 0.05±0.05 |
| SAMMAZ-14 | 0.40±0.15 | 0.25±0.12 | 0.00±0.00 | 0.60±0.18 | 0.10±0.07 | 0.00±0.00 |
| SAMMAZ-52 | 0.30±0.13 | 0.05±0.05 | 0.00±0.00 | 0.50±0.15 | 0.40±0.13 | 0.00±0.00 |
| TZEE-Pop-STR | 0.30±0.15 | 0.10±0.07 | 0.00±0.00 | 0.55±0.15 | 0.20±0.12 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 0.90±0.23 | 0.15±0.08 | 0.00±0.00 | 0.95±0.19 | 0.55±0.15 | 0.00±0.00 |
| SAMMAZ-38 | 0.45±0.15 | 0.17±0.09 | 0.00±0.00 | 0.70±0.16 | 0.33±0.11 | 0.00±0.00 |
| SAMMAZ-16 | 0.25±0.10 | 0.06±0.06 | 0.00±0.00 | 0.70±0.23 | 0.39±0.14 | 0.00±0.00 |
| SAMMAZ-19 | 0.35±0.13 | 0.22±0.13 | 0.00±0.00 | 0.70±0.15 | 0.39±0.14 | 0.00±0.00 |
| DMR-LSR-Y | 0.70±0.16 | 0.25±0.10 | 0.00±0.00 | 0.60±0.13 | 0.30±0.11 | 0.00±0.00 |
| SAMMAZ-31 | 0.44±0.20 | 0.06±0.06 | 0.00±0.00 | 0.63±0.18 | 0.29±0.14 | 0.00±0.00 |
| 2008-SYN-EE-W-DT- | 0.55±0.17 | 0.10±0.07 | 0.00±0.00 | 0.65±0.15 | 0.25±0.16 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 0.35±0.13 | 0.15±0.08 | 0.00±0.00 | 0.40±0.13 | 0.15±0.08 | 0.00±0.00 |
| SAMMAZ-15 | 0.45±0.19 | 0.15±0.09 | 0.00±0.00 | 0.50±0.14 | 0.10±0.07 | 0.00±0.00 |
| TZE-W-Pop-DT-STR- | 0.70±0.16 | 0.20±0.12 | 0.00±0.00 | 0.60±0.15 | 0.20±0.12 | 0.00±0.00 |
| BR-9928-DMR-SR-Y | 0.65±0.20 | 0.10±0.07 | 0.00±0.00 | 0.75±0.20 | 0.20±0.09 | 0.00±0.00 |
| SAMMAZ-29 | 0.50±0.19 | 0.10±0.10 | 0.00±0.00 | 0.80±0.17 | 0.15±0.08 | 0.00±0.00 |
| SAMMAZ-17 | 0.70±0.23 | 0.05±0.05 | 0.00±0.00 | 0.75±0.18 | 0.40±0.13 | 0.00±0.00 |
| SAMMAZ-32 | 0.55±0.20 | 0.25±0.12 | 0.00±0.00 | 0.95±0.20 | 0.35±0.13 | 0.00±0.00 |
| SUWAN-1-SR-Y | 0.10±0.07 | 0.35±0.18 | 0.00±0.00 | 0.70±0.15 | 0.15±0.08 | 0.00±0.00 |
| SAMMAZ-26 | 0.25±0.16 | 0.30±0.11 | 0.00±0.00 | 0.45±0.17 | 0.25±0.10 | 0.00±0.00 |
| EVDT-Y-2000-STR | 0.65±0.21 | 0.10±0.10 | 0.00±0.00 | 0.70±0.18 | 0.20±0.10 | 0.00±0.00 |
| BR-9943-DMR-SR-W | 0.40±0.17 | 0.05±0.05 | 0.00±0.00 | 0.60±0.15 | 0.63±0.23 | 0.00±0.00 |
| SAMMAZ-45 | 0.90±0.36 | 0.60±0.28 | 0.00±0.00 | 0.50±0.14 | 0.50±0.19 | 0.00±0.00 |
| | NS | NS | NS | NS | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

### 4.4.16. Abundance of fall armyworm egg mass and larva on 25 open pollinated varieties of maize in the late planting seasons of 2018

Abundance of egg mass was generally lower in the late maize planting season of 2018 with a range of 0.00±0.00 to 0.09±0.09 and 0.00±0.00 to 0.08±0.08 at 3-WAS and 5-WAS respectively (Table 4.32). As in the previous season, no egg mass was found on all maize varieties at 7-WAS. In contrast, larval abundance on maize varieties was considerable in the late season of 2018. At 3-WAS, the highest numbers (0.95±0.19) was observed on SAMMAZ-16 while the lowest (0.21±0.11) was on TZE-Y-DT-STR-C4. At 5-WAS, TZE-W-DT-STR-C4 had the lowest larval abundance (0.20±0.09) while the highest number (0.55±0.14) was observed in SAMMAZ-14. No FAW larvae were found on all varieties at 7-WAS with the exception of SAMMAZ-15 and BR-9943DMR-SR-W with 0.11±0.07 and 0.10±0.10 respectively. There was no significant difference in the abundance of FAW egg mass and larva on all varieties at 3-, 5- and 7-WAS in the late maize planting season of 2018.

### 4.4.17. Abundance of fall armyworm egg mass and larva on 25 open pollinated varieties of maize in the early planting seasons of 2019

In the early maize planting season of 2019, abundance of FAW egg mass at 3-WAS ranged from 0.00±0.00 in several varieties to 0.91±0.34 in SAMMAZ-19 (Table 4.33). There was a significant difference in the number of egg mass laid on varieties with the highest and lowest values at 3-WAS. At 5-WAS, however, egg-mass abundance ranged from 0.00±0.00 in many varieties to 0.25±0.18 in BR-9943-DMR-SR-W. Similarly, egg-mass abundance at 7-WAS ranged from 0.00±0.00 in many varieties to 0.14±0.14 in EVDT-Y-2000-STR. No significant difference was however observed in the abundance of egg mass laid on all varieties at 5-WAS and 7-WAS in the early planting season of 2019.

At 3-WAS in the early maize planting season of 2019 (Table 4.33), larval abundance was highest (0.82±0.23) on SAMMAZ-31 which and lowest (0.12±0.08) on TZE-W-DT-STR-C4. There was a significant difference between larval abundance on SAMMAZ-31 and TZE-W-DT-STR-C4. At 5-WAS, abundance of FAW larvae was generally low with no (0.00±0.00) larvae found on many varieties while the highest (0.38±0.13) number in the

**Table 4.32. Abundance (mean ± SE) of fall armyworm egg mass and larva on 25 open pollinated varieties of maize evaluated in the late planting season of 2018 at Ibadan, Nigeria (N=20)**

| Variety | Egg mass | | | Larva | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.21±0.11 | 0.21±0.11 | 0.00±0.00 |
| SAMMAZ-37 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.85±0.18 | 0.40±0.11 | 0.00±0.00 |
| EVDT-W-99-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.60±0.25 | 0.50±0.22 | 0.00±0.00 |
| SAMMAZ-14 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.65±0.15 | 0.55±0.14 | 0.00±0.00 |
| SAMMAZ-52 | 0.05±0.05 | 0.00±0.00 | 0.00±0.00 | 0.85±0.17 | 0.30±0.13 | 0.00±0.00 |
| TZEE-Pop-STR- | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.50±0.50 | 0.50±0.50 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 0.05±0.05 | 0.00±0.00 | 0.00±0.00 | 0.55±0.15 | 0.20±0.09 | 0.00±0.00 |
| SAMMAZ-38 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.70±0.16 | 0.55±0.11 | 0.00±0.00 |
| SAMMAZ-16 | 0.00±0.00 | 0.05±0.05 | 0.00±0.00 | 0.95±0.19 | 0.35±0.13 | 0.00±0.00 |
| SAMMAZ-19 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.67±0.19 | 0.40±0.13 | 0.00±0.00 |
| DMR-LSR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.55±0.17 | 0.50±0.17 | 0.00±0.00 |
| SAMMAZ-31 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.71±0.29 | 0.13±0.13 | 0.00±0.00 |
| 2008-SYN-EE-W- | 0.09±0.09 | 0.08±0.08 | 0.00±0.00 | 0.36±0.15 | 0.17±0.11 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.46±0.14 | 0.39±0.14 | 0.00±0.00 |
| SAMMAZ-15 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.38±0.13 | 0.17±0.09 | 0.11±0.07 |
| TZE-W-Pop-DTSTR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.80±0.17 | 0.55±0.19 | 0.00±0.00 |
| BR-9928-DMR-SR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.55±0.14 | 0.40±0.20 | 0.00±0.00 |
| SAMMAZ-29 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.25±0.10 | 0.29±0.11 | 0.00±0.00 |
| SAMMAZ-17 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.70±0.16 | 0.40±0.13 | 0.00±0.00 |
| SAMMAZ-32 | 0.05±0.05 | 0.00±0.00 | 0.00±0.00 | 0.60±0.18 | 0.55±0.11 | 0.00±0.00 |
| SUWAN-1-SR-Y | 0.00±0.00 | 0.05±0.05 | 0.00±0.00 | 0.74±0.13 | 0.35±0.11 | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.80±0.16 | 0.25±0.14 | 0.00±0.00 |
| EVDT-Y-2000-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.65±0.13 | 0.50±0.12 | 0.00±0.00 |
| BR-9943DMR-SR- | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.40±0.11 | 0.50±0.12 | 0.10±0.10 |
| SAMMAZ-45 | 0.00±0.00 | 0.05±0.05 | 0.00±0.00 | 0.78±0.17 | 0.42±0.12 | 0.00±0.00 |
| | NS | NS | NS | NS | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

**Table 4.33..Abundance (mean ± SE) of fall armyworm egg mass and larva on 25 open pollinated varieties of maize evaluated in the early planting season of 2019 at Ibadan, Nigeria (N=20)**

| Variety | Egg mass | | | Larva | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 0.25±0.14$^{ab}$ | 0.08±0.08 | 0.00±0.00 | 0.25±0.11$^{abcd}$ | 0.15±0.10$^{ab}$ | 0.00±0.00 |
| SAMMAZ-37 | 0.08±0.08$^{ab}$ | 0.00±0.00 | 0.00±0.00 | 0.77±0.17$^{cd}$ | 0.08±0.08$^{ab}$ | 0.00±0.00 |
| EVDT-W-99-STR | 0.17±0.17$^{ab}$ | 0.23±0.17 | 0.00±0.00 | 0.25±0.18$^{abcd}$ | 0.15±0.10$^{ab}$ | 0.00±0.00 |
| SAMMAZ-14 | 0.18±0.09$^{ab}$ | 0.06±0.06 | 0.00±0.00 | 0.28±0.11$^{abcd}$ | 0.38±0.13$^{b}$ | 0.00±0.00 |
| SAMMAZ-52 | 0.33±0.19$^{ab}$ | 0.00±0.00 | 0.00±0.00 | 0.17±0.11$^{bc}$ | 0.08±0.08$^{ab}$ | 0.07±0.07 |
| TZEE-Pop-STR- | 0.39±0.18$^{ab}$ | 0.07±0.07 | 0.00±0.00 | 0.31±0.13$^{abcd}$ | 0.00±0.00$^{a}$ | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 0.29±0.14$^{ab}$ | 0.06±0.06 | 0.00±0.00 | 0.12±0.08$^{a}$ | 0.18±0.10$^{ab}$ | 0.00±0.00 |
| SAMMAZ-38 | 0.36±0.2$^{ab}$ | 0.07±0.07 | 0.00±0.00 | 0.29±0.13$^{abcd}$ | 0.29±0.13$^{ab}$ | 0.13±0.10 |
| SAMMAZ-16 | 0.58±0.23$^{ab}$ | 0.05±0.05 | 0.00±0.00 | 0.79±0.15$^{cd}$ | 0.16±0.12$^{ab}$ | 0.13±0.09 |
| SAMMAZ-19 | 0.91±0.34$^{b}$ | 0.00±0.00 | 0.00±0.00 | 0.36±0.15$^{abcd}$ | 0.00±0.00$^{a}$ | 0.00±0.00 |
| DMR-LSR-Y | 0.33±0.19$^{ab}$ | 0.08±0.08 | 0.00±0.00 | 0.44±0.19$^{abcd}$ | 0.00±0.00$^{a}$ | 0.00±0.00 |
| SAMMAZ-31 | 0.18±0.18$^{b}$ | 0.00±0.00 | 0.00±0.00 | 0.82±0.23$^{d}$ | 0.00±0.00$^{a}$ | 0.06±0.06 |
| 2008-SYN-EE-W-DT | 0.25±0.12$^{ab}$ | 0.00±0.00 | 0.00±0.00 | 0.30±0.11$^{abcd}$ | 0.15±0.08$^{ab}$ | 0.05±0.05 |
| 2008-EVDT-STR-Y | 0.36±0.20$^{ab}$ | 0.00±0.00 | 0.00±0.00 | 0.27±0.14$^{abcd}$ | 0.00±0.00$^{a}$ | 0.00±0.00 |
| SAMMAZ-15 | 0.19±0.10$^{ab}$ | 0.05±0.05 | 0.00±0.00 | 0.19±0.10$^{abc}$ | 0.05±0.05$^{ab}$ | 0.00±0.00 |
| TZE-W-Pop-DT-STR | 0.00±0.00$^{a}$ | 0.00±0.00 | 0.00±0.00 | 0.14±0.14$^{bc}$ | 0.25±0.16$^{ab}$ | 0.00±0.00 |
| BR-9928-DMR-SR-Y | 0.05±0.05$^{a}$ | 0.00±0.00 | 0.00±0.00 | 0.42±0.16$^{abcd}$ | 0.12±0.08$^{ab}$ | 0.00±0.00 |
| SAMMAZ-29 | 0.00±0.00$^{a}$ | 0.00±0.00 | 0.00±0.00 | 0.73±0.20$^{bcd}$ | 0.14±0.14$^{ab}$ | 0.00±0.00 |
| SAMMAZ-17 | 0.00±0.00$^{a}$ | 0.06±0.06 | 0.00±0.00 | 0.33±0.13$^{abcd}$ | 0.00±0.00$^{a}$ | 0.00±0.00 |
| SAMMAZ-32 | 0.31±0.13$^{ab}$ | 0.15±0.10 | 0.00±0.00 | 0.46±0.14$^{abcd}$ | 0.08±0.08$^{ab}$ | 0.00±0.00 |
| SUWAN-1-SR-Y | 0.40±0.16$^{ab}$ | 0.13±0.09 | 0.00±0.00 | 0.27±0.15$^{abcd}$ | 0.13±0.09$^{ab}$ | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00$^{a}$ | 0.00±0.00 | 0.00±0.00 | 0.67±0.21$^{abcd}$ | 0.00±0.00$^{a}$ | 0.10±0.10 |
| EVDT-Y-2000-STR | 0.33±0.19$^{ab}$ | 0.00±0.00 | 0.00±0.00 | 0.25±0.13$^{abcd}$ | 0.00±0.00$^{a}$ | 0.14±0.14 |
| BR-9943-DMR-SR | 0.36±0.24$^{ab}$ | 0.25±0.18 | 0.00±0.00 | 0.36±0.15$^{abcd}$ | 0.00±0.00$^{a}$ | 0.00±0.00 |
| SAMMAZ-45 | 0.26±0.17$^{ab}$ | 0.05±0.05 | 0.00±0.00 | 0.37±0.11$^{abcd}$ | 0.05±0.05$^{ab}$ | 0.00±0.00 |
| | | NS | NS | | | NS |

Mean values in a column followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test.
NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

week was observed on SAMMAZ-14. There was also a significant difference in the abundance of larvae found on SAMMAZ-14 and those without larvae at 5-WAS in the early maize planting season of 2019. No significant difference was however observed amongst maize varieties at 7-WAS where the abundance of FAW larvae ranged from 0.00±0.00 in most varieties to 0.14±0.14 in EVDT-Y-2000-STR.

#### 4.4.18. Abundance of fall armyworm egg mass and larva on 25 open pollinated varieties of maize in the late planting seasons of 2019

In the late planting season of 2019 (Table 4.34), abundance of egg mass was very low with a range of 0.00±0.00 to 0.19±0.14 at 3-WAS and 0.00±0.00 to 0.05±0.05 at 5-WAS. At 7-WAS, no egg mass was found on all varieties. No significant difference was observed in the abundance of egg mass laid on all varieties at all weeks of observation in the late maize season of 2019. At 3-WAS in the late maize season of 2019, larval abundance ranged from 0.00±0.00 on several varieties to 0.40±0.16 on SAMMAZ-14. Similarly, at 5-WAS, larval abundance ranged from 0.00±0.00 on several varieties to 0.50±0.12 on SAMMAZ-52. Very few numbers of larvae were observed on DMR-LSR-Y (0.06±0.06) and SAMMAZ-45 (0.05±0.05) at 7-WAS while all others had no larvae. There was a significant difference in the number of larvae observed on varieties with abundance values of 0.00±0.00 and SAMMAZ-52 at 5-WAS. On the other hand, no significant difference was found between the number of larvae on all varieties at 3-WAS and 7-WAS in the late maize planting season of 2019.

#### 4.4.19. Foliar damage by fall armyworm on 25 open pollinated varieties of maize in the 2018 and 2019 planting seasons

All varieties evaluated for resistance to foliar damage by FAW during the early and late maize planting seasons of 2018 showed moderate susceptibility in at least one of the weeks of observation (Table 4.35). At 3-WAS, foliar damage scores ranged from 3.0 (moderately susceptible response) to 4.0 (susceptible response). However, only varieties EVDT-W-99-STR, SAMMAZ-52, TZE-W-DT-STR-C4, SAMMAZ-19, SAMMAZ-31 and SAMMAZ-29 were susceptible to the damage at 3-WAS in the early season of 2018. Furthermore, at 5-WAS and also at 7-WAS in the early season of 2018, foliar damage scores ranged from 2.0 (moderately resistant) to 3.0 (moderately susceptible) with 2008-

**Table 4.34. Abundance (mean±SE) of fall armyworm egg mass and larval on 25 open pollinated varieties of maize in the late maize planting season of 2019 at Ibadan, Nigeria (N=20)**

| Variety | Egg mass | | | Larva | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 0.17±0.11 | 0.00±0.00 | 0.00±0.00 | 0.08±0.08 | 0.00±0.00[ab] | 0.00±0.00 |
| SAMMAZ-37 | 0.10±0.07 | 0.00±0.00 | 0.00±0.00 | 0.20±0.12 | 0.25±0.10[ab] | 0.00±0.00 |
| EVDT-W-99-STR | 0.05±0.05 | 0.00±0.00 | 0.00±0.00 | 0.40±0.15 | 0.40±0.13[ab] | 0.00±0.00 |
| SAMMAZ-14 | 0.07±0.07 | 0.00±0.00 | 0.00±0.00 | 0.40±0.16 | 0.13±0.10[ab] | 0.00±0.00 |
| SAMMAZ-52 | 0.05±0.05 | 0.00±0.00 | 0.00±0.00 | 0.05±0.05 | 0.50±0.12[b] | 0.00±0.00 |
| TZEE-Pop-STR | 0.07±0.07 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00[ab] | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.25±0.12 | 0.20±0.09[ab] | 0.00±0.00 |
| SAMMAZ-38 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.18±0.10 | 0.13±0.09[ab] | 0.00±0.00 |
| SAMMAZ-16 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00[a] | 0.00±0.00 |
| SAMMAZ-19 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.25±0.25 | 0.00±0.00[a] | 0.00±0.00 |
| DMR-LSR-Y | 0.19±0.14 | 0.00±0.00 | 0.00±0.00 | 0.13±0.09 | 0.24±0.11[ab] | 0.06±0.06 |
| SAMMAZ-31 | 0.17±0.17 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.17±0.17[ab] | 0.00±0.00 |
| 2008-SYN-EE-W-DT | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00[a] | 0.00±0.00 |
| 2008-EVDT-STR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.25±0.16 | 0.14±0.14[ab] | 0.00±0.00 |
| SAMMAZ-15 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.06±0.06 | 0.27±0.21[ab] | 0.00±0.00 |
| TZE-W-Pop-DT-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00[a] | 0.00±0.00 |
| BR9928DMR-SR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00[a] | 0.00±0.00 |
| SAMMAZ-29 | 0.00±0.00 | 0.05±0.05 | 0.00±0.00 | 0.15±0.11 | 0.35±0.11[ab] | 0.00±0.00 |
| SAMMAZ-17 | 0.05±0.05 | 0.00±0.00 | 0.00±0.00 | 0.15±0.11 | 0.25±0.10[ab] | 0.00±0.00 |
| SAMMAZ-32 | 0.05±0.05 | 0.00±0.00 | 0.00±0.00 | 0.16±0.09 | 0.21±0.12[ab] | 0.00±0.00 |
| SUWAN-1-SR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.25±0.25 | 0.25±0.25[ab] | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.20±0.12 | 0.35±0.11[ab] | 0.00±0.00 |
| EVDT-Y-2000-STR | 0.05±0.05 | 0.00±0.00 | 0.00±0.00 | 0.15±0.08 | 0.25±0.10[ab] | 0.00±0.00 |
| BR-9943-DMR-SR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.05±0.05 | 0.05±0.05[ab] | 0.00±0.00 |
| SAMMAZ-45 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.35±0.13 | 0.10±0.07[ab] | 0.05±0.05 |
| | NS | NS | NS | NS | | NS |

Mean values in a column followed by the same letter are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test.
NS: Not Significantly Different at $\alpha_{0.05}$
WAS: Weeks After Sowing

**Table 4.35. Fall armyworm foliar damage rating of 25 open pollinated varieties of maize evaluated in the early and late maize planting seasons of 2018 at Ibadan, Nigeria (N=20)**

| Variety | Early Season | | | Late Season | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 3 | 3 | 3 | 3 | 3 | 2 |
| SAMMAZ-37 | 3 | 3 | 2 | 3 | 4 | 3 |
| EVDT-W-99-STR | 4 | 3 | 3 | 3 | 4 | 2 |
| SAMMAZ-14 | 3 | 3 | 2 | 3 | 3 | 3 |
| SAMMAZ-52 | 4 | 3 | 3 | 3 | 3 | 3 |
| TZEE-Pop-STR-QPM-Y | 3 | 3 | 2 | 3 | 3 | 2 |
| TZE-W-DT-STR-C4 | 4 | 3 | 3 | 3 | 3 | 2 |
| SAMMAZ-38 | 3 | 3 | 3 | 3 | 3 | 3 |
| SAMMAZ-16 | 3 | 3 | 3 | 3 | 3 | 2 |
| SAMMAZ-19 | 4 | 3 | 3 | 3 | 3 | 3 |
| DMR-LSR-Y | 3 | 3 | 3 | 3 | 3 | 2 |
| SAMMAZ-31 | 4 | 3 | 3 | 3 | 3 | 3 |
| 2008-SYN-EE-W-DT-STR | 3 | 2 | 2 | 3 | 3 | 3 |
| 2008-EVDT-STR-Y | 3 | 2 | 2 | 3 | 3 | 2 |
| SAMMAZ-15 | 3 | 3 | 2 | 2 | 2 | 3 |
| TZE-W-Pop-DT-STR-QPM-C0 | 3 | 3 | 3 | 3 | 3 | 3 |
| BR-9928-DMR-SR-Y | 3 | 3 | 3 | 3 | 3 | 2 |
| SAMMAZ-29 | 4 | 3 | 3 | 2 | 3 | 3 |
| SAMMAZ-17 | 3 | 3 | 3 | 3 | 3 | 3 |
| SAMMAZ-32 | 3 | 3 | 3 | 3 | 3 | 3 |
| SUWAN-1-SR-Y | 3 | 3 | 2 | 3 | 3 | 3 |
| SAMMAZ-26 | 3 | 3 | 2 | 3 | 3 | 3 |
| EVDT-Y-2000-STR | 3 | 2 | 2 | 3 | 3 | 3 |
| BR-9943-DMR-SR-W | 3 | 3 | 3 | 3 | 3 | 3 |
| SAMMAZ-45 | 3 | 3 | 3 | 3 | 3 | 3 |
| SEM | 0.172 | 0.183 | 0.151 | 0.193 | 0.182 | 0.14 |

0 – 5 foliar damage rating scale: 0 – Highly resistant; 1 – Resistant; 2 – Moderately resistant; 3 – Moderately susceptible; 4 – Susceptible; 5 – Highly susceptible

WAS: Weeks After Sowing

SEM: Standard Error of Means

-SYN-EE-W-DT-STR, 2008-EVDT-STR-Y and EVDT-Y-2000-STR showing a consistent mean score of 2.0 in both weeks.

In the late season of 2018, only SAMMAZ-15 and SAMMAZ-29 had foliar damage scores of 2.0 while all other varieties had scores of 3.0 (Table 4.35). On the other hand, at 5-WAS, foliar damage scores ranged from 2.0 – 4.0 with susceptible responses observed in SAMMAZ-37 and EVDT-W-99-STR while SAMMAZ-15 alone showed moderate resistance. At 7-WAS, only eight varieties had moderately resistant scores of 2.0; all others showed moderate susceptibility to foliar damage by FAW.

Foliar damage scores in the early and late maize planting seasons of 2019 (Table 4.36) also ranged from 2.0 (moderately resistant response) to 3.0 (moderately susceptible response). In the early season of 2019, varieties SAMMAZ-52, TZE-W-DT-STR-C4, SAMMAZ-19, 2008-EVDT-STR-Y and BR9928DMR-SR-Y consistently showed a foliar score of 2.0 at 3-, 5- and 7-WAS. In contrast, only TZE-Y-DT-STR-C4, SAMMAZ-15 and BR9928DMR-SR-Y had foliar damage scores of 2.0 in the late season of 2019.

### 4.4.20. Linear regression of fall armyworm larval abundance and foliar damage on maize plants in the early and late planting season of 2018 and 2019

There was a significant and relatively strong relationship between larval abundance and foliar damage observed on maize plants (Fig. 4.17) at 5-WAS ($r = 0.5358$; $p = 0.0058$) but not at 3-WAS ($r = 0.3488$; $p = 0.0875$) or at 7-WAS ($r = 0.0916$; $p = 0.6631$) in the early season of 2018. On the other hand, a significant and relatively strong relationship was observed between larval abundance and foliar damage on maize plants (Fig. 4.18) at 3-WAS ($r = 0.6348$; $p = 0.0007$) and at 5-WAS ($r = 0.4812$; $p = 0.0149$) but not at 7-WAS ($r = 0.1983$; $p = 0.3421$) in the late season of 2018.

Also, in the early maize planting season of 2019, a relatively strong and significant relationship was observed between larval abundance and foliar damage on maize plants (Fig. 4.19) at 3-WAS ($r = 0.6055$; $p = 0.0013$) and at 5-WAS ($r = 0.4776$; $p = 0.0158$) but not at 7-WAS ($r = 0.0506$; $p = 0.8102$).

**Table 4.36. Fall armyworm foliar damage rating of 25 open pollinated varieties of maize evaluated in the early and late maize planting seasons of 2019 at Ibadan, Nigeria (N=20)**

| Variety | Early Season | | | Late Season | | |
|---|---|---|---|---|---|---|
| | 3-WAS | 5-WAS | 7-WAS | 3-WAS | 5-WAS | 7-WAS |
| TZE-Y-DT-STR-C4 | 3 | 2 | 2 | 2 | 2 | 2 |
| SAMMAZ-37 | 3 | 2 | 2 | 2 | 3 | 2 |
| EVDT-W-99-STR | 2 | 2 | 3 | 3 | 3 | 2 |
| SAMMAZ-14 | 3 | 2 | 2 | 3 | 3 | 2 |
| SAMMAZ-52 | 2 | 2 | 2 | 2 | 3 | 3 |
| TZEE-Pop-STR-QPM-Y | 3 | 2 | 3 | 2 | 3 | 2 |
| TZE-W-DT-STR-C4 | 2 | 2 | 2 | 2 | 3 | 2 |
| SAMMAZ-38 | 2 | 2 | 3 | 2 | 3 | 2 |
| SAMMAZ-16 | 3 | 2 | 2 | 2 | 2 | 2 |
| SAMMAZ-19 | 2 | 2 | 2 | 2 | 3 | 2 |
| DMR-LSR-Y | 3 | 2 | 2 | 2 | 3 | 2 |
| SAMMAZ-31 | 3 | 2 | 3 | 2 | 3 | 2 |
| 2008-SYN-EE-W-DT-STR | 3 | 3 | 2 | 2 | 3 | 2 |
| 2008-EVDT-STR-Y | 2 | 2 | 2 | 2 | 3 | 2 |
| SAMMAZ-15 | 3 | 2 | 2 | 2 | 2 | 2 |
| TZE-W-Pop-DT-STR-QPM-C0 | 2 | 3 | 2 | 2 | 3 | 3 |
| BR-9928-DMR-SR-Y | 2 | 2 | 2 | 2 | 2 | 2 |
| SAMMAZ-29 | 3 | 3 | 2 | 2 | 3 | 2 |
| SAMMAZ-17 | 3 | 3 | 2 | 2 | 3 | 2 |
| SAMMAZ-32 | 3 | 2 | 2 | 2 | 3 | 2 |
| SUWAN-1-SR-Y | 3 | 2 | 2 | 2 | 3 | 2 |
| SAMMAZ-26 | 3 | 2 | 2 | 2 | 3 | 2 |
| EVDT-Y-2000-STR | 3 | 2 | 3 | 3 | 3 | 2 |
| BR-9943-DMR-SR-W | 3 | 2 | 2 | 3 | 3 | 2 |
| SAMMAZ-45 | 3 | 2 | 2 | 2 | 3 | 2 |
| SEM | 0.129 | 0.138 | 0.13 | 0.13 | 0.17 | 0.10 |

0 – 5 foliar damage rating scale: 0 – Highly resistant; 1 – Resistant; 2 – Moderately resistant; 3 – Moderately susceptible; 4 – Susceptible; 5 – Highly susceptible
WAS: Weeks After Sowing
SEM: Standard Error of Means

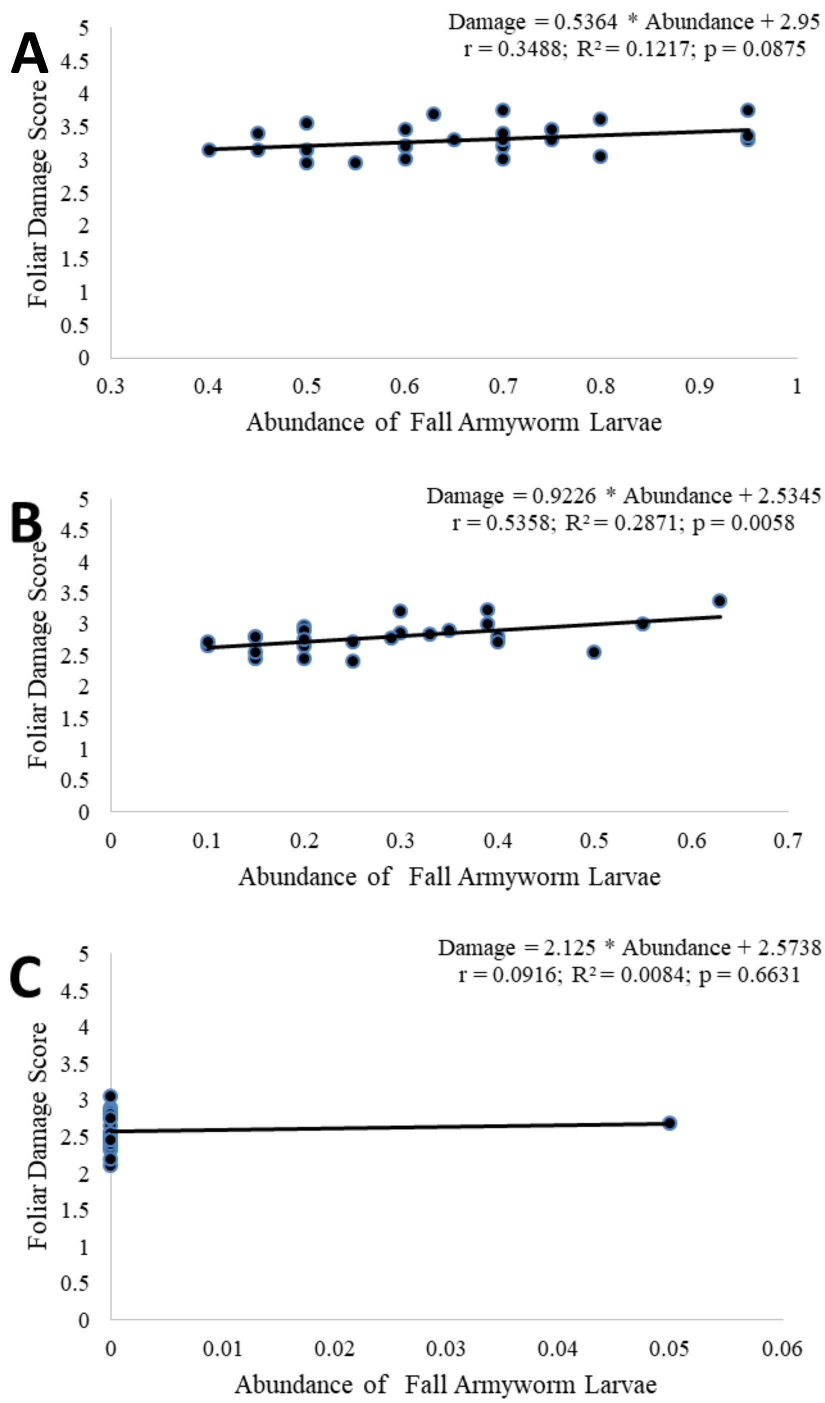



**Figure 4.17. Linear regression of fall armyworm larval abundance and foliar damage on maize plants in the early planting season of 2018 (a) three weeks after sowing (b) five weeks after sowing (c) seven weeks after sowing**

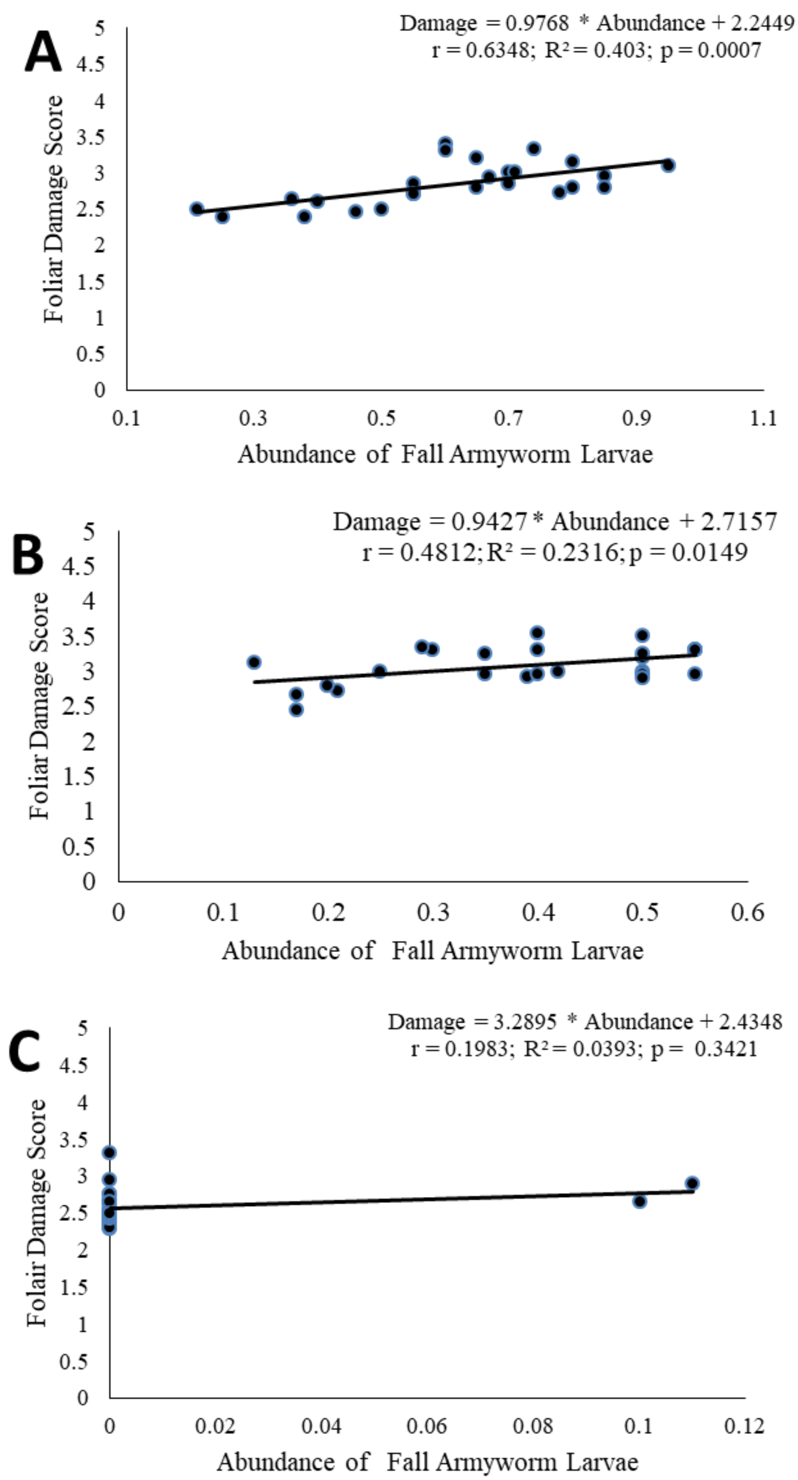



**Figure 4.18. Linear regression of fall armyworm larval abundance and foliar damage on maize plants in the late planting season of 2018**
**(a) three weeks after sowing (b) five weeks after sowing (c) seven weeks after sowing**

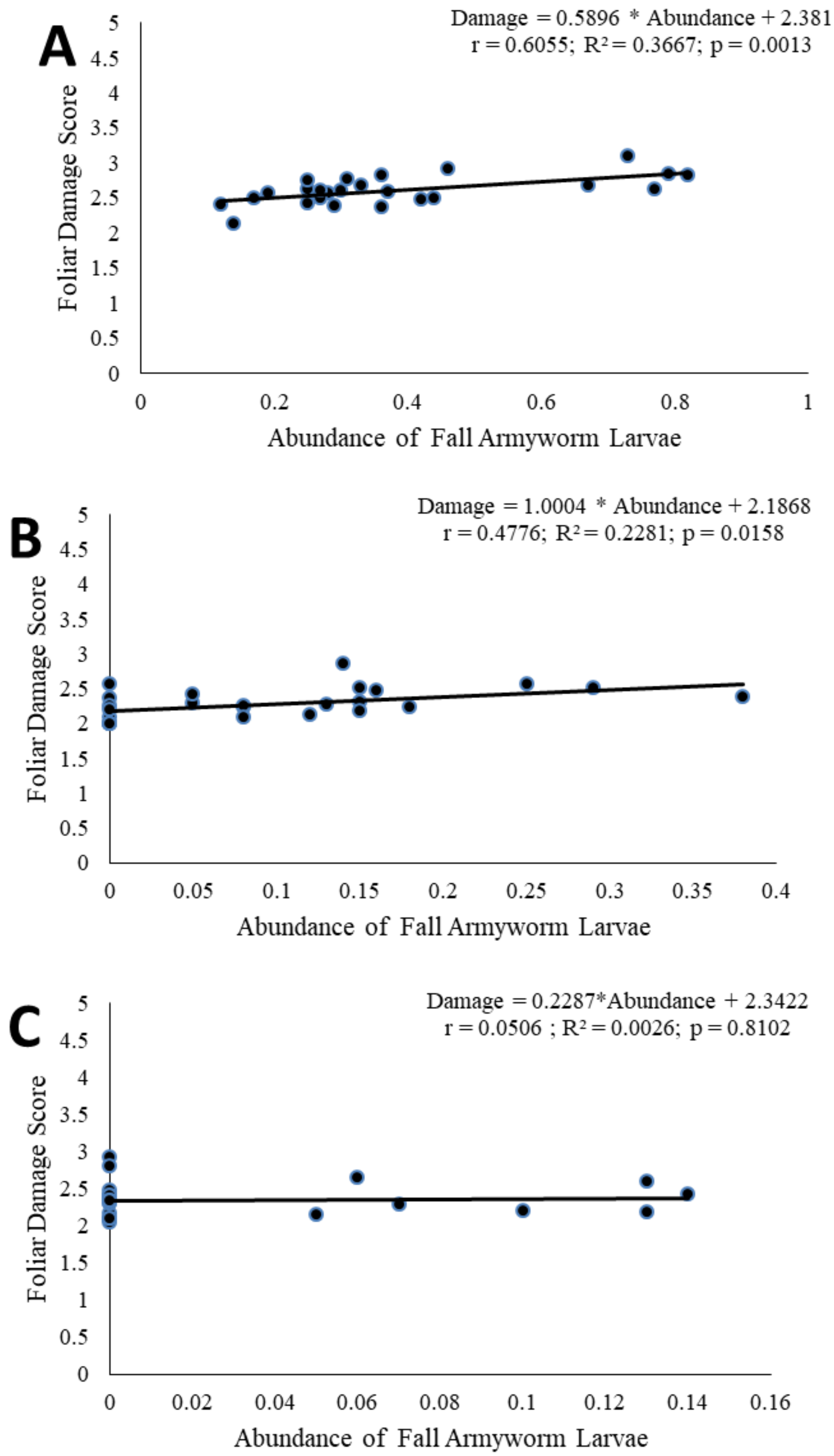



**Figure 4.19. Linear regression of fall armyworm larval abundance and foliar damage on maize plants in the early planting season of 2019 (a) three weeks after sowing (b) five weeks after sowing (c) seven weeks after sowing**

Similarly, there was a significant and relatively strong relationship between larval abundance and foliar damage on maize plants (Fig. 4.20) at 3-WAS (r = 0.5922; $p$ = 0.0018) and at 5-WAS (r = 0.4684; $p$ = 0.0182) but not at 7-WAS (r = 0.0327; $p$ = 0.8768) in the late season of 2019.

### 4.4.21. Abundance (mean ± SE) of stem borer and fall armyworm larva in stems and cobs of 25 open pollinated varieties of maize in the early planting seasons of 2018

In the early planting season of 2018, stem borer larvae were found in the stems of most varieties, with the highest (1.38±1.24) numbers occurring in 2008-EVDT-STR-Y (Table 4.37.). In contrast, no FAW larvae were found in maize stems within the same period. There was no significant difference in the number of stem borers found in stems of all varieties in the early planting season. Similarly, abundance of stem borers in maize cobs in the early planting season ranged from 0.00±0.00 in both EVDT-W-99-STR and SAMMAZ-31 to TZE-Y-DT-STR-C4 (2.50±1.38) > TZE-W-Pop-DT-STR-QPM-C0 (2.50±1.31). There was, however, no significant difference in the abundance of stem borers occurring in all evaluated varieties. In addition, with the exception SAMMAZ-17 (0.38±0.26), SAMMAZ-38 (0.13±0.13) and SAMMAZ-32 (0.13±0.13), no stem borer larvae were found in the cobs of the maize varieties. Also, no significant difference was observed in the number of FAW larvae occurring in the cobs of varieties in the early maize planting season of 2018.

### 4.4.22. Abundance (mean ± SE) of stem borer and fall armyworm larva in stems and cobs of 25 open pollinated varieties of maize in the late planting seasons of 2018

In the late planting season of 2018, abundance of stem borer larvae in maize stems ranged from 0.00±0.00 in several varieties to 2.00±1.07 in TZE-W-Pop-DT-STR-QPM-C0 (Table 4.38). All other varieties had intermediate values and were not significantly different from the varieties with the highest or lowest values. On the other hand, the highest (0.88±0.52) abundance of stem borer larvae in maize cobs during the period was observed in SAMMAZ-37 followed by SAMMAZ-15 with 0.80±0.37. No significant difference was however found in the abundance of stem borer larvae in the stems and cobs of all varieties in the late planting season of 2018. No FAW larvae were found in maize stems (Table 4.38). In contrast, cobs of several varieties were infested with FAW larvae with the highest numbers occurring in and only a few occurred in SAMMAZ-45

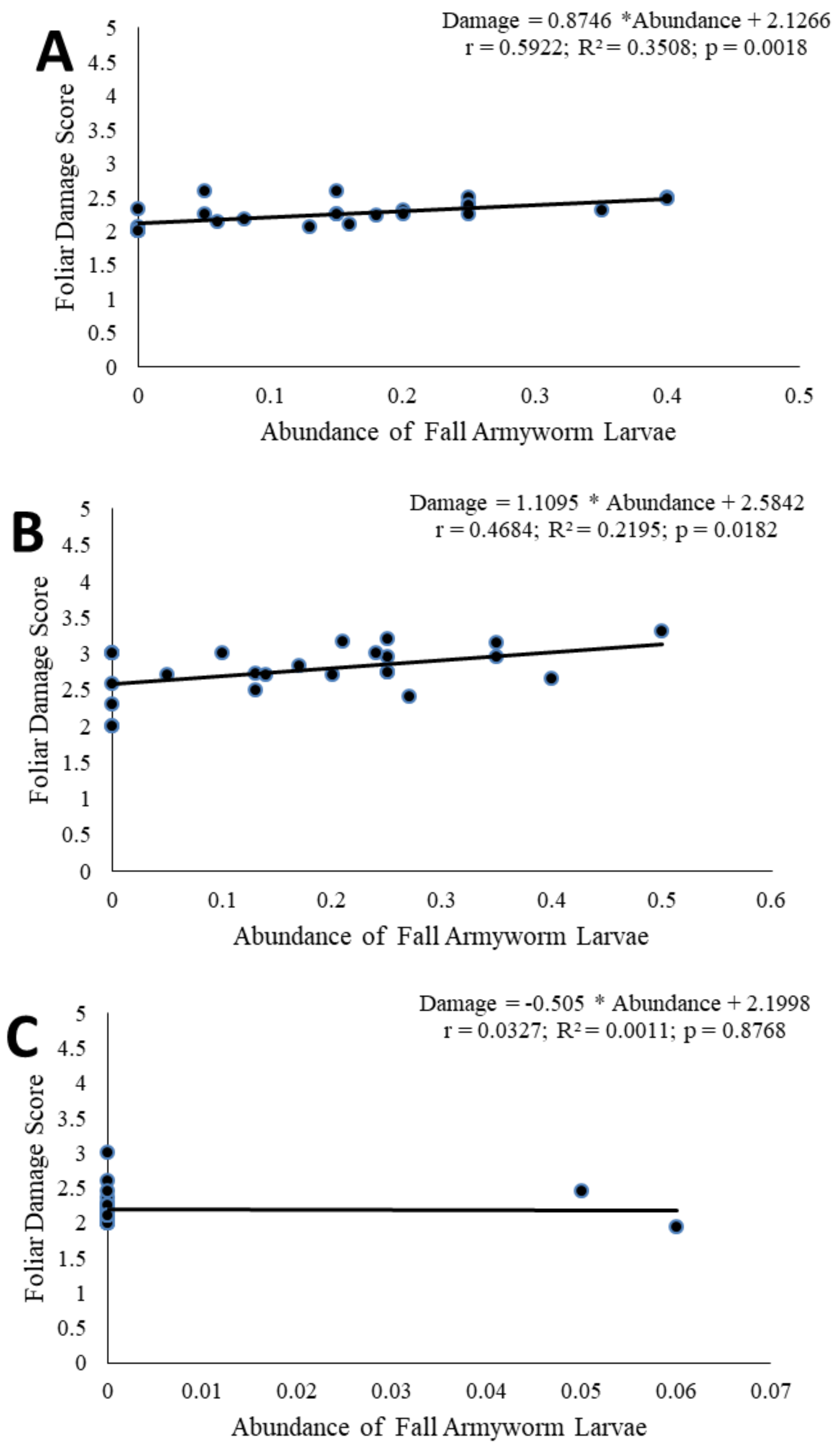



**Figure 4.20. Linear regression of fall armyworm larval abundance and foliar damage on maize plants in the late planting season of 2019 (a) three weeks after sowing (b) five weeks after sowing (c) seven weeks after sowing**

**Table 4.37. Abundance (mean ± SE) of stem borer and fall armyworm larva in maize stems and cobs during the early planting seasons of 2018 at Ibadan, Nigeria**

| Variety | Abundance in stems | | Abundance in cobs | |
|---|---|---|---|---|
| | **SB** | **FAW** | **SB** | **FAW** |
| TZE-Y-DT-STR-C4 | 0.38±0.26 | 0.00±0.00 | 2.50±1.38 | 0.00±0.00 |
| SAMMAZ-37 | 0.00±0.00 | 0.00±0.00 | 1.29±0.42 | 0.00±0.00 |
| EVDT-W-99-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-14 | 0.00±0.00 | 0.00±0.00 | 0.29±0.29 | 0.00±0.00 |
| SAMMAZ-52 | 1.00±0.54 | 0.00±0.00 | 0.63±0.32 | 0.00±0.00 |
| TZEE-Pop-STR-QPM-Y | 0.25±0.16 | 0.00±0.00 | 1.45±0.75 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 0.75±0.41 | 0.00±0.00 | 1.88±0.83 | 0.00±0.00 |
| SAMMAZ-38 | 0.00±0.00 | 0.00±0.00 | 1.00±0.72 | 0.13±0.13 |
| SAMMAZ-16 | 0.13±0.13 | 0.00±0.00 | 0.88±0.58 | 0.00±0.00 |
| SAMMAZ-19 | 0.00±0.00 | 0.00±0.00 | 1.83±0.48 | 0.00±0.00 |
| DMR-LSR-Y | 0.00±0.00 | 0.00±0.00 | 1.00±0.44 | 0.00±0.00 |
| SAMMAZ-31 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 0.13±0.13 | 0.00±0.00 | 0.80±0.37 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 1.38±1.24 | 0.00±0.00 | 0.29±0.18 | 0.00±0.00 |
| SAMMAZ-15 | 0.50±0.27 | 0.00±0.00 | 0.25±0.25 | 0.00±0.00 |
| TZE-W-Pop-DT-STR-QPM-C0 | 0.13±0.13 | 0.00±0.00 | 2.50±1.31 | 0.00±0.00 |
| BR9928DMR-SR-Y | 0.38±0.26 | 0.00±0.00 | 1.14±0.46 | 0.00±0.00 |
| SAMMAZ-29 | 0.38±0.26 | 0.00±0.00 | 2.43±1.38 | 0.00±0.00 |
| SAMMAZ-17 | 0.38±0.26 | 0.00±0.00 | 0.71±0.42 | 0.38±0.26 |
| SAMMAZ-32 | 0.13±0.13 | 0.00±0.00 | 0.57±0.20 | 0.13±0.13 |
| SUWAN-1-SR-Y | 0.00±0.00 | 0.00±0.00 | 0.13±0.13 | 0.00±0.00 |
| SAMMAZ-26 | 0.63±0.42 | 0.00±0.00 | 0.88±0.35 | 0.00±0.00 |
| EVDT-Y-2000-STR | 0.25±0.16 | 0.00±0.00 | 1.29±0.42 | 0.00±0.00 |
| BR-9943-DMR-SR-W | 0.38±0.18 | 0.00±0.00 | 0.50±0.19 | 0.00±0.00 |
| SAMMAZ-45 | 0.00±0.00 | 0.00±0.00 | 1.38±0.65 | 0.00±0.00 |
| | NS | NS | NS | NS |

Mean values in a column followed by the same letter are not significantly different at 5% significance level according to Tukey's Honestly Significant Difference test.
NS: Not Significant at $\alpha_{0.05}$
SB: Stem Borer species
FAW: Fall armyworm species

**Table 4.38. Abundance (mean ± SE) of stem borer and fall armyworm larva in maize stems and cobs during the late maize planting seasons of 2018 at Ibadan, Nigeria**

| Variety | Abundance in stems | | Abundance in cobs | |
|---|---|---|---|---|
| | **SB** | **FAW** | **SB** | **FAW** |
| TZE-Y-DT-STR-C4 | 0.40±0.25 | 0.00±0.00 | 0.60±0.40 | 0.20±0.20 |
| SAMMAZ-37 | 0.38±0.18 | 0.00±0.00 | 0.88±0.52 | 0.38±0.18 |
| EVDT-W-99-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-14 | 1.13±0.74 | 0.00±0.00 | 0.38±0.18 | 0.75±0.16 |
| SAMMAZ-52 | 1.14±0.46 | 0.00±0.00 | 0.43±0.20 | 0.71±0.47 |
| TZEE-Pop-STR-QPM-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 1.71±0.84 | 0.00±0.00 | 0.00±0.00 | 0.29±0.18 |
| SAMMAZ-38 | 0.75±0.41 | 0.00±0.00 | 0.38±0.26 | 0.38±0.18 |
| SAMMAZ-16 | 0.88±0.58 | 0.00±0.00 | 0.50±0.38 | 0.25±0.16 |
| SAMMAZ-19 | 1.00±0.55 | 0.00±0.00 | 0.20±0.20 | 0.40±0.25 |
| DMR-LSR-Y | 0.75±0.41 | 0.00±0.00 | 0.50±0.38 | 0.25±0.16 |
| SAMMAZ-31 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 1.00±0.58 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 0.50±0.50 | 0.00±0.00 | 0.75±0.75 | 0.75±0.48 |
| SAMMAZ-15 | 0.00±0.00 | 0.00±0.00 | 0.80±0.37 | 0.20±0.20 |
| TZE-W-Pop-DT-STR-QPM-C0 | 2.00±1.07 | 0.00±0.00 | 0.25±0.25 | 0.38±0.18 |
| BR-9928-DMR-SR-Y | 1.00±0.42 | 0.00±0.00 | 0.25±0.16 | 0.00±0.00 |
| SAMMAZ-29 | 1.00±0.45 | 0.00±0.00 | 0.40±0.25 | 0.00±0.00 |
| SAMMAZ-17 | 1.13±0.79 | 0.00±0.00 | 0.50±0.38 | 0.13±0.13 |
| SAMMAZ-32 | 1.43±0.95 | 0.00±0.00 | 0.71±0.36 | 0.00±0.00 |
| SUWAN-1-SR-Y | 1.00±0.38 | 0.00±0.00 | 0.25±0.16 | 0.75±0.25 |
| SAMMAZ-26 | 1.38±0.57 | 0.00±0.00 | 0.63±0.26 | 0.63±0.26 |
| EVDT-Y-2000-STR | 1.13±0.55 | 0.00±0.00 | 0.25±0.25 | 0.25±0.16 |
| BR-9943-DMR-SR-W | 1.25±0.49 | 0.00±0.00 | 0.13±0.13 | 0.38±0.26 |
| SAMMAZ-45 | 1.50±0.54 | 0.00±0.00 | 0.25±0.25 | 0.88±0.40 |
| | NS | NS | NS | NS |

NS: Not Significant at $\alpha_{0.05}$
SB: Stem Borer species
FAW: Fall armyworm species

(0.88±0.40) > 2008-EVDT-STR-Y (0.75±0.48) and SUWAN-1-SR-Y (0.75±0.25). There was however no significant difference in the abundance of FAW larvae in cobs of all maize varieties during the late maize planting season of 2018.

### 4.4.23. Abundance (mean ± SE) of stem borer and fall armyworm larva in stems and cobs of 25 open pollinated varieties of maize in the early planting seasons of 2019

During the early planting season of 2019 (Table 4.39.) abundance of stem borer larva in maize stems ranged from 0.00±0.00 in SAMMAZ-19 and SAMMAZ-26 to 2.00±0.63 in SAMMAZ-16 and 1.86±1.42 in TZE-W-DT-STR-C4. There was no significant difference in the abundance of stem borers occurring in stems of all maize varieties. As in previous seasons, no FAW larvae were found in stems of all maize varieties. Stem borer larvae abundance in cobs during the early planting season of 2019 was lowest in BR-9943-DMR-SR-W (0.00±0.00) < SAMMAZ-52 (0.17±0.17) < 2008-EVDT-STR-Y (0.20±0.20) < EVDT-Y-2000-STR (0.29±0.18) < TZE-Y-DT-STR-C4 (0.33±0.21). On the other hand, the highest value occurred in cobs of variety EVDT-W-99-STR (3.00±1.68). There was a significant difference in the abundance of stem borer larva in cobs of varieties with the lowest and highest values. No FAW larvae were found in cobs of all varieties in the early planting season of 2019 with the exception of TZEE-Pop-STR-QPM-Y and EVDT-Y-2000-STR. These however had very low (0.13±0.13) abundance that were not significantly different from the other varieties.

### 4.4.24. Abundance (mean ± SE) of stem borer and fall armyworm larva in stems and cobs of 25 open pollinated varieties of maize in the late planting seasons of 2019

In the late maize planting season of 2019, abundance of stem borer and FAW larvae were relatively lower than in previous seasons (Table 4.40). Stem borer larval abundance in stems and cobs ranged from 0.00±0.00 to 0.13±0.13 and from 0.00±0.00 to 0.50±0.27 respectively. On the other hand, FAW larvae were neither found in maize stems or cobs in the late planting season of 2019. There was no significant difference in the abundance of stem borer or FAW larvae in stems or cob of all varieties.

**Table 4.39. Abundance (mean ± SE) of stem borer and fall armyworm larva in maize stems and cobs during the early maize planting seasons of 2019 at Ibadan, Nigeria**

| Variety | Stem | | Cob | |
|---|---|---|---|---|
| | SB | FAW | SB | FAW |
| TZE-Y-DT-STR-C4 | 0.67±0.67 | 0.00±0.00 | 0.33±0.21a | 0.00±0.00 |
| SAMMAZ-37 | 0.50±0.34 | 0.00±0.00 | 0.50±0.22ab | 0.00±0.00 |
| EVDT-W-99-STR | 1.25±0.48 | 0.00±0.00 | 3.00±1.68b | 0.00±0.00 |
| SAMMAZ-14 | 0.67±0.42 | 0.00±0.00 | 0.33±0.21ab | 0.00±0.00 |
| SAMMAZ-52 | 0.17±0.17 | 0.00±0.00 | 0.17±0.17a | 0.00±0.00 |
| TZEE-Pop-STR-QPM-Y | 0.17±0.17 | 0.00±0.00 | 0.83±0.40ab | 0.13±0.13 |
| TZE-W-DT-STR-C4 | 1.86±1.42 | 0.00±0.00 | 0.86±0.46ab | 0.00±0.00 |
| SAMMAZ-38 | 0.20±0.20 | 0.00±0.00 | 1.17±0.79ab | 0.00±0.00 |
| SAMMAZ-16 | 2.00±0.63 | 0.00±0.00 | 0.88±0.35ab | 0.00±0.00 |
| SAMMAZ-19 | 0.00±0.00 | 0.00±0.00 | 0.67±0.33ab | 0.00±0.00 |
| DMR-LSR-Y | 0.86±0.40 | 0.00±0.00 | 1.14±0.46ab | 0.00±0.00 |
| SAMMAZ-31 | 0.67±0.42 | 0.00±0.00 | 0.67±0.49ab | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 0.63±0.26 | 0.00±0.00 | 1.25±0.25ab | 0.00±0.00 |
| 2008-EVDT-STR-Y | 1.80±1.80 | 0.00±0.00 | 0.20±0.20a | 0.00±0.00 |
| SAMMAZ-15 | 0.25±0.16 | 0.00±0.00 | 0.88±0.74ab | 0.00±0.00 |
| TZE-W-Pop-DT-STR-QPM-C0 | 0.40±0.25 | 0.00±0.00 | 1.00±0.55ab | 0.00±0.00 |
| BR9928DMR-SR-Y | 1.00±0.57 | 0.00±0.00 | 0.38±0.18ab | 0.00±0.00 |
| SAMMAZ-29 | 0.17±0.17 | 0.00±0.00 | 1.33±0.96ab | 0.00±0.00 |
| SAMMAZ-17 | 1.14±0.74 | 0.00±0.00 | 0.43±0.20ab | 0.00±0.00 |
| SAMMAZ-32 | 0.67±0.67 | 0.00±0.00 | 2.00±1.29ab | 0.00±0.00 |
| SUWAN-1-SR-Y | 1.50±0.96 | 0.00±0.00 | 2.17±0.87ab | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.50±0.29ab | 0.00±0.00 |
| EVDT-Y-2000-STR | 0.14±0.14 | 0.00±0.00 | 0.29±0.18a | 0.13±0.13 |
| BR-9943-DMR-SR-W | 0.14±0.14 | 0.00±0.00 | 0.00±0.00a | 0.00±0.00 |
| SAMMAZ-45 | 1.13±0.72 | 0.00±0.00 | 0.50±0.27ab | 0.00±0.00 |
| | NS | NS | | NS |

Mean values in a column followed by the same letter are not significantly different at 5% significance level according to Tukey's Honestly Significant Difference test.

NS: Not Significant at $\alpha_{0.05}$

**Table 4.40. Abundance (mean ± SE) of stem borer and fall armyworm larva in maize stems and cobs during the late maize planting seasons of 2019 at Ibadan, Nigeria**

| Variety | Stem | | Cob | |
|---|---|---|---|---|
| | **SB** | **FAW** | **SB** | **FAW** |
| TZE-Y-DT-STR-C4 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-37 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| EVDT-W-99-STR | 0.13±0.13 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-14 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-52 | 0.00±0.00 | 0.00±0.00 | 0.50±0.27 | 0.00±0.00 |
| TZEE-Pop-STR-QPM-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-38 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-16 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-19 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| DMR-LSR-Y | 0.00±0.00 | 0.00±0.00 | 0.14±0.14 | 0.00±0.00 |
| SAMMAZ-31 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-15 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| TZE-W-Pop-DT-STR-QPM-C0 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| BR-9928-DMR-SR-Y | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-29 | 0.00±0.00 | 0.00±0.00 | 0.25±0.25 | 0.00±0.00 |
| SAMMAZ-17 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-32 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SUWAN-1-SR-Y | 0.13±0.13 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-26 | 0.00±0.00 | 0.00±0.00 | 0.13±0.13 | 0.00±0.00 |
| EVDT-Y-2000-STR | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| BR-9943-DMR-SR-W | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| SAMMAZ-45 | 0.00±0.00 | 0.00±0.00 | 0.13±0.13 | 0.00±0.00 |
| | NS | NS | NS | NS |

NS: Not Significant at $\alpha_{0.05}$
SB: Stem Borer species
FAW: Fall armyworm species

### 4.4.25. Grain yield from 25 open pollinated varieties of maize in the early and late planting seasons of 2018

In the early season of 2018 (Table 4.41), the highest (437.90±180.7) yield was obtained from SAMMAZ-17 while the lowest (60.80±12.1) was from SAMMAZ-31. Late season yield (Table 4.41) was generally lower than in the early season with EVDT-Y-2000-STR having the highest (288.60±62.99) grain yield value while SAMMAZ-31 again had the lowest (0.00±0.00). There was a significant difference in the grain yield from varieties with the highest and lowest values in both seasons of 2018. Furthermore, in the early maize planting season of 2019 (Table 4.42), SAMMAZ-29 had the lowest grain yield (32.33±26.04) while SAMMAZ-14 had the highest (193.0±87.25) value. In contrast, SAMMAZ-29 had the highest (168.50±141.8) grain yield in the late season of 2019 (Table 4.42). None of the varieties, however, differed significantly in grain yield during the early and late seasons of 2019.

**Table 4.41. Grain yield (mean ± SE) from 25 open pollinated varieties of maize in the early and late maize planting seasons of 2018 at Ibadan, Nigeria**

| Variety | Grain yield at harvest (g) | |
|---|---|---|
| | Early planting season | Late planting season |
| TZE-Y-DT-STR-C4 | 187.50±47.31$^{ab}$ | 77.50±23.90$^{ab}$ |
| SAMMAZ-37 | 121.00±18.87$^{ab}$ | 167.60±21.54$^{ab}$ |
| EVDT-W-99-STR | 104.00±0.00$^{ab}$ | 77.60±0.00$^{ab}$ |
| SAMMAZ-14 | 254.70±43.33$^{ab}$ | 139.70±34.63$^{ab}$ |
| SAMMAZ-52 | 385.00±188.10$^{ab}$ | 93.93±21.21$^{ab}$ |
| TZEE-Pop-STR-QPM-Y | 119.90±30.60$^{ab}$ | 41.50±0.00$^{ab}$ |
| TZE-W-DT-STR-C4 | 298.20±70.49$^{ab}$ | 190.80±47.76$^{ab}$ |
| SAMMAZ-38 | 212.30±23.24$^{ab}$ | 148.70±48.50$^{ab}$ |
| SAMMAZ-16 | 144.80±70.49$^{ab}$ | 150.70±46.56$^{ab}$ |
| SAMMAZ-19 | 196.00±115.10$^{ab}$ | 115.30±48.27$^{ab}$ |
| DMR-LSR-Y | 406.00±139.70$^{ab}$ | 184.30±50.92$^{ab}$ |
| SAMMAZ-31 | 60.80±12.10$^{b}$ | 0.00±0.00$^{b}$ |
| 2008-SYN-EE-W-DT-STR | 56.55±16.25$^{ab}$ | 108.00±35.05$^{ab}$ |
| 2008-EVDT-STR-Y | 116.50±46.70$^{ab}$ | 110.00±78.56$^{ab}$ |
| SAMMAZ-15 | 175.80±65.56$^{ab}$ | 204.50±95.54$^{ab}$ |
| TZE-W-Pop-DT-STR-QPM-C0 | 182.80±26.37$^{ab}$ | 249.40±49.16$^{ab}$ |
| BR-9928-DMR-SR-Y | 225.10±73.96$^{ab}$ | 223.50±85.09$^{ab}$ |
| SAMMAZ-29 | 166.80±43.29$^{ab}$ | 151.90±46.12$^{ab}$ |
| SAMMAZ-17 | 437.90±180.70$^{a}$ | 107.80±35.34$^{ab}$ |
| SAMMAZ-32 | 102.60±29.84$^{ab}$ | 250.10±103.60$^{ab}$ |
| SUWAN-1-SR-Y | 327.70±138.20$^{ab}$ | 167.20±27.57$^{ab}$ |
| SAMMAZ-26 | 175.90±34.20$^{ab}$ | 164.80±17.31$^{ab}$ |
| EVDT-Y-2000-STR | 372.50±175.30$^{ab}$ | 288.60±62.99$^{a}$ |
| BR-9943-DMR-SR-W | 217.50±104.80$^{ab}$ | 124.10±32.77$^{ab}$ |
| SAMMAZ-45 | 277.20±122.00$^{ab}$ | 143.80±34.65$^{ab}$ |

Mean values in a column followed by the same letter (s) are not significantly different at $\alpha_{0.05}$ according to Tukey's Honestly Significant Difference test

**Table 4.42. Grain yield (mean ± SE) from 25 open pollinated varieties of maize in the early and late maize planting seasons of 2019 at Ibadan, Nigeria**

| Variety | Grain yield at harvest (g) | |
|---|---|---|
| | Early planting season | Late planting season |
| TZE-Y-DT-STR-C4 | 77.35±36.75 | 102.00±0.00 |
| SAMMAZ-37 | 129.10±32.23 | 53.40±38.92 |
| EVDT-W-99-STR | 169.00±60.54 | 143.10±0.00 |
| SAMMAZ-14 | 193.00±87.25 | 30.45±2.85 |
| SAMMAZ-52 | 114.00±66.80 | 44.58±20.01 |
| TZEE-Pop-STR-QPM-Y | 86.63±22.83 | 0.00±0.00 |
| TZE-W-DT-STR-C4 | 78.67±25.24 | 93.20±0.00 |
| SAMMAZ-38 | 86.78±38.41 | 122.00±0.00 |
| SAMMAZ-16 | 133.60±45.26 | 0.00±0.00 |
| SAMMAZ-19 | 183.30±4.65 | 0.00±0.00 |
| DMR-LSR-Y | 80.08±21.86 | 44.50±9.50 |
| SAMMAZ-31 | 80.53±29.77 | 0.00±0.00 |
| 2008-SYN-EE-W-DT-STR | 161.80±46.53 | 0.00±0.00 |
| 2008-EVDT-STR-Y | 105.10±0.00 | 44.20±20.70 |
| SAMMAZ-15 | 91.72±25.48 | 0.00±0.00 |
| TZE-W-Pop-DT-STR-QPM-C0 | 50.30±32.10 | 0.00±0.00 |
| BR-9928-DMR-SR-Y | 133.30±57.72 | 0.00±0.00 |
| SAMMAZ-29 | 32.33±26.04 | 168.50±141.8 |
| SAMMAZ-17 | 79.67±33.82 | 54.25±3.35 |
| SAMMAZ-32 | 132.60±78.30 | 21.70±1.00 |
| SUWAN-1-SR-Y | 59.87±41.75 | 36.70±0.00 |
| SAMMAZ-26 | 45.50±0.00 | 87.85±52.17 |
| EVDT-Y-2000-STR | 176.40±113.70 | 101.00±0.00 |
| BR-9943-DMR-SR-W | 50.77±21.94 | 78.08±10.01 |
| SAMMAZ-45 | 134.40±21.74 | 29.68±9.35 |
| | NS | NS |

NS: Not Significantly Different at $\alpha_{0.05}$

# CHAPTER FIVE

## DISCUSSION

In this study, farmers surveyed across maize producing agro-ecological zones (AEZ) of southwestern Nigeria experienced FAW damage in both 2016 and 2017. Also, maize damage by the pest was observed during the on-farm assessment in the AEZs. According to Abrahams *et al.* (2017), the existing environmental conditions in Africa favours FAW reproduction and its continued presence on the continent. Furthermore, in this study, infestation seemed to decrease from the southern guinea savanna to the humid forest agro-ecology. The humid forest or rainforest AEZ is characterized by relatively longer annual rainfall periods of 2000 mm and above (Oyenuga, 1967). In contrast, the southern guinea savanna zone represents the southern portion of the guinea savanna AEZ, which is the largest AEZ in Nigeria, with an average annual rainfall of 1051.7 mm (Oyenuga, 1967; Sowunmi and Akintola, 2010). The derived savanna occupies an intermediate position between the humid forest and southern guinea savanna, and is reported to receive an average annual rainfall of 1314 mm (Sowunmi and Akintola, 2010). In addition, a strong association was observed between AEZ and maize damage severity during the farmers' survey. Similarly, significantly higher damage severity to on-farm maize was observed in the humid AEZ during the on-farm survey suggesting that agro-ecological characteristics influence severity of maize damage by FAW in southwestern Nigeria.

Furthermore, most of the maize farmers surveyed in this study reported using conventional insecticides as the main control method against FAW in 2016 and 2017. A similar report was obtained from Ghana and Zambia where 72% and 60% of farmers respectively employed insecticides for FAW control on maize (Day *et al.*, 2017). Kumela *et al*. (2018) also reported that chemical spray application was the main method employed by most farmers in Ethiopia and Kenya. In a bid to reduce damage and save their harvest, smallholder farmers usually resort to spraying conventional insecticides, because they are quick-acting and most suitable for such insect pest outbreak situations (Dinham, 2003).

Chlorpyriphos, dichlorvos, dimethoate, beta-cyfluthrin, cypermethrin, deltamethrin, and lambda-cyhalothrin were also identified in the present study as the common insecticides sprayed for FAW control on maize in southwestern Nigeria. This agrees with Togola *et al.* (2018) who reported cypermethrin, deltamethrin, lambda-cyhalothrin, permethrin, and chlorpyriphos as common insecticide active ingredients used against FAW in Mokwa, north central Nigeria. Cases of excessive insecticide spray applications reported by some maize farmers in the present study was probably panic driven, since they were unfamiliar with the pest and had no knowledge of its control in 2016 and 2017. In addition to excessive insecticide spray application, maize farmers also reported using highly hazardous organophosphate (dimethoate) and pyrethroid ((bifluthrin) insecticides. According to FAO (2018b) several highly hazardous pesticides, including methomyl, methyl parathion, endosulfan and lindane, have been used against FAW in Africa.

Also, more than half of farmers interviewed in this study reported moderate effectiveness of insecticide against FAW on maize. According to Kumela *et al*. (2018) 46% and 60% of farmers in Ethiopia and Kenya, respectively, reported that insecticides were ineffective. The development of insecticide resistance in field populations of FAW, use of fake or adulterated insecticides, incorrect application rates or techniques, and wrong time of spray application are some of the factors affecting insecticide effectiveness for FAW control (Goergen *et al.,* 2016; Day *et al.,* 2017; Fatoretto *et al.,* 2017; FAO, 2018a; Kumela *et al.,* 2018; Rwomushana *et al.,* 2018; Kasoma *et al.,* 2020). Older FAW larvae, for example, usually hide and feed deep within maize whorls during the day. As such, insecticides must be sprayed directly into plant whorls very early or late in the day (FAO, 2018a; Kumela *et al.,* 2018). The absence of an association between insecticide spray times and insecticide effectiveness in this study was probably due to one or more of the aforementioned factors.

The use of conventional insecticides for pest control is attended by a number of problems like insecticide resistance, residue in foods, toxicity to non-target organisms and environmental contamination among others (Yu *et al.,* 2003; FAO, 2018a). However, biopesticides including microbial and botanical based extracts; biological control agents such as FAW predators, parasitoids and entomopathogens; insect growth regulators and semiochemicals have been recommended as lower risk alternatives to conventional pesticides for FAW management (FAO, 2018b, Bateman *et al.*, 2018). Cultural methods such as intercropping and push-pull systems have also been reported as effective and sustainable alternatives for FAW management in maize systems (FAO, 2018a; Midega *et al.*, 2018). Nevertheless, the preferred management option for FAW in Africa is an Integrated Pest Management program because it utilizes suitable combinations of all the aforementioned control options in a sustainable, eco-friendly and cost-effective manner (Day *et al.*, 2017; Bateman *et al.*, 2018).

In this study, FAW egg development was completed within an average of two days at 29.36±0.17$^{o}$C, 73.90±1.00% relative humidity, and 12 hours photoperiod. This agrees with Vickery (1929), Capinera (2001), and Sharanabasappa *et al.* (2018) that FAW eggs hatch within 2 –3 days. Furthermore, the larval stage, which consisted of six larval instars and a prepupal stage, was completed within 11 – 12 days under average conditions of 29.45±0.06$^{o}$C, 69.77±0.54%, 12 hours photoperiods. The number of larval instars observed in this study is in line with previous authors including Capinera (2000) and Prasanna *et al.* (2018). According to Ali *et al.* (1990), most FAW larvae develop through six instars especially at higher temperatures. Observed number of instars may however vary, depending on larval diet and rearing temperature (Ali *et al.*, 1990; Rojas *et al.*, 2018). Furthermore, total larval development in the present study occurred within 11 to 12 days. This period of larval development is shorter than the 14 – 19 days range reported outside Africa (Vickery, 1929; Chapman *et al.*, 1999a; Capinera, 2001; Sharanabasappa *et al.*, 2018).

Fall armyworm pupation takes 8 – 9 days during summers in North America and between 30 and 55 days in winter (Vickery, 1929; Capinera, 2001). Also, laboratory reared FAW in India completed pupation between 9 – 12 days (Sharanabasappa *et al.*, 2018). The 7 – 10 days pupal development period observed in this study was therefore consistent with the foregoing reports. Comparison of male and female moths in this study showed that males were smaller in body width than their female counterpart. Also, female moths were observed to consistently emerge a day earlier than the males from the same cohort and with the same pupation date.

Young maize leaves were preferred for oviposition by female FAW moths than stems in the present study (Prasanna *et al*., 2018). Female moths can, however, lay eggs on non-host plants or even on non-plant surfaces (Sparks, 1979; Rojas *et al.,* 2018). This probably explains why moths in the present study deposited eggs in rearing plastics and on paper strips in the present study. According to Sparks (1979), the indiscriminate deposition of egg masses by female on suitable and unsuitable objects occurs when FAW populations are high. However, in this study, egg mass was deposited under plastic lids and other non-plant surfaces even during experiments involving only a pair of FAW moths. This suggests that the observed indiscriminate deposition of eggs may not be due to high populations.

Unlike specialist insect species, generalist like FAW with a host range of more than 300 plant species (Montezano *et al.,* 2018) have been reported to have sensory limitations that constrain their abilities to differentiate between host suitability for larval development (Bernays, 2001). Rojas *et al.* (2018) also reported that the host suitability decisions are not made by the female FAW moths at the point of oviposition but by the neonate larvae. This is probably because FAW, unlike insects whose larval stages are confined to the host, has neonate larvae that can easily disperse by ‘ballooning’ off unsuitable plant hosts shortly after egg eclosion (Thompson, 1988; Zalucki *et al.,* 2002; Rojas *et al.,* 2018). The indiscriminate egg laying behavior FAW may thus be because females cannot differentiate suitable hosts or because they do not have ecological reasons for doing so.

Furthermore in the present study, egg masses were preferentially laid under maize leaves than on it. Also, a progressive decrease in the number of deposited egg mass from the distal portions of maize blades to the middle and proximal portion towards the stem was observed. This agrees with the statement that female FAW moths usually lay their eggs on leaf undersides (Sparks, 1979; Prasanna *et al.,* 2018) especially during periods of low population density (Sparks, 1979). The preference for the abaxial leaf side as opposed to the adaxial side may not be unconnected with the need to protect the eggs from direct exposure to sunlight and the possible desiccation they may be subjected to.

Studies on influence of feeding on FAW moth longevity might hold important consequences for pest risk analysis, especially as it relates to their dispersal across regions. As an invasive transboundary insect pest, FAW has successfully spread to Africa and Asia from its native origin in the Americas (Goergen *et al.,* 2016; Day *et al.,* 2017; Rwomushana *et al.,* 2018). It is generally speculated that the pest spread from its native America to Africa as contaminants of traded commodities or as stowaways on aircrafts or by wind-assisted flight (Cock *et al*., 2017; Assefa and Ayalew 2019; Kasoma *et al.*, 2020). While the first two channels seem more likely and are readily more accepted, wind-assisted flight is considered the least probable introduction route into Africa. Though FAW moths are known to undertake wind-assisted travels over several hundred kilometers at heights of several hundred metres in the Americas (Rose et al., 1975; Johnson, 1987; Westbrook *et al.*, 2016; Zhou *et al*., 2020), there is no evidence of the species ability to travel wind-assisted over very large distances like the one between the Americas and Africa. Nevertheless, whether as contaminants or as a stowaway, it is evident that the ability of unfed FAW moths to survive for up to seven days, as shown in the present study, enhanced its spread to and from the African continent.

Female FAW moths paired with three males each laid fewer eggs than females paired with only a male. The lower oviposition in females paired at 3♂:1♀ may be due to the absence of multiple mating opportunities for the females in confinement due to interferences from competing males**.** This observation agrees with the report of Sparks (1979) who stated that virgin female FAW mate once per night and usually make known their readiness to mate by releasing an appropriate sex pheromone to which two to several males respond and amongst which very rigorous fights occur until only one male succeeds to mate. The potato tuber moth, *Phthorimaea opercula* (Lepidoptera: Gelechiidae); the fall cankerworm, *Alsophila pometaria* (Lepidoptera: Geometridae); and the tomato leaf miner, *Tuta absoluta* (Lepidoptera: Gelechiidae) are some of the few moth species known to exhibit parthenogenesis (Liu *et al.*, 2018). However, isolated FAW virgin females in the present study laid unfertilized eggs which failed to hatch showing that female FAW moths are not parthenogenic.

In this study, food quantity was identified as an important factor influencing larval cannibalism in FAW populations. However, its effect on larval cannibalism was observed to be accentuated by the number and age of larvae being reared. On the other hand, the amount of space available to individual larvae in a cohort-reared FAW culture did not make any difference on observed percent mortality. As shown by observations of small larvae feeding together in the same maize plant whorl, cannibalism in FAW does not occur in populations composed of younger larvae instars (Vickery, 1929; Chapman *et al.*, 1999b). But as the larvae grow older, cannibalistic behaviour sets in amongst the conspecifics of the same or different ages or instars (Chapman *et al.,* 1999b; Kasoma *et al.,* 2020). It is believed that species that exhibit cannibalism do so to obtain certain direct benefits like higher survival, faster development and increased body mass (Church and Sherratt, 1996, Chapman *et al.*, 1999b; Kuate *et al*., 2019). They may also enjoy indirect benefits such as the reduction or elimination of future competition, predation or spread of diseases associated with larger populations (Kuate *et al.,* 2019; Kasoma *et al.,* 2020). On the other hand, cannibalism could lead to injury, reduction of fitness or increased risk of infection in cannibals (Polis, 1981; Chapman *et al.,* 1999b).

The field varietal studies also provided some insights on the period of FAW infestation in the study area. FAW eggs and larvae were observed as early as the third week after sowing, that is, at the four-leaf stage in both seasons of each year of field evaluation. This suggests that FAW eggs are laid as early as 10 days or two weeks after sowing, that is, when maize seedlings are at the two- or three-leaf stage (Prasanna *et al.*, 2018; FAO, 2018a). At this very young stage, the egg masses and the tiny neonate larvae on the infested plants often go unnoticed to the untrained eyes. The larvae thus continue to cause cryptic damage until the third or fourth week after sowing when foliar feeding damage has become conspicuous. Farmers in Ethiopia and Kenya mostly experienced damage to maize within the first two months after sowing (Kumela *et al.*, 2018). This latter report is consistent with the experience of about 90% of maize farmers in the present study.

According to FAO (2018a) farmers should scout their maize fields for FAW eggs and larvae every three to four days over a period of 40 days after sowing.

The decreasing number of egg masses recorded on plants as they progressed from the early-whorl vegetative stage to the tasseling stage in this study also confirms the preference of FAW females for young maize plants as oviposition sites. This agrees with Prasanna *et al.* (2018) who stated that maize plants are infested as early at the vegetative stage with the first generation of FAW emerging at V2 and completing its development on the infested plant after which emerged adults repeat the egg laying cycle – a process responsible for the occurrence of overlapping FAW generations on the same plant. The presence of FAW larvae in maize cobs at harvest during field evaluations suggests that moths can oviposit beyond the vegetative growth phase, when the plant has stopped producing the fresh tender leaves preferred for oviposition.

The importance of plant age to FAW infestation and foliar damage on maize is again reflected in this study by the decreasing population of larvae from the third to the seventh week after sowing. The occurrence of several feeding holes and 20 – 40 percent foliar damage to furl leaves even at the seventh of growth (when larval infestation was scanty on maize plants) however shows that observed damage severity is not always a true reflection of high larval infestation. This holds important consequences for Integrated Pest Management programs as it suggests that insecticides should not be applied for FAW control simply on the basis of observed foliar damage. On the contrary, decision making for fall armyworm control on maize should be based on data from actual field scouting for eggs and larvae (Sibanda, 2017; FAO, 2018a) as well as on visual evaluation of maize foliar damage.

All the maize varieties evaluated in this study had been developed with improved agronomic and environmental traits such as better yield, better protein quality, higher pro vitamin A content as well as tolerance to drought and low nitrogen (NACGRAB, 2016). However, they generally exhibited moderate response to foliar damage by FAW. According to Prasanna *et al.* (2018), native resistance in maize confers partial resistance because they are polygenic and quantitative. SAMMAZ-14, SAMMAZ-15, BR-

9928DMR-SR and BR-9943-DMR-SR varieties were developed with resistance to stem borer, with the last two varieties reported to be highly resistant to the pest (NACGRAB, 2016). However, BR-9928-DMR-SR and BR-9943-DMR-SR both showed partial response to foliar damage by FAW. Varieties like the genetically modified MON810 event confer partial resistance to FAW even though it was developed for stem borer control in maize (Prasanna *et al.*, 2018). The generally moderate seasonal damage severity on all evaluated varieties in this study may therefore be attributed to the ability of maize plants to compensate for foliar damage experienced over a short period (Kansiime *et al.,* 2019).

Furthermore, no FAW larva was found in maize stems in all seasons confirming that the larva does not tunnel or feed in stems like stem borer species. Larvae of stem borers species like *B. fusca* or *S. calamistis* usually tunnel and feed extensively in maize stems leading to stem weakness and lodging (Ong'amo *et al.,* 2016). In contrast, both stem borer and FAW larvae caused damage to maize kernels especially during the late planting season of 2018 when they were occasionally found feeding in the same ear although at different locations. This agrees with Day *et al.* (2017) who suspected possible interactions between FAW and other already existing insect pests of maize in Africa – notably stem borers. Hruska and Gould (1997) also reported a strong correlation in whorl stage infestation of FAW and *Diatraea lineolata* (Walker) in Managua, Nicaragua.

Although all varieties evaluated in this study yielded grains, the quantities were far below the expected average yield of three to four tonnes per hectare (NACGRAB, 2016). The low grain yield cannot however be completely attributed to fall armyworm damage. Vertebrate field pests including rodents and quelea birds attacked and destroyed cobs during grain filling stage in this study. Also, the higher abundance of stem borer species found in maize cobs caused more damage to kernels than other insect pest species.

Though maize yield losses caused by FAW in the present study cannot be accurately determined since insecticide protected plots were not set up for comparison with damaged plots (Ortega *et al.,* 1980; Hruska and Gould, 1997), one may infer from the foregoing that in the absence of the aforementioned non-FAW biotic stressors, grain yield loss attributable to FAW alone would be lower. While also reporting high levels of damage to on-farm maize in Eastern Zimbabwe, Baudron *et al*. (2019) reported lower damage estimates of 11.57% on yield compared to the 22 - 67% estimated yield losses in Ghana and Zambia (Abraham *et al*., 2017a) or the 32% and 47% yield losses reported in Ethiopia and Kenya (Kumela *et al*., 2018). Baudron *et al.* (2019) suspected that the higher yield estimates obtained by other authors may have been over-estimated because they were based on behavioural surveys of farmers' perception of FAW damage and not on vigorous field scouting methods. The foregoing does not rule out the fact that FAW infestation and damage can significantly impact yield if left uncontrolled. Already, maize damage by the fall armyworm has caused yield losses of between 8 – 20 million tonnes in Africa (ICIPE, 2020). Hruska and Gould (1997) also showed that between 15 and 73% of yield loss may be incurred when 55 to 100% of on-farm maize is infested at the middle or late growth phase.

# CHAPTER SIX

## CONCLUSIONS AND RECOMENDATIONS

Based on findings from the farmers' survey, on-farm damage assessment and field varietal screening, it was confirmed that the fall armyworm is a major pest of maize in the three maize producing agro-ecological zones of southwestern Nigeria. The study also showed significant interaction between agro-ecology and FAW damage severity with field maize cultivated in the humid forest agro-ecological zone being more vulnerable to FAW damage. Though egg mass infestations and abundance at the third and fifth week-after-sowing was consistently higher in the early than late season, infestation and abundance of fall armyworm were generally not statistically different in the two maize planting seasons With respective to FAW control, conventional chemicals were the main control method employed against FAW in the southwestern region of Nigeria. However, this method was adjudged to have moderate effectiveness by maize farmers in the region despite multiple spray applications. It was inferred that factors such as wrong spray application techniques and timing was probably responsible for the undesirable level of effectiveness.

Fall armyworm completed its entire lifecycle in Ibadan within 20 to 25 days with the egg, larval and pupal stages having developmental periods of between 2 – 3 days, 11 – 12 days and 7 – 10 days, respectively at an approximate average daily temperature of 30 $^{o}$C and relative humidity of 70%. Under these rearing conditions, FAW larvae went through six larval instar stages. Moth morphometrics showed that females are generally bigger than their male counterparts. Also, females preferred young maize plants for oviposition with egg infestations occurring as early as 10 to 14 days after field sowing, that is, when plants were at 2 – 3 leaf stage. In addition, female moths were shown to preferentially oviposit on the dorsal portion of leaf undersides. Even though egg-laying could continue well into the reproductive stage depending on moth population levels, field infestation of eggs was observed to reduce with plant age in all seasons. Furthermore, unfed FAW moths lived for up to a week while those that have access to food lived for about two weeks. Food abundance, larval population and larval age were identified to be more important factors affecting cannibalism in FAW populations than the amount of rearing space. Findings in the study suggest that cannibalism levels in FAW population could be significantly reduced while rearing FAW in a cohort if food quantity was offered proportionate to the number of larvae being reared.

All the open pollinated maize varieties evaluated in this study experienced FAW foliar damage but none was highly resistant (immune), resistant or completely susceptible to the pest. Instead they generally showed a moderate response to FAW foliar damage, even in the early planting season of 2018 where infestation and abundance of fall armyworm was higher. SAMMAZ-14, SAMMAZ-15, BR-9928DMR-SR and BR-9943DMR-SR varieties, which were developed with resistance to stem borers, also showed a moderate response to FAW foliar damage. The pink stem borer, *S. calamistis* was the most abundant stem borer species in the study area and may be found in association with FAW in maize cobs especially periods of high FAW infestations. Kernel damage and observed yield reduction in the present study were mainly caused by stem borer and vertebrate pest attack and not by FAW.

Based on the conclusions reached from the present study, it is recommended that:

i. Training be organized for farmers in the region on how to properly scout for and identify FAW eggs and larvae in maize fields.

ii. Maize farmers be taught how and when to spray their FAW infested fields for improved effectiveness if conventional chemicals must be used.

iii. Smallholder farmers are taught how to apply Integrated Pest Management principles for sustainable control of FAW control in southwestern Nigeria so as to put an end to the current overdependence on conventional insecticides in the region.

iii. In the absence of FAW resistant maize varieties, stem borer resistant maize varieties like BR9928DMR-SR may be planted in southwestern Nigeria

iv. Maize breeders develop improved varieties with resistance to both FAW and stemborers.

v. Laboratory rearing of FAW larvae may be done in cohorts provided sufficient and regular supply of abundant food is made available proportionate to the number of larvae being reared.

## 6.1. Contributions to knowledge

The following contributions have been made to existing knowledge in the field of entomology

i. Infestation and damage by the fall armyworm, *Spodoptera frugiperda* to field maize were higher in the humid forest than in the derived savanna and southern guinea savanna agroecological zones.

ii. Field infestation and abundance of *S. frugiperda* eggs and larvae were higher in the early maize planting season than the late season

iii. Field infestation and abundance of *S. frugiperda* eggs decreased with increasing plant age making the early whorl-stage more susceptible to damage than other growth stages.

iv. Fall armyworm completed its entire lifecycle within 20 to 25 days making it a multivoltine insect pest that can attack and damage field maize multiple times in a growing season.

v. The use of a 1♂:1♀ pairing ratio was more ideal when rearing *S. frugiperda* for laboratory studies.

vi. Cohort rearing of *S. frugiperda* larvae for laboratory studies was enhanced when larvae were fed abundantly and regularly.

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## APPENDICES

### Appendix I

### QUESTIONNAIRE ON MAIZE FARMERS' PERCEPTION OF DAMAGE BY FALL ARMY WORM AND THEIR KNOWLEDGE OF ITS MANAGEMENT

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The aim of this questionnaire is to gain background information on the perception of maize farmers on damage by the Fall Army Worm (*Spodoptera frugiperda*) and their knowledge of its management. Your sincere and objective responses will be greatly appreciated. Thank you.

State: ___________ LGA: _____________________ Questionnaire No.: ______

Community/Town: ___________________ Farmer's name: _____________________________

Farmer's Phone Number: _________________________________

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PLEASE TICK [ ] AND FILL AS APPROPRIATE

**Demographic Information**

1. Gender: Male [ ] , Female [ ]
2. Age in years :___________
3. Marital Status: Married [ ] Single [ ] Widowed [ ] Divorced [ ]
4. Highest Level of Education: Primary [ ] Secondary [ ] Tertiary [ ] No formal education [ ]
5. Household size: ____________
6. Size of land cultivated to maize ___________________

**Current Farming Practices and Experience with Fall Army Worm on Maize**

7. How many years have you been cultivating maize? _______________________
8. What is your maize **farming system**? Rain-fed [ ] Irrigation [ ] Wetland [ ]
9. What is your purpose for maize cultivation? Consumption [ ] Sales [ ] Consumption and Sales [ ]
10. Which of these years did you plant maize? 2016 [ ] 2017 [ ] 2016 and 2017 [ ] None [ ]

11. When did fall armyworm attack your maize? 2016 [ ] 2017 [ ] 2016 and 2017 [ ]
12. What maize variety did you cultivate when you experienced fall armyworm attack? ___________________
13. How did you cultivate maize on your farm when it was attacked by fall armyworm? Maize only [ ] Maize and legume crop [ ] Maize and tuber crop [ ] Maize and several crops [ ]
14. The fall armyworm **looks** like? Small green grasshopper[ ] Small brown butterfly[ ] Small crawling worm[ ]
15. How did you **know** it was fall armyworm and not stem borer? Color is different [ ] Size is different [ ] Eating habit is different [ ] Fecal excretion on maize leaves [ ] I cannot tell the difference [ ]
16. Please briefly describe how the fall armyworm is different based on your answer in (15) above?

    ______________________________________________________________________________

    ______________________________________________________________________________
17. How old were your maize plants when they were attacked by fall armyworm? Less than 1 month [ ] 1-2 months [ ] more than 2 months [ ]
18. How would you describe the damage to your maize farm by fall armyworm? Damage to a few leaves [ ] Damage to a few plants [ ] Damage to more than half of the plants [ ] Damage to all plants [ ]
19. What is your **main source(s)** of information on fall armyworm? Farmers [ ] Extension agents [ ] Media [ ]
20. What **method(s)** did you employ for the control of the pest? Chemical spray [ ] Traditional method [ ] Hand picking [ ] No Control [ ]
21. If you used traditional method in (20) above, what are the specific method(s) employed?

______________________________________________________________

22. If you used chemical spray in (20) above, what is/are the names of the insecticide?

______________________________________________________________

23. If you sprayed chemical in (20) above, how many times did you spray?1 – 2 [ ] 3 – 4 [ ] 5 – 6 [ ] 7 – 10 [ ]
24. If you used chemical spray in (20) above, what is the effectiveness? Excellent [ ]  Moderate [ ]  Poor [ ]
25. What is your expected maize yield if no damage by fall armyworm? ________________________
26. What was your yield when fall armyworm damaged your maize farm? ______________________

**PERCEPTION OF MAIZE FARMERS ON DAMAGE BY THE FALL ARMY WORM**
**Please tick appropriately your feelings about the statements below.**
**SA=Strongly Agree, A=Agree, U=Undecided, D=Disagree, SD=Strongly Disagree**

| S/N | STATEMENTS | SA | A | U | D | SD |
|---|---|---|---|---|---|---|
| 27 | Maize damage by the fall army worm is a problem to be worried about | | | | | |
| 28 | Fall armyworm damage reduces the quantity of maize harvested | | | | | |
| 29 | Fall armyworm damage decreases the profit from maize production | | | | | |
| 30 | Fall armyworm on maize farms can easily be detected before damage occurs | | | | | |
| 31 | Damage by fall armyworm is more severe in early maize than in late maize | | | | | |
| 32 | Damage is more severe on maize when intercropped than when planted sole | | | | | |
| 33 | Sufficient education is available to maize farmers on fall armyworm | | | | | |

**KNOWLEDGE OF MAIZE FARMERS ON THE MANAGEMENT OF THE FALL ARMY WORM**

**Please tick TRUE or FALSE to answer the questions below**

| S/N | QUESTIONS | TRUE | FALSE |
|---|---|---|---|
| 34 | Regular inspection of maize leaves can help prevent damage by fall armyworm | | |
| 35 | Fall armyworm is easier to manage when farmers regularly share information on its presence or absence on their farms | | |
| 36 | Spread of fall armyworm can be quickly prevented by uprooting and burning infested maize plants | | |
| 37 | It is very easy to control fall armyworm with chemical spray when the worm has entered the maize whorl | | |
| 38 | It is possible to effectively control the fall armyworm when it has spread all over the farm | | |
| 39 | Filling the whorls of young maize plants with ash or sand can help reduce fall armyworm damage | | |
| 40 | Over use of chemical spray may result in insecticide resistance in fall armyworm | | |

## Appendix II

Weather data at the experimental site (May - December, 2018 and 2019)

| Year | Maize Planting Season | Month | Total Rainfall (mm) | Relative Humidity (%) | Temperature $^{o}C$ | |
|---|---|---|---|---|---|---|
| | | | | | Min. | Max. |
| 2018 | Early | May | 576.9 | 87 | 23 | 32 |
| | | June | 539.6 | 88 | 23 | 31 |
| | | July | 328.4 | 92 | 23 | 30 |
| | | August | 132.1 | 91 | 23 | 29 |
| | Late | September | 916.5 | 91 | 23 | 31 |
| | | October | 976.5 | 88 | 23 | 31 |
| | | November | 44.3 | 87 | 24 | 33 |
| | | December | 0.0 | 83 | 21 | 35 |
| 2019 | Early | May | 261.4 | 88 | 23 | 33 |
| | | June | 461 | 96 | 23 | 31 |
| | | July | 262.3 | 92 | 23 | 29 |
| | | August | 338.1 | 92 | 23 | 28 |
| | Late | September | 549.3 | 89 | 23 | 30 |
| | | October | 727.9 | 88 | 22 | 30 |
| | | November | 356.2 | 86 | 23 | 33 |
| | | December | 0.0 | 86 | 22 | 35 |

Source: National Horticultural Research Institute (NIHORT)