INCIDENCE AND SEVERITY OF PINK STALKBORER (*SESAMIA CALAMISTIS* HAMPSON) AND SCREENING OF MAIZE GENOTYPES FOR RESISTANCE IN SOUTHERN GUINEA SAVANNA OF NIGERIA

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PhD/SAAT/2016/ 918

A THESIS SUBMITTED TO THE POST GRADUATE SCHOOL FEDERAL UNIVERSTY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (PhD) IN CROP PROTECTION

MAY, 2023

ABSTRACT

Maize (*Zea mays* L) is one of the most important food crops in the world. In developing countries, maize or its derivatives are consumed on a daily basis. In Nigeria, it is cultivated on a small, medium, or large scale. Despite its cultivation and uses, production is seriously constrained by stem borers. This study determined the incidence and severity of *Sesamia calamistis* and reactions of selected maize genotypes to infestation. Maize farms were surveyed in four states (Kwara, Nasarawa, Niger and Oyo), Southern Guinea Savanna of Nigeria from May to August, 2019 cropping season. Four Local Government Areas (LGAs) were selected in Kwara (Oyun, Irepodun, Ilorin East and Edu), Nasarawa (Keana, Keffi, Wamba and Lafia), Niger (Bosso, Gurara, Paikoro and Wushishi), and Oyo (Afijio, Atiba, Egbeda and Eleyele) States. In each LGA, five maize farms were surveyed for the incidence and severity of stem borer infestations. Stalk borers were also collected from the infested maize plants and identified conventionally by the use of dichotomous keys. Sorting, combing and recording of stem borers were also carried out in Insect museum at Department of Crop Protection, Ahmadu Bello University, Zaria. The screenhouse experiment consisted of 40 treatments (maize genotypes signated as M-G1 to M-G40), arranged in a completely randomised design with three replicates. The maize genotypes were obtained from the Breeding Unit of the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. Three trials were conducted; each trial comprised forty pots replicated three times, making a total of one hundred and twenty pots, filled with 15kg of steam-sterilized soil. Infestation of maize with stem borers was done by introducing four 2nd instar larvae to each stand of maize at 4 weeks after sowing (WAS). Data were collected on the number of plants that suffered stem-lodging and dead heart. Also, evaluated were plant height at 4, 6, 8, 10 and12 WAS, number of days to 50% tasseling, number of days to 50% silking, ear height, ear position, number of ear per plant, grain moisture, stem diameter, plant stand at harvest and grain weight. Results indicated that the majority of the farmers were not planting certified and hybrid seeds and the cropping systems practiced by most farmers in the study area encouraged favourite breeding environments for the survival and infestation of stem borers. The highest (50%) and lowest (10%) *Sesamia calamistis* incidence was obtained in Kwara and Oyo States respectively, while highest severity was found in Kwara (5.0) and Niger (5.0) States and the lowest severity was obtained in Oyo (1.0) State. *Sesamia calamistis* was the only stem borer species in the studied location. The maize genotypes M-G8, M-G9, M-G17, M-G20, M-G25 and M-G27 had lower severity of infestation. On the other hand, M-G39, M-G15, M-G27, M-G30, M-G32, M-G12, M-G16, M-G2, M-G37, M-G19, M-G18, M-G24, M-G28, M-G6, M-G13, M-G23, M-G7, M-G5, M-G34, M-G8, M-G9, M-G28, M-G17, M-G10, M-G22, M-G31 and M-G38 were tolerant to dead heart, while M-G1 M-G2, M-G6, M-G13, M-G14, M-G18, M-G19, M-G24, M-G29, and M-G33 were tolerant to rotten ear. In all, the M-G27 genotype had the highest (24.33 g/plant) significant ($P \leq 0.05$) grain weight. Cluster analysis showed that M-G2 (13.9 g/plant), M-G16 (11 g/plant), M-G22 (17.2 g/plant) and M-G23 (18.2 g/plant) belonged to the same cluster with M-G27 that produced the heaviest grain weight (24.3 g/plant) under artificial infestation of *Sesamia calamistis*. The members of this cluster also exhibited a good combination of tolerance to dead heart (0 %) and ear rotten (score = 1 – 2), earliness to tasseling (51 – 60 days after sowing) and silking (59 – 67 days after sowing). Stem borers prediction analysis showed that stem lodging symptom in maize genotypes as a result of stem borers' infestation caused a reduction in yield (40.81 g/plant).

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Maize (*Zea mays* L.) is a major staple food crop grown in diverse agro-ecological zones and is consumed by people with varying food preferences and socio-economic backgrounds in sub-Saharan Africa (SSA) (Olaniyan, 2015). The 16 out of 22 countries in the world where maize forms the highest percentage of calorie intake in the national diet are in Africa (Nuss and Tanumihardjo, 2011). According to Food and Agriculture Organisation (FAO, 2015), the top 20 countries, namely South Africa, Nigeria, Ethiopia, Egypt, Tanzania, Malawi, Kenya, Zambia, Uganda, Ghana, Mozambique, Cameroon, Mali, Burkina Faso, Benin, DRC, Angola, Zimbabwe, Togo, and Cote d'Ivoire account for 96% of the total maize production in sub-Saharan Africa. Maize, which may be eaten as a vegetable or processed into various dishes, is regarded as a hunger breaker after a long dry period in developing countries.

Maize is the most cultivated cereal in the world followed by rice and wheat for its high nutritional value particularly because of its carbohydrate content (FAO, 2017). It is perhaps one of the most important cereal crops cultivated for food, livestock feed and industrial raw materials (Ukeh *et al*., 2010). About 50 species of maize environmental biotypes exist and consist of different colours, textures and grain shapes and sizes. White, yellow, brown and red are the most common types. However, sustainable maize production especially in the developing world is threatened by various stresses including abiotic constraints such as drought and nitrogen. Others are viruses, bacteria, fungi and insect pests such as stem borers

(Ukeh *et al*. 2010). The major stem boring species associated with maize production in Nigeria are moths belonging to the families Noctuidae and Pyralidae, namely: the maize stalk borer (*Busseola fusca* Fuller), the pink stem borer (*Sesamia calamistis* Hampson), the millet stem borer (*Acigona ignefusalis* Hampson) and the African sugar cane borer (*Eldana saccharina* Walker); (Okweche *et al*., 2010). Stem borers have been the most damaging group of insect pests in maize cultivation worldwide (Tefera *et al*., 2011). They cause 10–100% losses in maize grain yield (Sosan and Daramola 2001). However, Cock *et al*. (2017) reported that within Africa, damage to maize varies with locations/regions, with sub-Saharan Africa recording the highest population of stem borers being directly correlated with damage and grain yield loss may result from.

The damage caused to growing points (dead heart), damage to leaf (windowpane) stem tunneling, hole (as a point of entry to secondary rot organisms), stem lodging, stem breakage, tassel and direct damage to ear shank and ear leading to loss of stand and grain yield reduction (Sosan and Daramola, 2001). However, the consequence on yield is variable and depends upon sowing, borer species composition and abundance as well as insecticide treatment (Ajala *et al*., 2010; Okweche *et al*., 2010). It has been observed that early-planted maize suffers less from borer attacks than late-planted maize in the Middle Belt of Nigeria (Okweche *et al*., 2010). Heavy stem borer infestations have precluded the second cropping of maize even in areas with potential for two rain-fed crops (Sylvain and Tuarira, 2015). The different recommendations on dates appropriate for sowing exist across all agro-ecological zones where maize is cultivated. Maize cropping is between March/April (early) and August/September (late) in the Southern agro-ecological zone of the country (rainforest) where it is highly produced (Nyukuri *et al*., 2014).

Among the developed countries, average yields in the United States range around 6 tons per hectare. In the Republic of South Africa, where a large portion of the maize is produced on large-scale commercial farms, average yields range from less than 2 tonnes to almost 3 tons per hectare, depending on weather conditions. Nigeria is the largest African producer, with over 33 million tons. Though, Nigeria maize yield fluctuated substantially in recent years (IITA-BIP, 2020). This large yield gap is attributable to both abiotic and biotic constraints (Wambugu and Wafula, 2000). The major abiotic constraint is the drought that causes an annual yield loss of about 15% (Kamara *et al.*, 2003), while the second most important constraint is nitrogen and phosphorus deficiency (Whitbread *et al*., 2004). Biotic factors that reduce maize yields in Africa are stem borers, the parasitic weed, *Striga* and Maize *Streak Virus* (MSV). The Maize *Streak Virus* reportedly caused yield losses that ranged from a trace to almost 100% (Alegbejo *et al.,* 2002). Stem borers are serious biotic constraints in cereals production across Africa causing between 20 and 40% of yield losses during the cultivation period, and between 30 to 90% during storage (Wahedi *et al.,* 2016). The other diseases that affect maize include leaf blight, rusts, stalk and ear rots, and systemic foliar diseases (Alegbejo *et al.*, 2002).

Busseola fusca (Fuller), also known as the African stem borer, is a moth, indigenous to tropical Africa (Goergen *et al*., 2016). Although indigenous, it was first recognised as a pest of maize in South Africa and has become economically important in many of the maize growing countries on the African continent (Kfir *et al.,* 2002). *Buseola fusca* also co-exists with an alien invasive moth *Chilo partellus,* the spotted stem borer, particularly in the agro-ecological zones of Kenya. In some areas, such as the high elevations of the eastern Highveld

region of South Africa, *B. fusca* has been reported to have been partially displaced by *C. partellus* (Goergen *et al.*, 2016)

Busseola fusca larvae feed on the above-ground parts of the grass hosts, causing economically important yield losses to crops such as maize. Feeding and tunnelling by *B. fusca* larvae can destroy the growing point (resulting in “dead hearts”), early leaf senescence, interference with nutrient and metabolite translocation resulting in malformation of the grain, stem breakage, plant stunting, and direct damage to ears (Kfir *et al.,* 2002). Tunnels in the plant stem may also predispose hosts to infection. Yield loss estimates may vary with region, *B. fusca* infestation levels and plant developmental stage. First instar larvae feed in the young terminal leaf whorls producing characteristic patterns of small holes and 'window-panes' where tissues have been eaten away. Later they eat into the growing points, which may be killed so that the dead central leaves form characteristic dry, withered 'dead-hearts (Kfir *et al.,* 2002). Older larvae tunnel extensively in stems, eating out long frass-filled galleries which may weaken stems and cause breakages. Larvae also tunnel into maize cobs and the peduncles of sorghum and millet inflorescences may seriously affect grain production.

Most farmers in Africa depend on local methods of farming with little or no idea of pesticides usage and time of planting. Insect Pests continue to ravage farms causing a low level of productivity. Even in the area where pesticides are used, poisonous substances such as organophosphates and organochlorines are used and are very toxic to humans and soil organisms (Abrahams *et al.*, 2017). Many insecticidal compounds used today fall within organophosphates and carbamates (Stokstad, 2017). There are problems of pesticide resistance and negative effects on non-target organisms including man and the environment. These synthetic insecticides are more hazardous to handle, leave toxic residues in food

products, not easily biodegradable. Besides, their influence on the environment is deleterious. Unlike synthetic that kill both pests and predators outright, the natural insecticides are relatively inactive against the latter. The botanical insecticides are generally pest-specific and are relatively harmless to non-target organisms including man. They are also biodegradable and harmless to the environment (Ukeh *et al*., 2010). Furthermore, unlike conventional insecticides which are based on a single active ingredient, plant-derived insecticides comprise an array of chemical compounds which act concertedly on both behavioural and physiological processes. Thus, the chances of pests developing resistance to such substances are less likely.

One plant species may possess substances with a wide range of activities, for example, extracts from the neem tree *Azadirachta indica* Juss are antifeedant, antioviposition, repellent and growth-regulating (Okweche and Umoetok, 2015). Azadirachtin, the most active component of *A. indica* seed oil has been reported to alter insect behaviour due to its antifeedant, repellent and phagodeterrent properties. Oparaeke (2005) reported the effectiveness of *Gmelina* fruit extract on the control of *Clavigralla tomentosicollis* and *Maruca* pod borer on cowpea. It is less attacked by insect pests all through the season probably due to its high alkaloid and tannin contents. Liquid from the fruits is toxic to larvae of moths and butterflies (Oparaeke, 2005)

1.2 Statement of the Research Problem

Stem borers have been the most damaging group of insect pests in maize cultivation worldwide (Tefera *et al*., 2011). Feeding by borer larvae on maize plants usually results in crop losses as a consequence of the death of the growing point (dead heart), early leaf senescence, reduced translocation, lodging and direct damage to the ears. Yield loss due to

stem borers in Africa varies from 0 - 100 % among ecological zones, regions and seasons. In sub-Saharan Africa, particularly Nigeria, they can cause 20 - 40% losses during cultivation and 30 – 90% losses postharvest. However, estimated yield losses higher than 40% are expected to occur at the smallholder level where suppression of the pest by chemicals is generally not practiced. Yield losses of 12% for every 10% plant infested have been reported in Tanzania and Kenya. The Economic Injury Level (EIL) of *C. partellus*in maize are 3 and 4 larvae per plant in maize 20 and 40 days after plant emergence, respectively. In Kenya, Harris (1962) found that all stem borer species caused average annual losses of 13.5% valued at US$80 million. Losses to *C. partellus* were estimated at the US $23 million/year; the majority of other stem borer losses were attributed to *B. fusca.* Some maize varieties including Sammaz 14 and Flint have been reported to be tolerant to stem borers in Nigeria (Bamaiyi and Oniemayin, 2011). However, resistance

may break down in the presence of virulent stem borer biotypes.

1.3 Justification of the Study

Today, there is a renewed interest in Nigeria to go back to Agriculture and see it as a profession. Maize is a major staple food for millions of people in the country. It is perhaps the most important cereal crop cultivated for food, feed and industrial raw materials Ukeh *et al*. (2010). Despite the cultivation and uses of maize, production is seriously constrained by stem borers. Inaccurate information from various reports is still propagated on its distribution (Kfir *et al*., 2002) and host range (Muyekho *et al.*, 2005). Contrary to these reports, *B. fusca* does occur in the lower altitudes in East Africa and it feeds on only a few host plant species. During the last decade, the interactions of this insect pest with plants (Alata *et al.,* 2008: Calatayud *et al.,* 2008) as well as its reproductive biology (Kruger *et al.,* 2012:

Kruger *et al.*, 2014) and genetics, (Sezonlin *et al.*, 2006) have been well documented in East African countries. In West Africa, *B. fusca* is only of economic importance in the dry agro-ecological zones (Schulthess *et al*., 2001) and little information exists about the ecology and management of this pest in this region. The severity and nature of stem borer damage depend upon the borer species, the plant growth stage, the number of larvae feeding on the plant and the plant's reaction to the borer feeding. Moreover, the amounts of yield loss vary greatly depending upon the country, season, maize variety, and fertilisation, the severity of the damage, stem tunneling and generation of stem borers involved. The first and second generations cause more yield loss than the third generation.

Knowledge of the incidence and severity of maize stem borers would be useful for developing resistant maize varieties. Information on the spatial distribution of stem borers could serve as an avenue for assessing yield losses induced by stem borers in the study area. Such information would create awareness for government, research institutes; Agricultural Development Programmes (ADPs) and other stakeholders on the need to intensify management strategies. Unique cultures of the stem borers obtained during the study could be used for screening maize lines and genotypes for stem borer resistance. Besides, resistant maize genotypes would be recommended to farmers for cultivation to reduce malnutrition and food insecurity in the country.

1.4 Aim and Objectives of the Study

This study aimed to obtain information on the occurrence and severity of maize stem borers and reactions of selected maize genotypes to infestation.

The objectives of the study were to;

i. determine the incidence and severity of maize stalk borer infestation in the study area,

ii. evaluate the growth and yield parameters of selected maize genotypes under stalk borer infestation and

iii. predict stalk borer's infestation on maize yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Maize Production and Uses

Maize is one of the major cereal crops and ranks third in production worldwide following wheat and rice. In sub-Saharan Africa maize is one of the most important staple foods, providing food and income to over 300 million resource-poor smallholders (Romney *et al*., 2003). Over 650 million people consume an average of 43 kg of maize per year (a 35 % increase since 1960), reaching 85–140 kg in Kenya, Lesotho, Malawi, South Africa, Zambia and Zimbabwe. Its cultivation spans the entire continent and is the dominant cereal food crop in many countries, accounting for 56 % of the total harvested area of annual food crops and 30-70 % of total caloric consumption. Over 100 million people in Africa utilise maize as a staple food crop (Byerlee and Heisey, 1996), including as a constituent of livestock feed.

Maize is a monoecious plant grown from latitude 58 ^{o}N to 40 ^{o}S, adaptable to a wide range of agro-ecological zones in Africa. Its acreage in tropical highlands (1800–2800 meters above sea level (masl)) is 1.7 million ha, in the subtropics and mid-altitude zones (1200–1800 masl) 8.1 million ha, and in lowland tropics (< 1200 masl) 12.3 million ha (Pingali, 2001). Africa harvests 29 million hectares, and as the largest producer, Nigeria produced 1.69 metric tonnes per hectare in 2019, its highest production rate. In 2020, maize yield for Nigeria was 1.77 metric tonnes per ha. Though Nigeria maize yield fluctuated substantially in recent years, it tended to increase through the 1971 - 2020 period ending at 1.77 tons per ha in 2020 (IITA-BIP, 2020).

2.2 Yield Diminishing Factors

The yield potential for sub-Saharan Africa is 5 tones /ha in tropical highlands, 7.0 tones /ha in subtropical and mid-altitude zones and 4.5 tones /ha in tropical lowlands, compared to the current yields of 0.6, 2.5 and 0.7 tones/ha respectively (Pingali, 2001). Factors constraining maize production include African streak viruses such as; *Panicum streak virus* (PanSV), *Sugarcane streak virus* (SSV), *Sugarcane streak Mauritius virus* (SSMV) and *Sugarcane streak Egypt virus* (SSEV) (Willment *et al.*, 2001), Maize is susceptible to common species of *Pythium* and moderately susceptible to *Sclerotium rolfsii* and *Rhizoctonia* spp. Maize is also susceptible to stalk and cob rots caused by several *Fusarium* species but these do not normally affect vegetable crops. Among the biotic factors that reduce maize yields in Africa are stem borers, the parasitic weed *Striga* and *Maize Streak Virus* (MSV) (IITA, 2014).

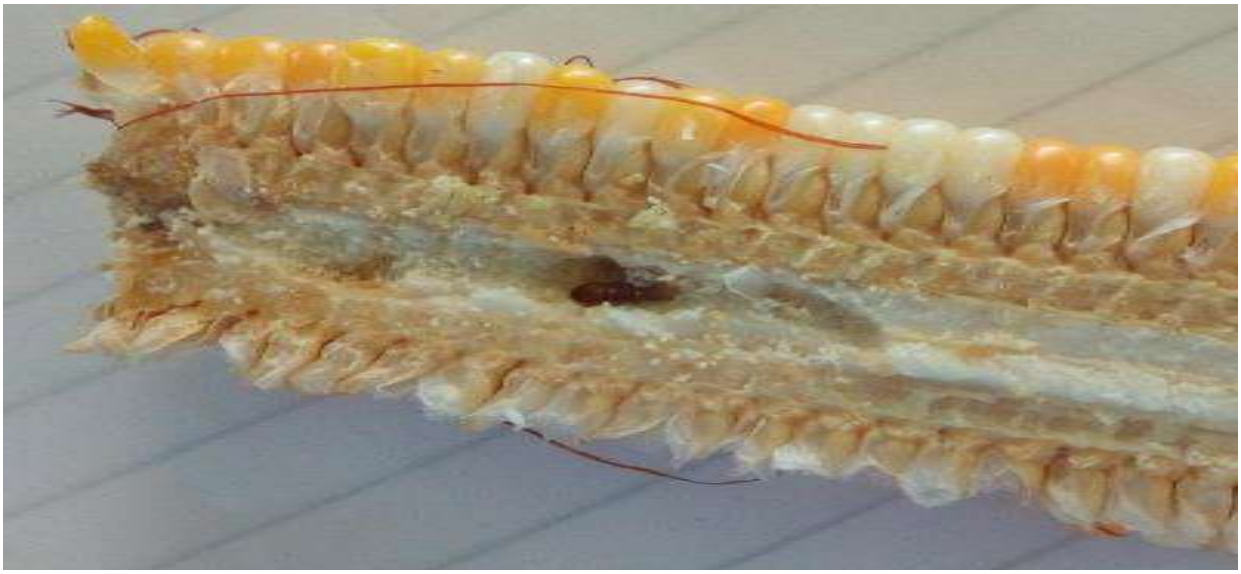
2.3 Maize Stem Borers

A generally accepted estimate of annual losses during the early part of the 20th century was 10% of the national crop. South African maize production increased from less than one million metric tons (mt) in 1910 to 2.6 mt in 1950 and 8.2 mt in 1972. This increase in production as well as the concomitant increase in area under maize production (4.7 million ha in 1972) significantly raised the economic status of the pest. Until the mid-1970s *B. fusca* received surprisingly little research attention for half a century and control strategies of the time relied heavily on principles derived from the earlier research.

Busseola fusca was first mentioned as *Sesamia fusca* in a report by Fuller in 1901 and described under the same name by Hampson in 1902. In 1953 African species of *Sesamia* and related genera were morpho-taxonomically revised and finally, *S. fusca* was placed in

the *Busseola* Thurau genus (De Groote, 2002). The first description of the oviposition site, eggs, larval behaviour and damage symptoms caused by *B. fusca* stemmed from South Africa. Since 1920, *B. fusca* has assumed an important pest of maize and sorghum in sub-Saharan Africa, and the first recommendations on how to control this pest were given in 1905. Since then, a plethora of information on its distribution, pest status and injuriousness were produced (Kfir *et al.*, 2002). *Busseola. fusca* is considered to be the most destructive lepidopteran pests of maize and sorghum in Africa (Kfir *et al*., 2002) (Plate 2.1a and b). Estimates of crop losses vary greatly in different regions and agro-ecological zones. In Kenya alone, losses due to *B. fusca* damage on maize fluctuate around 14% on average (De Groote, 2002) while in the humid forest zone of Cameroon losses of around 40% are common in mono-cropped maize fields (Chabi-Olaye *et al*., 2005). This pest still presents a major constraint to the production of maize in areas where they are abundant. *Busseola fusca* larvae feed on the above-ground parts of the grass hosts, causing economically important yield losses to crops such as maize.

A



B

Plate 2.1: Damage symptoms of stem borers to maize plant and cob (source: ICIPE, 2016)

2.4 Distribution of Maize Stem Borers in Africa

Busseola fusca is currently known to occur in most countries south of the Sahara and has not yet been reported anywhere outside of Africa (Haile and Hofsvang, 2002). The insect seems to display geographical differences in ecological preferences. In Eastern and Southern Africa *B. fusca* is a pest at higher altitudes (>1,500 m), while in West Africa it occurs from sea level to above 2,000 m. Haile and Hofsvang (2002) recorded *B. fusca* between 1,450 m and 2,350 m in Eritrea (East Africa) and Cameroon (Central Africa) it is abundant from mid to high altitudes (700-1,000 m) (Ndemah *et al.* 2001). Others have reported that it is unable to tolerate the warm temperatures occurring below 610 m. The distribution of *B. fusca* seems to be further influenced by moisture gradients. In West Africa, *B. fusca* is recorded as a pest in the dry savannah zone in lower altitudes (Kfir *et al.*, 2002) yet other studies recorded it being more abundant in the rainforest than the savanna (Sezonlin *et al*., 2006). Three major population groups of *B. fusca* have been distinguished: a homogeneous and geographically

isolated population from West Africa, and two populations from East and Central Africa with overlapping distributions (Sezonlin *et al.,* 2006).

Maize stem borer is a major pest in Africa and occurs in contrasting climatic zones. A single species can complete 2-3 generations in the warmer West African countries such as Burkina Faso, southern Ghana, and northern Nigeria and also complete the same number of generations in the much cooler, higher altitude areas of Ethiopia and Lesotho (Ebenebe *et al*., 2000). The annual heat sum in such different areas will be very different. All the biological evidence supports the suggestion that there are different mitochondrial clades with overlapping distributions and different ecological characteristics (Felix *et al*., 2009).

2.5 Distribution of Stem Borers Infesting Maize in Nigeria

The major species of stem borer associated with maize in Nigeria are the maize stalk borer, *Busseola fusca* Fuller (Noctuidae), the pink stalk borer, *Sesamia calamistis* Hampson (Noctuidae), the millet stem borer, *Coniesta ignefusalis* Hampson (Noctuidae) and the Africa sugarcane borer, *Eldana saccharina* Walker (Pyralidae) (Balogun and Tanimola, 2001). Others of less importance are the spotted stalk borer (*Chilo partellus* Swinehoe. Pyralidae), *C. orichalcociliella, C. suppressalis,* and the ear borer (*Mussidia nigrivenella* Pyralidae) (Khan *et al.,* 2000). Simon *et al*.(2015) observed that *S. calamistis* was more abundant than both *B. fusca* in the Eastern and Southern States of Nigeria. Okweche *et al*. (2010) reported that *B. fusca* is the most predominant borer species in the guinea savanna agro-ecological zone of Nigeria followed by *S. calamistis, E. saccharina, C. ignefusalis and C. partellus* in early and late-planted maize. Obhiokhenan *et al.* (2002) reported higher stem borer populations in the Mangrove zone followed by rain forest and derived savanna zones of Cross River State. The survey by Obhiokhenan *et al.* (2002) also showed that *S. calamistis* was

more abundant than any other stem borers in all the vegetational zones of Cross River State followed by *Chilo* spp while. *B. fusca* was not found.

2.6. **General Stem Borer Damage and Larval Behaviour**

Most stem borer species produce similar symptoms on maize and sorghum plants (Plate 2.2-2.7). Among cereals, maize is damaged more by stem borers because it has more amino acids, sugars, than the other graminaceous hosts (Krüger *et al.*, 2012) are more attractive to *B. fusca* than they are to *C. partellus*. Generally, soon after hatching, stem borer larvae crawl over the plant, congregate in the funnel and feed on the rolled leaves a few days before penetrating the stem (Félix *et al.*, 2009). As the leaves grow away from the funnel, a characteristic pattern of holes and "window panes" can be seen, leaving a transparent upper cuticle referred to as window panning (Chabi-Olaye *et al*., 2005). Window panes refer to early larval feeding in which the larvae do not completely chew through the leaf but leave a thin layer of transparent leaf epidermis. Larvae can also feed on basal meristems of young maize plants resulting in the formation of a dead heart. The dead heart is caused by the borers boring into the stalk and tunneling upward. Dead hearts cause the death of cereals such as maize, while sorghum, millet and rice compensate by tillering.

Older larvae make holes and tunnels in stems where they feed for 3 to 5 weeks, causing extensive tunnels. Larval tunneling within the stalk may also predispose plants and ears to infection by fungal pathogens, further compromising the long-term storability and quality of food products.

There is evidence of variation in the lengths of stem tunneling associated with the different stem borer species. *B. fusca* larvae produce the largest stem tunneling, followed by *C.*

partellus. Mostly, the holes are prepared for pupation. The feeding habit reduces the flow of water and nutrients throughout the plant and can reduce grain weight, kernel number, thereby reducing yields (Ratnadass *et al*., 2001). The extensive tunneling of stem borers inside the stems weakens the plants, causing breakage and lodging (Ebenebe *et al.*, 2000). Lodged plants are likely to yield lower and make harvesting more difficult. For instance, Ndemah *et al*. (2006) reported that yield losses as high as 40 % could result from lodging. Damage to the stem can lead to infection by *Fusarium* stalk rot (Félix *et al.*, 2009). Other plant parts such as tassels and ears are prone to stem borer damage (Plate 2.5). Extensive damage can result in the complete death of the plant. After killing the plant, larvae usually migrate to new plants and enter by boring into the stem near the base. Plants damaged by stem borers are often stunted and may die. Infested plants if they survive may or may not produce harvestable ears. If they do, they are usually smaller than normal plants making them less marketable especially if they are sold as green mealies. In addition, those plants that do not produce ears compete with plants for water, nutrients and sunlight. The magnitude of the damage is influenced by soil fertility (Muyekho *et al*., 2005), farming systems (Alata *et al.*, 2008) and maize moths fly at night and lay eggs on maize plants between the leaf sheath and the stem on the youngest fully unfolded leaf. Eggs hatch into caterpillars, which move into the growing points, where they start to feed.

Plate 2.2: Symptoms of larvae damages caused by the African pink stem borer, *Sesamia calamistis*: (A) "dead heart" of young leaves, (B) stems filled with frass, and (C) frass deposits in maize cobs and empty grains (source: ICIPE, 2016**)**

Plate 2.3: Maize stalk borer, *Busseola fusca* damage to maize plant (source: ICIPE, 2016**)** A= characteristic "window panes" B= shot holes where tissue has been eaten away C= galleries filled with frass D= dead heart symptoms of damage to stem and cob E= cobs showing frass F= deposits and empty grains

Plate 2.4: Spotted stem borer, *Chilo partellus* damage to maize plant (source: ICIPE, 2016)

A= larvae on leaves with characteristic "window" B= yellow streaks caused by mining

C=dead upper part of plant D= damage to seeds on maize cob E= damage to maize stem

Plate 2.5: Stem borers hidden in maize tassel (source: ICIPE, 2016**)**

Plate 2.6: Exit hole of stem borer on maize stalk (source: ICIPE, 2016**)**

2.7 Yield Losses Due to Maize Stem Borers in Africa

Yield losses depend on the age of the plant at infestation. In Ghana, yield loss as high as 40% has been attributed to *B. fusca* infestations. In the Democratic Republic of Congo (DRC), *B. fusca* occasionally caused yield losses of 8-9% in early planted maize, and 22-25% in late-planted maize (Félix, 2008). In Kenya, *B. fusca* accounted for 82% of all maize losses (Sezonlin *et al.*, 2006). *Chilo partellus* is the most damaging pest in Eastern and Southern Africa and causes significant grain yield losses. Its control has been a challenge among smallholder farmers (Félix *et al*., 2013). *Buseola fusca* can feed on maize kernels at maturity (Félix *et al.*, 2009). *Buseola. fusca* larva produces a higher effect on grain weight reduction as compared to *C. partellu*s. In Ethiopia, *B. fusca* and *C. partellus* are considered to be the most damaging insect pests, with reported yield losses of 0 to 100%, 39 to 100%, 10 to 19% and 2 to 27% from South, North, East and Western Ethiopia, respectively.

In South Africa, annual yield loss caused by stem borers to maize is 10% although between 25-75% losses have been recorded. In Mozambique, (Chabi-Olaye *et al.,* 2005) reported yield losses of over 50% due to *C. partellus* in the smallholder farming sector. In the Maputo and Gaza provinces of Mozambique and the Limpopo valley, estimated yield losses of 100% were reported to be caused by *C. partellus*. The larvae of the 3rd generation were reported to infest 87% of cobs of maize planted late and to severely damage 70% of their grain. Yields in East Africa were reduced by 15-45% by *C. partellus* alone. In South Africa, yield losses in maize and sorghum have exceeded 50%. In Kenya, it was found that all stem borer species caused average annual losses of 13.5% valued at US$80 million. Losses to *C. partellus* were estimated at US$ 23 million/year; the majority of other stem borer losses were attributed to *B. fusca.* In Burundi, *B. fusca* caused yield loss of 30-50% in regions between 1500 and 2100 m.

In Kenya, yield losses of up to 18% due to *C. partellus* and *Chilo orichalcociliellus* have been reported. Maximum grain yield reduction and stalk damage in maize was reported due to *C. partellus* on a 20-day-old crop, while there was an insignificant larval effect on yields for a 60-day-old crop. Generally, the amounts of yield loss vary greatly, depending upon the country, season, maize variety, fertilization, severity damage, stem tunneling and generation of stem borers involved. The first and second generations cause more yield losses than the third generation (Sezonlin *et al.*, 2006). Nigeria is Africa's largest producer of maize with nearly 8 million tons (IITA, 2014)

2.8 Biology of Maize Stem Borers

Good knowledge of the biology of *B. fusca* is a prerequisite for understanding how this species interacts with plants. Most of the information produced for *B. fusca* during the last century, which forms the basis of the knowledge of the biology and ecology of this pest, stemmed from South Africa. However, since the majority of the studies in South Africa addressed *B. fusca* at high altitudes and in commercial farming systems, some aspects regarding its biology and interactions with the environment may differ from those in other agro ecological zones.

Buseola fusca exhibits complete metamorphosis, including egg, larval, pupal, and adult stages. *Buseola fusca* has 2-3 distinct generations in most locations. However, in areas that are warm and humid, some *B. fusca* larvae may give rise to a fourth adult generation. Another factor that plays a role in the biology of *B. fusca* is larval diapauses. Research conducted on the diapauses strategies of *B. fusca* revealed that larvae diapauses in most locations during cold, dry periods. The state of host plant maturity is thought to be a critical factor in the induction of diapauses while soil moisture is imperative for its termination (Kfir *et al.*, 2002).

Temperature and photoperiod appear not to influence diapauses. It has been suggested that diapauses in *B. fusca* is obligatory, but this is unconfirmed. Between 9 and 14 days after pupation, the adults emerge from emergence windows bored by the larvae before pupation (Chabi-Olaye *et al*., 2008). Plants most attractive for oviposition are those that germinated 3-5 weeks before eclosion. Female *B. fusca* prefers the underside of the youngest fully unfolded leaf as oviposition sites (Chabi-Olaye *et al*., 2008). Eggs generally hatch about a week later, while larvae take 3-5 weeks to develop. *Busseola fusca* eggs are hemispherical, with crenulations, and are laid in clusters (Lusweti *et al*., 2011). Reports of total fecundity vary from 30-100 eggs and occasionally up to 723 eggs (Ong'amo *et al.*, 2006). Upon hatching, larvae disperse and then enter the leaf whorls, boring into the stems, producing extensive tunnels in the stem and cob. The larvae of *B. fusca* look similar to those of *C. partellus* in many ways. *Busseola fusca* larvae are 40 mm long when fully grown, normally a creamy white colour with a distinctive grey tinge. Sometimes *B. fusca* larvae have a pink colour similar to *C. partellus*. Both borers have a brown head capsule, but *B. fusca* can be distinguished from *C. partellus* by the hooks on the prologs. Hooks on the prolegs of *B. fusca* are arranged in a semicircle, while those in *C. partellus* are arranged in a full circle (Lusweti *et al*., 2011)

2.8.1 Eggs of *B. fusca*

Busseola fusca females' ovipositors are highly variable numbers (from 100 up to 800) of round and flattened eggs in batches (Kruger *et al.*, 2012). The batches are laid behind the vertical edges of leaf sheaths of pre-tasseling plants and also, but rarely, underneath the outer husk leaves of ears. Center for Agriculture and Bioscience International (CABI) (2006) recorded eggs on 12 to 16week old plants, but only when these were planted very late in the

season. It appears that the position at which the eggs are found correlates with the developmental stage of the plant and with increasing plant age, egg batches are increasingly found higher up on the plant (Negassi *et al*., 2006). Studies have also shown that leaf sheaths fitted more loosely around stems as plants get older and that female preferred the sheaths of the youngest unfolded leaves for oviposition. Although it is rare to find more than one *B. fusca* egg batch per plant cases of between 2 and 4 egg batches per plant have been observed. This could be attributed to extremely high population pressure at late planting dates (Kruger *et al.*, 2012).

In South Africa, with its unimodal rainfall pattern allowing for one crop per annum, it was also observed that egg batches of spring moth generation were smaller than those of summer moths (Kruger *et al*., 2012). A possible explanation is that body reserves of spring moths are smaller than those of the summer moth since the former would have utilized reserves during diapause. Similarly, in Nigeria spring moths laid approximately 65% fewer eggs than summer moths. Field studies during which more than a thousand egg batches were collected in South Africa, showed that the average size of an egg batch of 1st and 2nd generation females were 22 and 33 eggs respectively and a single moth lays 7–8 egg batches (Lusweti *et al*., 2011).

2.8.2 Larvae of *B. fusca*

Eggs of *B. fusca* hatch after about one week and larvae migrate first to the whorl where they feed on young and tender leaves deep inside the whorl. In contrast to stem borer species from the *Sesamia* and *Chilo* genera, young *B. fusca* larvae do not consume any leaf tissue outside of the whorls of plans. Larvae can remain in the whorls of especially older plants (6–8 weeks old) up to the 4th instars. From the 3rd instars onwards, larvae migrate to the lower parts of

the plant where they penetrate the stem. Some larvae do however migrate away from natal plants with approximately 4% of larvae leaving the natal plant immediately after hatching. The larval stage lasts between 31 and 50 days (Kruger *et al.*, 2012) and consists of 7–8 instars with a minimum of 6 (Plate 2.8). The larval stage consisted of 5 stages and was completed during approximately 35 days. Additional instars were observed when the conditions were suboptimal or when larvae went into diapauses (Malusi and Okuku, 2013). It is well known that *B. fusca* undergoes a facultative diapauses consisting mostly of a larval quiescence (Plate 2.9).

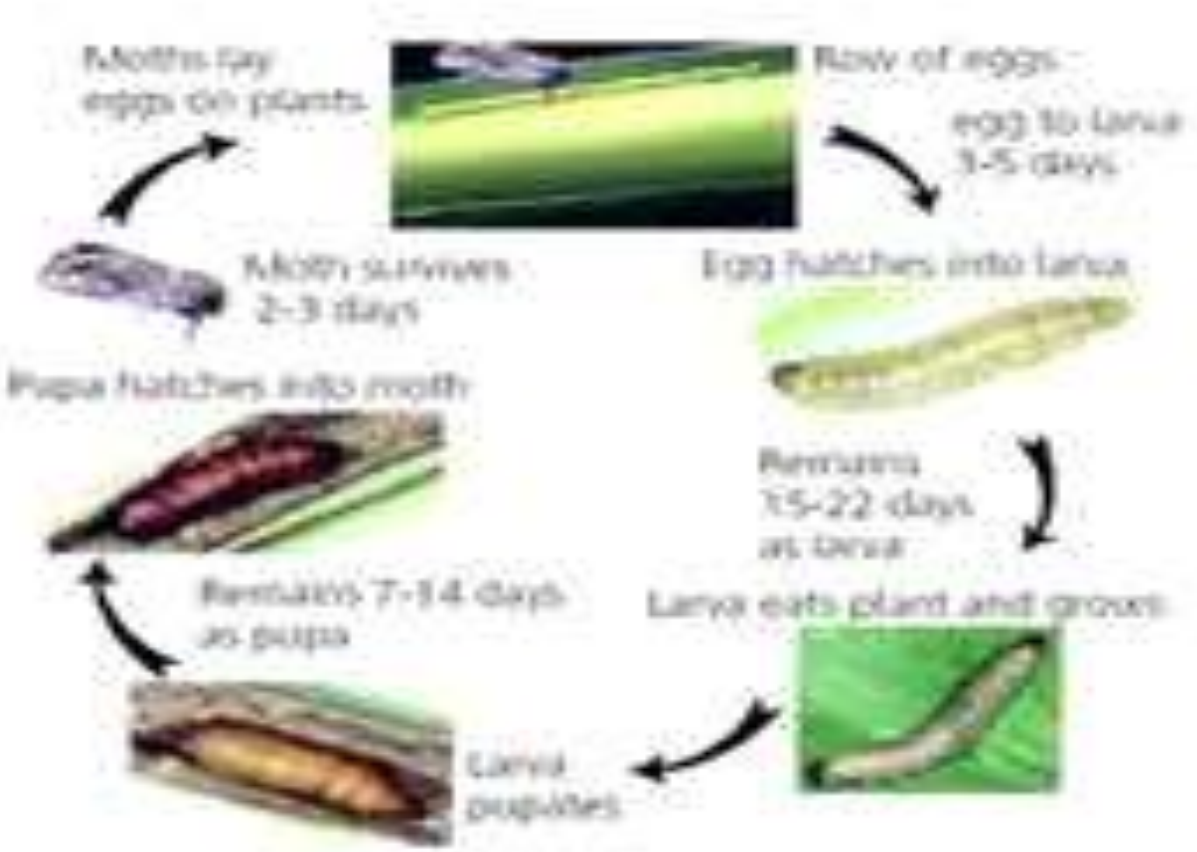


Plate 2.7: Lifecycle of *Busseola fusca* (source: ICIPE, 2016**)**

Plate 2.8: Larvae of *Busseola fusca* (source: ICIPE, 2016**)**

2.8.3 Larval migration patterns

Busseola fusca larvae migrate throughout all larval stages (Oyewale *et al*., 2020). This migration commences immediately after the egg hatch and ceases during the last instars when larvae prepare pupa cells in which they become pupae, or go into diapauses. Clear patterns in the intra-seasonal progression of larval infestations have been described by Van Rensburg *et al.* (1989). Although a small proportion of larvae migrate off plants immediately after hatching, the great majority (81%) of larvae up to the 4th instar remain in the whorl (Calatayud *et al.,* 2007). The low degree of damage caused by stem borer larvae to whorl leaves of wild hosts indicates that they do not feed in whorls for extended periods. In late-infested maize and sorghum, 1st instar larvae may commence feeding on silk of ears, panicles or in young emerging panicles for some time before migrating and commencing feeding inside ears or stems.

The migration does not cease after the larvae leave plant whorls to feed inside maize stems. Larvae migrate until the 6th instar, a density-dependent behaviour. Migration of late-instar larvae between plants also increases the likelihood of parasitism and predation. Studies have shown that large numbers of 5th and 6th instar larvae of *B. fusca*, parasitized by *C. sesamiae*, are often observed inside the last whorl leaves of plants when maize plants commence anthesis and flowers emerge. In areas where *B. fusca* goes into facultative diapauses for at least 5 months, only one 6th instars larvae occur per stem base, a few cm below soil level. In warmer areas, *B. fusca* goes into diapauses in the lower part of the stem, 25–60 cm above the soil surface.

Up to 70 % of larvae may migrate to adjacent rows over 5 weeks, and the incidence of plants remaining with a single larva at this time may be as high as 67% (Kruger *et al.*, 2012). This extent of occurrences of a single larva per stem despite the pseudo-aggregated oviposition behaviour illustrates the high migration potential of *B. fusca*. It also explains the patchy infestation pattern of *B. fusca* in the field and the increased percentage of plants damaged by larvae over time.

2.8.4 Adults of *B. fusca*

The mean sex ratio of *B. fusca* is 1:1 (male: female) (Kruger *et al.*, 2012). The adults emerge about 13–14 days after pupation and they emerge mostly between sunset and midnight (Calatayud *et al.*, 2007). Most male insects emerge before the onset of the scotophase, while most females do so one hour later (Plate 2.10). The average life span of moths ranges between 8 and 10 days (Calatayud *et al.*, 2007).

Plate 2.9: Adults of *B. fusca* (source*:* ICIPE, 2016*)*

2.8.5 Adults behaviour and preferences

Light extensively to study the flight patterns of *B. fusca* (Van Rensburg *et al.,* 1997). Generally, in areas where only one rainy season occurs, distinct flight patterns are observed. Moth numbers in pheromone and light traps show less discernible patterns in areas where maize is cultivated throughout the year. It has been known since the early 1970s that more than one generation of moths occurred in a season and that early infestations in a given season were derived from late infestations of the preceding season. Infestation patterns also vary between localities and are associated with the rainfall and temperature gradient existing from east to west in the greater production area. For instance, in South Africa, the first flight commences during early spring after the first good rains. The first and second flights are separated by a distinct period in December during which no moths occur. In an attempt to assist producers in identifying potentially hazardous on-farm flight levels, a pheromone trapping system was developed during the 1980s (Oyewale *et al*., 2020). The system was, however, shown to be unreliable during periods of pronounced moth activity due to poor competition of the synthetic pheromone with the natural product.

2.9 African Pink Stem Borer (*Sesamia calamistis*, Hampson)

This species is found in sub-Saharan Africa and some of the islands in the Indian Ocean. It commonly occurs in wetter localities at all altitudes. The main crops affected are maize, sorghum, pearl millet, wheat, rice and sugarcane. The larvae (caterpillars) can tunnel into the stem which can result in broken stems or drying and eventual death of the growing point of the maize plant. The common names are African pink stem borer, pink stalk borer, pink stalk borer of sugarcane, African pink borer of sugarcane, Mauritius pink borer of sugarcane, and

southern pink borer of sugarcane. Synonyms are *Sesamia mediastriga* Bethune-Baker, 1911. The purple stem borer (*Sesamia inferens*) (Lepidoptera: Noctuidae) which attacks maize, sorghum, pearl millet, finger millet, wheat, rice, oats, barley, sugarcane and some wild grasses (Kruger *et al.*, 2012).

2.9.1 Eggs and larvae of *S. calamistis*

Eggs are inserted between the lower leaf sheaths and the stem in batches of 10-40 and arranged in two to four contiguous rows. On average, each female lays around 300 eggs in five days. Egg-laying occurs from the time plants are two weeks old until flowering. The most serious damage, however, occurs at the early plant stages. Most larvae penetrate the stem shortly after they emerge from their eggs. Larval feeding might result in dead hearts and the tunneling and girdling activity of the larvae often results in stalk breakage. During the ear filling period, the majority of the larvae occur in the ears. Development of the larvae takes 4-6 weeks. Most larvae pupate within the stem or cobs. The African pink stalk borer breeds throughout the year and has no period of suspended development (diapauses). However, it is less abundant during the dry season when it is limited to mature grasses - elephant grass (*Pennisetum purpureum*), *Setaria*species and itch grass (*Rottboellia exaltata*) among others, as a food source (Kruger *et al.*, 2012). Eggs are hemispherical, about 1 mm in diameter and slightly flattened with radial ridges (crenulations). They are creamy-white when laid but darken as they develop. The larva of the African pink stalk borer looks smooth and shiny and lack obvious hairs or markings. Their colour is variable but they are usually creamy-white with a distinctive pink suffusion (hence the common name) (Plate 2.11). The head and prothoracic shield (a plate on the dorsal surface of the thorax) are brown; the dorsal part of the last abdominal segment bearing the anus (the suranal plate) is yellow-brown. Setae (bristles)

are present on small, inconspicuous pinacula (hardened - sclerotized - areas that indicate points of muscle attachment) and the spiracles (breathing holes found along the side of the body) are elongate-oval with black surrounds. The crochets (hooks) of the larval abdominal prolegs are arranged in lines as is the case for noctuid stem borers. This contrasts with pyralid borers whose crochets are arranged in circles. Mature larvae are between 30-40 mm long, pink with buff and pink dorsal markings and a brown head (Ratnadass *et al.*, 2001).

2.9.2 Adults of *S. calamistis*

Adults are up to about 18 mm long, brown to yellowish-brown with a wrinkled (creased) frontal region of the head and a terminal "tail" (cremaster) with four large and two small spines. The wingspan in females of the African pink stalk borer is 20-30 mm and in males a little less. The forewings are pale-brownish, with variable but generally inconspicuous darker markings along the margin and an overall silky appearance while the hind wings are white (Ratnadass *et al.*, 2001).

Plate 2.10: Developmental stages of African pink stem borer, *Sesamia calamistis*: (A) egg, (B) larva, (C) pupa, and (D) male (above) and female (below) adults(source: ICIPE, 2016**)**

2.10 Millet Stem Borer, *Coniesta ignefusalis*

The millet stem borer, *Coniesta ignefusalis* (Hampson), is in the genus Diatraea. Although its status as a good species has never been in doubt, its correct generic placing has still not been determined. Taxonomists have assigned such different genera as Haimbachia, Eoreuma, and Donacoscaptes. It was most recently assigned to *Acigona*, but as the genus is now known to be a noctuid and not a pyralid, it has been recommended that the species should remain in *Coniesta* until a thorough taxonomic revision can be undertaken (Khan *et al*., 2000).

2.10.1 Eggs and larvae of *C. ignefusalis*

Eggs are about 1-mm long and are laid in batches of 20-25 between leaf sheaths and stems. They are yellowish-white and elliptical and are partially flattened by the pressure of growing stems against the leaf sheaths. Larvae grow to a length of about 20 mm and have a prominent, reddish-brown head. During the growing season, the white body of active larvae is conspicuously marked with black spots. During the dry season, they enter into diapauses and lose these black markings. The pyralid larvae are easily distinguished from those of the noctuid stem borer by the circular series of crotchets on the ventral abdominal prolegs. Pupae are up to 15 mm long, yellowish to reddish-brown and with thorn-like spikes on the abdominal segments. Hatched larvae remain clustered for approximately 24 hours then tunnel into the leaf sheaths caused by *Coniesta ignefusalis* larvae on pearl millet and eventually enter the stalk. During feeding and development, the stem borer causes different types of damage depending on the stage of millet growth and the generation of infesting larvae. First-generation larvae cause dead hearts and a consequent loss of crop stand. Second-generation larvae cause lodging, disrupt the plant vascular system and prevent or limit grain formation.

Larvae can migrate between plants, moving a maximum of 1.2 m in the insectary and 1.8 m in the field. Larval survival during the growing season is high, probably because larvae enter leaf sheaths or stems within 24 hours after hatching. During the wet season, larvae complete development in approximately 30 to 40 days (mean 34 days). There are usually six, but sometimes seven instars. Male pupae develop in 7-12 days (9.3 average) and females in 7-13 days (9.7 averages).

Adults are active mostly during scotophase, but remain on the lower leaf surface or along stems, with heads turned towards the ground during the day. In Nigeria, the sex ratio from light traps or by rearing adults from the field- collected eggs, larvae, and pupae showed significantly more females than males. In Niger a sex ratio of 1:1 was reported based on a sample of 1087 pupae, suggesting that the ratio imbalance from light trap catches could be due to differential responses of males and females to light (ICRISAT, 2018). Mating in the laboratory occurs late during the night of adult emergence or early the following night. Oviposition begins the first night after mating and peaks on the third night after emergence. It can continue through the sixth night after mating. In the field, adult females place their eggs in batches, averaging 20 to 50 eggs between the leaf sheath and the stem, or on lower leaf blades (Harris, 1962). Ismaila *et al*. (2010) reported that *C. ignefusalis* oviposition is mostly associated with leaf sheath and rarely occurs on leaves. Each female may layover 100 eggs in total. Newly deposited eggs are creamy-white to yellow, turning dark after 8 to 11 days, and hatch 24 hours after darkening. Two or three generations occur during each millet-growing season.

2.10.3 Adult emergence, mating, and dispersal

During the dry season, larvae remain in diapause until the onset of the next season rains and then pupate. Emerging adults infest the new millet plants. Nothing is known about adult movements and migratory habits. However, like most pyralids, the millet stem borer is unlikely to be a migratory pest. Mating is mediated by the female sex pheromone which attracts males. Ismaila *et al*. (2010) reported that female attractiveness was affected by age: males were more attracted to I-day old females than 4-day old ones probably because older females produce less pheromone. However, this needs to be further investigated (Plate 2.12).

B 

C 

D 

Plate 2.11: Stages of development of *Coniesta ignefusalis.* (Source: CIMMYT, 2011)

2.11 Sugarcane stem borer, *Eldana saccharina*

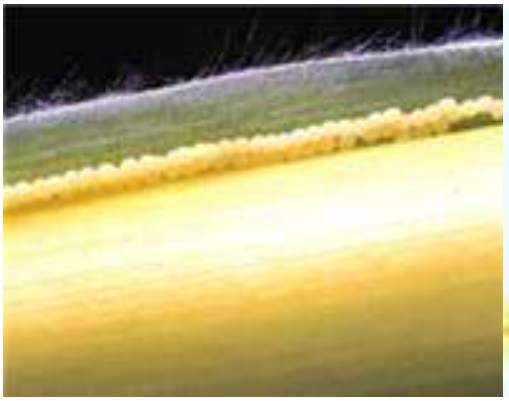
Eldana saccharina is indigenous to Africa. The African sugarcane stalk borer is widely distributed in sub-Saharan Africa including Burundi, the Democratic Republic of Congo, Kenya, Rwanda, Tanzania and Uganda. Sugarcane is the main crop host of the African sugarcane stalk borer but it will also attack maize (where it is a relatively minor pest), sorghum and rice. It attacks maize plants late in their development when it can affect grain filling which results in yield loss. Sugarcane stalk borer, African sugarcane stem borer, *Eldana* borer *Eldana conipyga* Strand, 1912 (Ismaila *et al*., 2010)

2.11.1 Eggs and larvae of *E. saccharina*

The eggs of the African sugarcane stalk borer are yellow, oval and laid in batches, usually on dry dead maize leaves. They become pink just before emergence. The African sugarcane stalk borer larvae are light-brown to dark-grey colour with brown pinnacle (hardened – sclerotized – areas that indicate points of muscle attachment), covered with very small dark coloured spots and have a distinct brown prothoracic shield. The head is reddish-brown to dark-brown. Larvae may be distinguished from other stem borer larvae by the circular arrangement of crochets (hooks) on the prolegs, piacular and tubercles (small rounded projections) along the body. Eggs are laid in batches of 50 - 100 eggs in folds of dead leaves, behind the leaf sheath or on dry leaves at the bases of plants or on plant debris on soil. Females may lay 400-600 eggs in their lifetime. Eggs hatch within 5-6 days. Young larvae feed externally on the green surface of the plant and later tunnel into the stems where they eat out tunnels within which they pupate. Larvae can develop in 21 days but development may last up to three months. The larvae do not go into a state of suspended development (diapauses). Adults emerge in 7-14 days after the onset of pupation and only live for a few days (ICRISAT, 2018).

2.11.2 Adults of *Eldena saccharina*

The adult African sugarcane stalk borer is small with a wingspan of 35 mm. The forewings are pale brown with two dark spots in the centre and elongate with a rounded front edge. The hind wings are whitish with a short fringe and brown longitudinal veins (Plate 2.13). At rest, the wings are folded over the abdomen in such a manner that their outer edges are parallel to each other, and they cover the lighter coloured hind wings which are hidden from view. Both the adult and larval stages are unlikely to be confused with any other stem borers present in Africa. Sugarcane is the main crop host of the African sugarcane stalk borer but it will also attack maize, sorghum and rice (Okweche *et al*., 2010). In the wild, its hosts are wild grasses (Poaceae) such as guinea grass (*Panicum maximum*), wetland sedges (Cyperaceae) such as *papyrus* (*Cyperus papyrus*), rushes (Juncaceae) and *typha* (Typhaceae)



Eggs of *Eldana saccharina* Larva of *Eldana saccharina*

Adults of *Eldana saccharina*

Plate 2. 12: Stages of development of *Eldana saccharina* (source CIMMYT, 2011)

2.12 Host Plants of Maize Stem Borers

The main crop hosts for *B. fusca* are maize and sorghum as well as pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana* L.), and sugarcane (*Saccharum officinarum*), but to a much lesser extent (Calatayud *et al.,* 2006). Although the host plant on which *B. fusca* originally evolved is unknown, indigenous African grasses have been recorded as hosts, specifically *Sorghum verticilliflorum* (Steud.), *Pennisetum purpureum* Schum., *Panicum maximum* Jacq., *Hyparrheniarufa* Nees (Stapf), *Rottboellia exaltata* (L.), and *Phragmites* sp. (Okweche *et al*., 2010).

2. 12.1 Behavioural basis of host plant selection

The different behavioural steps leading to host selection and oviposition have been well described in *B. fusca* (Calatayud *et al*., 2008). Similar to other noctuids, the behavioural steps leading to oviposition by a gravid moth follow a sequential pattern involving searching, orientation, encounter, landing, surface evaluation, and acceptance. Before landing, plant volatile influence the female orientation, indicating from a distance the suitability of the plant species; the female antennae bear numerous multiporous trichoidea sensilla able to collect volatiles (Calatayud *et al.,* 2006). Thereafter, the visual cues are also involved in the female's orientation and landing (Calatayud *et al.*, 2008). It is after landing that the final decision for oviposition takes place. The female typically sweeps her ovipositor on the plant surface as if evaluating the suitability of the plant, simultaneously touching it with the tips of her antennae, and then, if the plant is accepted, oviposition takes place. The tip of each antenna bears several uniporous sensilla able to taste the plant's surface (Calatayud *et al*., 2006). In addition, the ovipositor bears about nine uniporous chemosensory sensilla (*i.e.*, taste receptors) located

within the inner border of the ventral surface of each lobe of this organ (Calatayud *et al*., 2006). Combinations of tactile and gustatory stimuli from the plant are received during the ovipositor sweep behaviour.

During this behavioural step, the claws at the distal part of the ovipositor leave small injuries on the plant surface, which are deep enough to liberate inner plant cuticular compounds, which differ between plant species (e.g., between host and non-host plants) (Juma, 2005). These compounds are perceived by the taste receptors on the ovipositor, which then activate the appropriate behaviour (acceptance or rejection) depending on the nature/composition of these cuticular chemicals. Like all noctuid borer species, *B. fusca* females oviposit egg batches between the leaf sheath and the stem (Simon *et al*., 2015). *Busseola fusca* prefers to oviposit inside leaf sheaths of the youngest fully unfolded leaves. In choice tests, *B. fusca* moths show a preference for maize to sorghum plants of similar sizes (Rebe *et al*., 2004). It can therefore be concluded that the physical properties of the leaf sheath and stem play a crucial role in plant acceptance for oviposition. *Busseola fusca* prefers to oviposit on waxy plant species (Haile and Hofsvang, 2002) and do not oviposit at all on *Melinisminuti flora*, a species with glandular trichomes. It was also shown that 3–6 weeks old maize plants are most attractive for oviposition. Thus, *B. fusca* prefers pre-tasseling plants; oviposition rarely occurs on older maize plants, but if so, the insect lays batches on the upper part of the plants where the leaf sheaths are young and soft. Oviposition on maize plants in the post-anthesis period has been reported, but when provided with a choice, moths prefer plants during the vegetative stages of development. A significant correlation exists between stalk circumference and *B. fusca* egg number in maize (Alata *et al*., 2008).

All these reports and observations suggest that plant physical cues, such as surface texture (e.g., pubescence), plant size (e.g., stem diameter), and leaf sheath rigidity, strongly influence the acceptability by *B. fusca* of a host species or plant part. Alata *et al.* (2008) reported that *B. fusca* does not prefer to oviposit on plants with very small stem diameter and prefers to oviposit on plants with non-pubescent or smooth surfaces, over pubescent or rough surfaces. Pubescence and rough surfaces significantly affect the behavioural steps leading to oviposition since it interferes with the ovipositor sweep process necessary to find a suitable oviposition site. In addition, the rigidity of the support that the leaf sheath provides influences with the proper insertion of the ovipositor for egg deposition. It can be concluded that oviposition acceptance in *B. fusca* is very likely caused by evolved mechanisms of oviposition site selection; that is, suitable oviposition sites are restricted to the gaps between the leaf sheath and the stem, and, hence, rigidity and pubescence of the stem or leaf sheath will affect oviposition (Alata *et al*., 2008). Oviposition patterns, host selection and to a lesser extent larval distribution on plants seem to be closely related to crop phenology. Field studies on grain sorghum, oviposition on both main stems and tillers reached a maximum at six to eight weeks after plant emergence. This differs from the known pattern in maize of three to five weeks and could be ascribed to the difference in growth rates of the two crops. Elongation of grain sorghum stems is slower, while stalks of maize are generally thicker and thus favour oviposition at earlier crop growth stages. The period of oviposition is extended in grain sorghum, possibly due to tillering, which provided leaf sheaths of suitable tightness over a longer period of crop development than in maize.

Host selection in phytophagous insects is generally determined by the adults. However, in many Lepidoptera species, the larvae can engage in host plant selection (Wahedi *et al*. 2016).

After hatching underneath the leaf sheath, *B. fusca* neonate larvae ascend to the whorl, where they either feed on the leaves or disperse via ballooning-off. This dispersal phenomenon is generally density-dependent and might be influenced by host plant quality. After feeding in the leaf whorl, 3rd to 4th instar larvae descend and bore into the plant stem. Generally, lepidopteran larvae display food preferences *via* a phenomenon driven by chemo-receptors located on the mouthparts (Schoonhoven and Vanloon, 2002). Like other Lepidoptera species, *B. fusca* larvae possess sensory structures able to detect plant compounds, including volatiles (Juma *et al.,* 2008). Although the antennae of the larvae are short and simple, they bear three multiporous cone-shaped basiconic sensilla able to detect volatiles. The 3rd instar larvae can recognize the odours of their host plant at a distance.

The larvae possess also on their maxillary galeae two uniporous styloconic sensilla, which are contact chemoreceptors. They have also maxillary palps having eight small basiconic sensilla at the tip, which were also found to be gustatory (Juma *et al.,* 2008). Plant sugars are often considered as primary feeding stimuli, involved among the compounds that induce the host plant acceptance by herbivorous insects (Schoonhoven *et al.,* 2005). It was recently shown that sucrose is a feeding stimulant and positively influences food choice by *B. fusca* larvae, whereas turanose (an isomer of sucrose), as a deterrent, negatively contributes to larval food choice (Juma *et al*., 2013). The uniporous styloconic sensilla of the maxillary galeae can detect both sugars but the lateral styloconic appears more sensitive to sucrose at low concentrations whereas the medial styloconic is more sensitive to turanose. These findings indicate that the balance in concentrations of these sugars somehow influences the overall host plant choice made by the larvae.

Among the most important factors determining the larval choice of host plants might be differences in silicon (Si) content. In higher plants, silicon levels range between 0.1-10 % on a dry weight basis and they are generally higher in grasses than in dicotyledonous plants (Ismaila *et al.*, 2010). Plant resistance to insects, pathogens or abiotic factors is related to the level of accumulation and polymerization of silicon in tissues (Reynolds *et al.*, 2009). For *B. fusca*, it has been observed that silicon in plant epidermal cells appears to provide a physical barrier by increasing leaf abrasion, which subsequently increases wearing off of the mandibles of *B. fusca* larvae, which physically deter larval feeding (Juma, 2010). Consequently, *B. fusca* larvae prefer to feed on grasses that have low levels of silicon.

2.12.2 Pheromones and mating

Only the females emit pheromones. Males and females exhibit simple and rapid courtship behaviour without any particular characteristic events (Frérot *et al*., 2006). The sex pheromone of *B. fusca* females was first identified as a mixture of Z -11-tetradecen-1-yl acetate Z11–14: Ac), E -11-tetradecen-1-yl acetate E11–14: Ac), and Z-9-tetradecen-1-yl acetate Z9-14: Ac). More recently, an additional pheromone component, (Z)-11-hexadecen-1-yl acetate was identified and when added to the aforementioned three-component synthetic blend resulted in the improved attraction of males (Félix *et al*., 2009).

The females start calling a few hours after emergence, indicating the absence of a sexual maturation time (Calatayud *et al.*, 2007). The calling behaviour generally commences during the fourth hour after the onset of the scotophase but it is slightly delayed for young females having emerged the same night as compared to older females (Calatayud *et al.*, 2007). Mating starts within a few hours after moth emergence. Moreover, mating occurs generally during the

first six hours of the night, and the males can mate several times but only once per night (Gemmeda and Getu, 2018). A single spermatophore is generally sufficient to fertilize all eggs of a female throughout her life span, indicating that polyandry is not obligatory and not necessary. Laboratory studies also showed that female calling behaviour and male attraction was not influenced by the presence of plants, irrespective of it was host or non-host (Félix *et al*., 2009). The oviposition period lasts for 3–4 nights. It commences during the first night after mating, peaks during the second and then gradually decreases until the fifth night.

2.13 Management of Stem Borers

Most stem borer attacks on cereal crops result from infestation by more than one species and since there are important differences in biology and ecology that limit the effectiveness of some techniques, integrated pest management programmes must be devised to meet local conditions. Many different chemical and non-chemical control measures have been developed and applied since 1920 when Mally reviewed early work in South Africa, and these have been summarized, with bibliographies, by Harris and Nwanze (1992).

2.13. 1 Cultural control

Cultural methods and practices that can be used to control stem borers include appropriate crop residue disposal, planting date manipulation, host resistance, destruction of volunteer and alternative host plants, tillage practices, crop rotation and intercropping (Tekle, 2016)). These control measures do not guarantee 100% control but help to reduce infestation and enable sustainable maize production (Tekle, 2016). Cultural control is useful because it combines effectiveness with minimal extra labour and cost (Félix *et al*., 2009). Appropriate disposal of crop residues after harvest can reduce carried over populations of diapause larvae of stem

borers and so limit initial establishment on the following season's crop. Later sowing of maize is less affected by stem borer larvae than earlier sowings as it disrupts their seasonal cycle. It is thought that at the start of the rainy season, borer populations arising from diapausing-generation larvae will still be building up, so fewer moths will oviposit on early planted crops. In a study, the infestation of late-sown maize, attacked by the second generation of *B. fusca* was higher (22-100) than early-sown maize attacked by the first generation (0-22%).

Destruction of volunteer and alternative host plants reduces overwintering and hibernation of stem borer species. Stubble is probably the main source of initial stem borers' infestation in subsequent seasons (Malusi and Okuku, 2013). Deep ploughing is effective as it brings the larvae and pupae to the soil surface (Félix *et al*., 2009). The larvae will be then exposed to the heat from the sun and predators like cattle egret (*Bubulcus ibis*). Deep ploughing also controls stem borers because by burying, pupae and stem borer moths do not emerge from great depths. However, zero tillage shelters insect pests from plant materials. This may lead to an increase in the number of pests and must be avoided if stem borer numbers are to be reduced (Félix *et al*., 2009).

Appropriate disposal of crop residues after harvest can reduce carry-over populations of diapause larvae and so limit the initial establishment of the pest on the following season's crops. Burning or burying by deep ploughing is effective but in areas where stems of cereals are used as building and fencing materials, it may be better to devise means of destroying diapausing larvae without destroying the stems. Alternatively, simply leaving stems lying on the ground exposed to the full heat of the sun for a month or so after harvest has been shown to reduce populations of diapausing larvae. Using crop residues for fodder and silage has also

been recommended. Cultivation by disking and ploughing may also be effective, and, when preceded by slashing, can reduce larval populations by almost 100%. Intercropping maize and/or sorghum with cowpeas may reduce damage caused by *B. fusca*.

2.13.2 Host-plant resistance

Host resistance to the insect is the genetic property that enables a plant to avoid, minimize, tolerate or recover from an injury caused by the pests. These plants have genetic traits which manifest as antibiosis, in which the biology of the pest is adversely affected after feeding on the plant. Furthermore, they can have genetic traits which manifest as antixenosis (non-preference) where the plant is not desirable as a host and the pest seeks alternative hosts. They can also be tolerant and able to withstand or recover from the pest damage (Frérot *et al.*, 2006). Screening maize and sorghum genotypes for resistance to *B. fusca* have until recently been limited by the lack of effective techniques, especially the inability to rear *B. fusca* on artificial diets. Much screening has therefore been against field infestations, often against complexes of different borer species. In Ethiopia, barely 1% of nearly 6000 indigenous sorghum genotypes showed promising levels of tolerance but in South Africa, several lines of maize have intermediate levels of tolerance to whorl feeding by first-instar larvae (Maddoni *et al*., 2006). Mechanisms of resistance are not well understood but effects of preferential oviposition have been reported by Van Rensburg *et al*. (1989). Maddoni *et al*. (2006) suggested that three factors related to resistance are present in maize, the first killing early instar larvae, the second repelling larvae and the third retarding larval development.

2.13 .3 Biological control

Natural enemies play an important role in the control of lepidopterous borers in Africa. Biological control is the use of parasitoids, predators, nematodes and/or pathogens to maintain the density of a species at a lower level than would occur in their absence. The main attraction of this control is that it lowers the need for using chemicals and there is limited environmental pollution, which may affect non-targeted flora and fauna (Félix *et al*., 2009). It usually offers a lasting solution of stem borer control at one introduction hence beneficial to both smallholder and commercial farmers. Some parasitoids attack eggs, some attack larvae, while some attack pupae. *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) and *Platytelenomous busseola* (Hymenoptera) are egg parasitoids, that contribute to the natural mortality of stem borers. Hymenopteran parasitoids like *Cotesia* spp. have highly specialized ovipositors for stinging and depositing eggs in the host. The sting causes permanent paralysis in the host body. *Trichogramma sp*. parasitise eggs of stem borers while *Cotesia* spp. parasitize their larvae (Chabi-Olaye *et al,* 2004). Egg parasitism offers good control in that it stops the emergence of the damaging larval stage (Félix *et al.*, 2009). *Dentichasmiasismmbusseolae*(Heinrich)(Hymenoptera:Inchneumonidae), *Pediobusfurvus*(Gahan)(Hymenoptera:Eulophidae)and *Lepidoscelio*spp. *Xanthopim plastemmator* (Thunberg) (Hymenoptera: Ichneumonidae) are parasitoids of stem borers.

In South Africa, *Procerochas miasisnigro maculatus* Cameron (Hymenoptera: Ichneumonidae) was recorded with up to 100% pupal parasitism on *B. fusca i*n addition, in South Africa, *Dentichas miasis busseolae* caused up to 100% pupal parasitism of *C. partellu.* Furthermore, in South Africa, the parasitoid *Cotesia sesamiae* (Cameron) (Hymenoptera: (Hymenoptera: Braconidae) accounted for up to 90% of parasitized *B.fusca*

*la*rvae, but have not yet been able to maintain populations below economic threshold levels (Malusi and Okuku, 2013). Parasitoids of hosts which feed in exposed situations usually pupate in protective silken cocoons produced by the larvae themselves. Some parasitoids can pupate within the eaten out body of the host (Félix *et al.*, 2009). In Ghana, exotic species of *Trichogramma* showed have high fecundity and helped to control stem borers, including *B. fusca*. In Southern Benin, *Telenomusbusseola* (Ghana) (Hymenoptera: Sclionidae) and *Telenomusisis*(Polaszek) (Hymenoptera: Sclionidae) are the most important natural control factors of stem borers including *B. fusca* on maize. In Ethiopia, the Braconid, *Dolichogenidea fuscivora* was found to be the major larval parasitoids of *B. fusca* with parasitism as high as 71% in the dry season and 18% in the wet season. *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae) is the most important larval parasitoid of *B. fusca* with 20 to 25% parasitization in Ethiopia (Kruger *et al*., 2012). It is also a gregarious larval endoparasitoid of *S. calamistis. Pediobius furvus G*ahan is a gregarious primary pupal parasitoid of *B. fusca* in maize and sorghum in Ethiopia. According to Kruger *et al*. (2012), *Stenobracon rufus* is a solitary pupal parasitoid of *B. fusca* attacking maize and sorghum in Ethiopia with 14 % parasitization.

Generally, the levels of stem borer's parasitism by indigenous natural enemies are not satisfactory. *Cotesia flavipes* (Hymenoptera: Braconidae) was imported and released due to low background of low parasitism by native parasitoid species in Zimbabwe between1999 and 2002. Parasitoids locate borers by laying eggs into them while feeding inside the plant stems. Predators are valuable components of Integrated Pest Management (IPM). Ants (Hymenoptera: Formicidae) are the most important predators of stem borers in maize fields. They attack all stages of stem borers and are among the few predators preying on stem borer

larvae and pupae. According to Félix *et al*. (2009), *Componotus* spp. (Formicidae) and *Pheidole* spp. (Formicidae) appear to be the most important and common species in Zimbabwe. Ants of the genus *Lepisiota*were reported preying on eggs and larvae of stem borers (Van den Berg and Vaan Rensburg, 1996). In Ethiopia, Earwigs (Dermaptera) and ants were commonly seen preying on *B. fusca*. Entomopathogenic viruses, bacteria and fungi can be used as pathogens to control insect pests. *Bacillus thuringiensis* (Bt) lowered stem borer larvae in Kenya with a consequent increase in the yield. *Beauveria bassiana* is known to control *C. partellus* by infecting insect hosts through skin penetration. This makes them readily able to kill piercing and sucking pests that may not be killed by stomach poisons. High humidity is needed in this case for *Beauveria bassiana* germination (Félix *et al.*, 2009).

Potentials for biological control are currently being investigated, especially in East and South Africa. Classical biological control by the introduction of parasitoids from Asia and/or the Americas has been attempted on several occasions but with little success so far. The general situation in Africa has been reviewed by some authors over the past 30 years (Harris and Nwanze, 1992) and implementation programmes are now in progress in East and South Africa. Geographic differences in host acceptance and suitability do exist and were studied in Zimbabwe. (Chinwada *et al.*, 2001) reported 18 species of parasitoid developing on *B. fusca* in South Africa, of which the indigenous species *Cotesia sesamiae* and *Bracon sesamiae* were most abundant, and discussed proposals for further introductions of exotic species into South Africa. This could involve transfers within Africa of *B. fusca* parasitoids not known to occur in South Africa and/or introductions from outside Africa of stem borer parasitoids from other parts of the world.

2.13.4 Chemical control

In addition to cultural control measures aimed at the destruction of stubble to destroy overwintering populations of larvae, early chemical control involved whorl applications of lead arsenate as soon as visible symptoms of infestation became apparent. DDT, the first synthetic insecticide, replaced lead arsenate during the 1950s. During the early1960s it became common practice in some areas to apply DDT preventatively 28 to 35 days after planting. This inevitably led to some applications being given too early, whereas others were not economically justified given the pronounced spatial and temporal variability of infestation levels. DDT was withdrawn from the agricultural market in 1976. This immediately led to the evaluation and registration of several new generation insecticides, including organophosphate and carbamate compounds, later followed by synthetic pyrethroids (Kruger *et al.*, 2012). Most of these were considerably more expensive and some less persistent than DDT. At the same time, a steep increase in production costs without a concomitant increase in producer prices of maize placed the spotlight on the economics of stem borer control. Chemical control should start by looking for signs of damage when plants are 2 to 4 weeks old, depending on the area. If you find holes in the leaves then use any of the following chemicals:

- Thiodan 3% G (a. i. Cyfluthan-25g/l, Endosulfan 350g/l) - a pinch into the funnel of each plant (3- 4 kg/ha).
- Dipterex 2.5% G (a. i. Trichlorfon) - a pinch into the funnel of each plant (3 - 4 kg/ha).
- Bulldock 0.05% G (a. i. Cyfluthrin 25 g/l) - one shake in the funnel of each plant (7.5 - 10 kg/ha).
- Ambush 0.05%G (a. i. Permethrin 50 g/l) - one shake per plant in the funnel (7.5 - 10 kg/ha).
- Pymac(a. i. 25 g/l; the residue from pyrethrum processing) - a spoonful of Pymac should be applied into the funnel of each plant.

2.13.5 Integrated management of *Busseola fusca*

Since *B. fusca* is an important pest of maize in sub-Saharan Africa, a wide range of methods have been researched, tested and implemented to manage this pest. These include among others control by pesticides, cultural practices, host plant resistance as well as biological control agents (Kfir *et al.*, 2002). Cultural control is a long-established method of modifying the habitat to make the environment unfavourable for the survival and reproduction of pests. Moreover, it is the most relevant and economic method of stem borer control available for resource-poor farmers in Africa. This management strategy is considered the first line of defence against pests and among the oldest traditional practices, includes techniques such as destruction of crop residues, intercropping, and crop rotation, manipulation of planting dates, tillage methods and improvement of soil fertility. In addition, these control techniques aim to reduce rather than eradicate pest populations and they can be used in conjunction with other methods. Diagnostic work in West Africa indicated that increased plant diversity in (mixed cropping) and around (wild habitats) maize fields, or improvement of soil fertility via integration of grain legumes or cover crops as short fallow, or provision of nitrogen fertilizer or silicon (Si) could influence *B. fusca* infestation levels (Ndemah *et al.*, 2006).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Field Survey

Maize farms were surveyed from May to August, 2019 cropping season to determine the incidence of maize stem borer in the study area. The States surveyed were Kwara, Nassarawa, Niger and Oyo (Figure 3.1). In each state, four Local Government Areas (LGAs) were selected (Oyun, Irepodun, Ilorin East and Edu of Kwara state; Keana, Keffi, Wamba and Lafia of Nassarawa state; Bosso, Wushishi, Paikoro and Gurara of Niger state; and Egbeda, Akinyele, Atiba and Afijio LGAs of Oyo state). In each LGA, 5 maize farms were randomly selected for the survey. One Structured questionnaire (Appendix I) was used to collect information from farmer in each farm surveyed. Information on the longitude, latitude and elevation of each farm was obtained using Global Positioning System (GPS) equipment. Ten plants were examined per field. In each field, maize stem borer incidence was assessed as a percentage of the total plants exhibiting maize stem borer symptoms. The severity of infestation was also determined by counting holes on the plants' leaves (leaf damage) using a scale as shown in Table 3.1

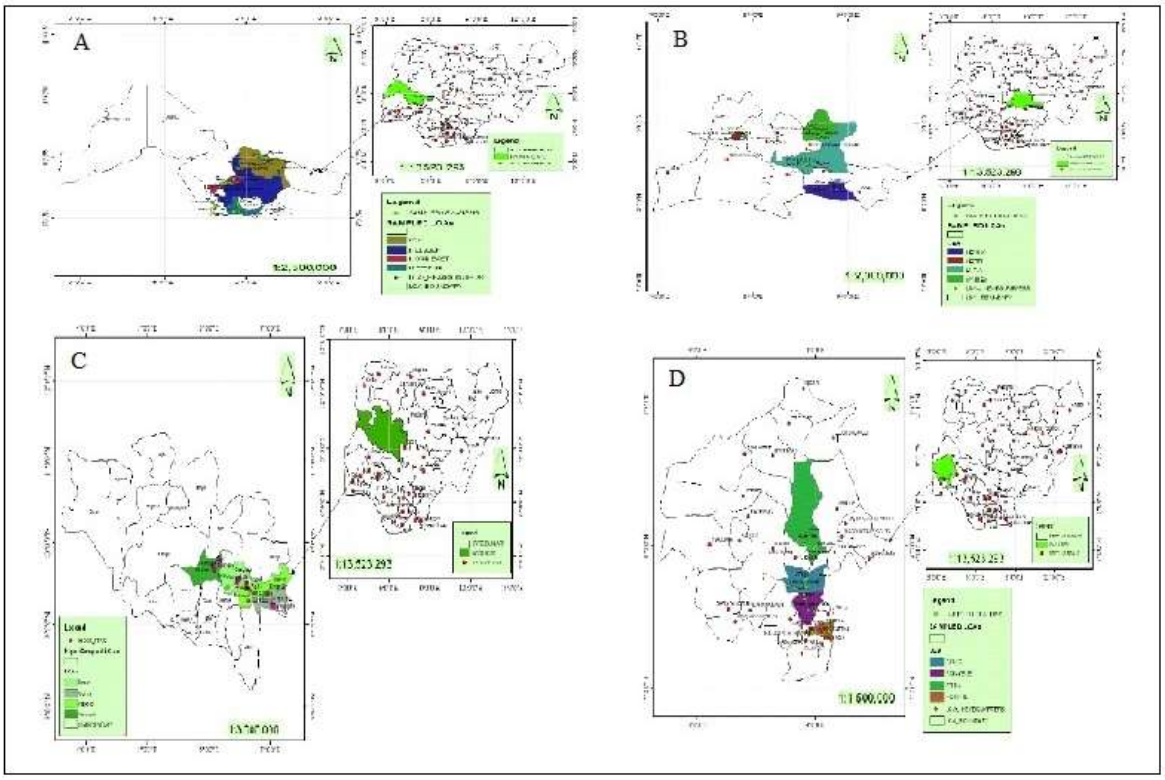


Figure 3.1 Maps showing States and Local Government Areas surveyed in Kwara (A), Nasarawa (B), Niger (C) and Oyo (D)

Table 3.1: Scale used for scoring stalk borer leaf damage from seedling to whorl stage in maize

Numerical Score	Visual ratings of plant damage	Reaction to resistance
0	No damage	Probable escape
1	Few pin holes	Highly resistant
2	Few pin holes on older leaves.	Resistant
3	Several shot holes on leaves (<50%).	Resistant
4	Several shot holes on leaves (>50%) or small lesions (<2 cm long)	Moderately resistant
5	Elongated lesions (> 2 cm long) on a few leaves.	Moderately resistant
6	Elongated lesions on several leaves.	Susceptible
7	Several leaves with elongated lesions or tattering.	Susceptible
8	Several leaves with long lesions with severe leaf tattering	Highly susceptible
9	Plant dying due to death of growing points (dead-hearts)	Extensively sensitive to damage

Source: CIMMYT, (2011)

3.1.1 Collection and Identification of maize stem borer species

Collection of larvae was done by destructive sampling on the plant showing symptoms of stem borer's infestation. The plants were cut open to remove the larvae, larvae were place in water and then transported to Entomology Laboratory of the Department of Crop Production, Federal University of Technology (FUT), Minna in different labeled perforated plastic for each field location for maintenance and rearing to adults (Plate 3.1).

Each larva was maintained on healthy maize seedlings (four weeks old) in a wooden cage measuring 50 cm ×50 cm in diameter and 150 cm in height, kept in a screenhouse. The seedlings used were raised from the maize variety; Pool -16 were in plastic pots (25 cm diameter and 30 cm deep) and Identification was done by the use of dichotomous keys.

Sorting, combing and recording of stalk bores were also carried out in Insect museum at the Department of Crop Protection, Ahmadu Bello University, Zaria.

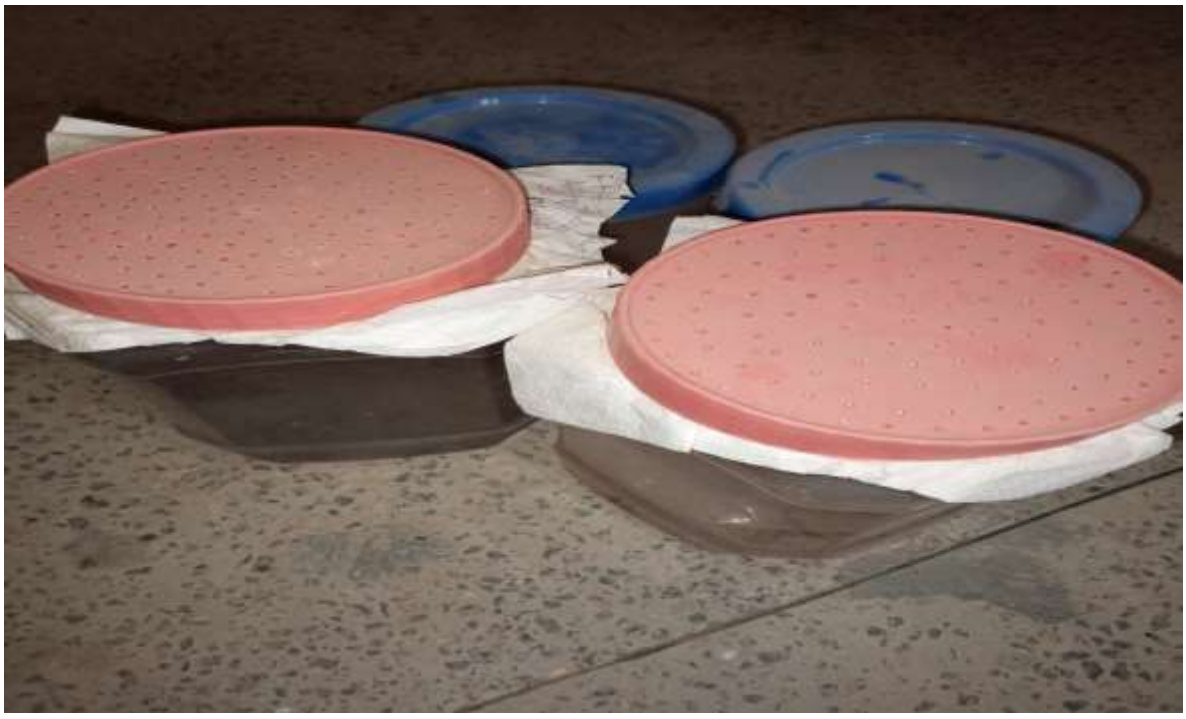


Plate 3.1: Perforated plastics used for moving stalk borer larvae from field to screenhouse

3.2 Screenhouse Experiment

3.2.1 Evaluation of Selected Maize Genotype for Maize Stem Borer Resistance

3.2.2 Description of the study area

The trials were conducted in the screenhouse of the Department of Crop Production, FUT, Minna. Minna lies on the latitude 90° 41' N, longitude 60° 30' E and altitude of between 200 and 300 m above sea level of Southern guinea savanna agro-ecological zone of Nigeria. It has a mean annual rainfall of 1200 mm. The rainfall has its peak in September and it usually begins in April and ends in of October. The temperature ranges between 35 and 37.5^{o}C, with relative humidity between 60 and 80% in July and 40 and 60% in January (Adeboye *et al*., 2011). Soils in Minna originated from basement complex rocks and generally are classified as Alfisols (Adeboye *et al*., 2011). The actual coordinates and elevation of the sites were captured using GPS.

3.2.3 Soil sterilization

Steam method of soil sterilization was employed using metal trough. The trough consisted of two pieces of a metal drum (the upper and the lower). The upper piece was perforated at the bottom. The lower piece was positioned on a piece of metal stand having three legs for support and was then half filled with water. The upper piece was designed to fit tightly on the lower piece. This was then filled with soil and covered with a thick sack. A moderate hole was made to permit the thermometer to the top of the soil. The covering was done to ensure sterilization up to the soil surface. Dry pieces of fire wood were arranged under the metal stand and used to make a fire. The steam produced by the boiling water in the lower piece

passed through the perforations at the bottom of the upper piece to effect sterilization of the soil until soil temperature reaches 100 ^{0}C (Adeboye *et al*., 2011)

3.2.4 Soil Sampling and Analysis

Surface soil samples were collected and air-dried, gently crushed, passed through a 2 mm sieve and thoroughly mixed together to determine the physical and chemical properties according to the method described by ISRIC/FAO (2002). Some were further passed through a 0.5 mm sieve to determine the total nitrogen. The soil samples were analysed using standard methods as described by Agbenin (2003). Particle size distribution was determined by the Bouyocous hydrometer method. Soil pH was determined in a 1: 2.5 soil to water using a glass electrode pH meter.

Total Nitrogen was determined by the micro Kjeldahl method. Available phosphorus (P) was extracted by the Bray P1 method. Colour was developed in soil extract using the ascorbic acid blue method. Exchangeable K+ was extracted with 1N neutral ammonium acetate (NH_4OAc) solution and amounts of K+ in solution were determined using a flame photometer (ISRIC/FAO (2002), (Table 3.2).

Table 3. 2 Physical and Chemical properties of soil the Soil

Parameters	Value
Particle size distribution (g kg^{-1}	
Sand	830
Silt	70
Clay	100
Textural class	Loamy sand
Chemical properties	
PH (1:2:5)	5.77
OC	6.87
Total N (g kg-1)	1.08
Available P (mg kg-1)	11.3
Exchangeable bases (cmolkg-1)	
Ca	3.20
Mg	1.30
K	0.08
Na	0.11
Exchangeable Acid	0.11

3.2.5 Collection of Seed and treatment procedure

Seeds of forty maize genotypes (M-G1 M-G2, M-G3, M-G4, M-G5, M-G6, M-G7, M-G8, M-G9, M-G10, M-G11, M-G12, M-G13, M-G14, M-G15, M-G16, M-G17, M-G18, M-G19, M-G20, M-G21, M-G22, M-G23, M-G24, M-G25, M-G26, M-G27, M-G28, M-G29, M-G30, M-G31, M-G32, M-G33, M-G34, M-G35, M-G36, M-G37, M-G38, M-G39 and M-G40) were obtained from the Breeding Unit of the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. The experiments were laid out in Completely Randomized Design with three replicates. Three trials were conducted; each trial comprised forty pots replicated three times, making a total of one hundred and twenty pots filled with 15 kg sterilized soil per pot (Plat 3.2 and 3.3).

Plate 3.2: Maize plants in screenhouse prior to infestation of stalk borer.

3.2.6 Crop establishment and management

Two seeds were sown per 15 kg of soil (per pot) in 2019, 2020 and 2021; each stand was later thinned to one plant per stand. Infestation of maize was done by introducing four 2nd instar *Sesamia calamistis* larvae to each stand of maize at 4 weeks after sowing (WAS) using camel hair brush (Tefera *et al*., 2011). N P K fertilizer was applied at 3WAS and urea was applied at 6 WAS to complement the N requirement of the crop at the rate of 120 kg N, 70 kg P and 83 kg **K** ha^{-1}. Manual weeding was carried out by hand-pulling at 4 and 8 WAS. Harvesting was done manually at mass maturity

3.2.7 Data Collection

3.2.7.1 ***Severity of Stem borers' infestation*****: -**Determination of the severity of stem borer infestation was based on leaf damage using a visual scoring 0-9 scale (International Maize and Wheat Improvement Center (CIMMYT, 2011) as shown in Table 3.1

3.2.7.2 ***Plant height*****:** Height of plants was measured in centimeters (cm) from the base of the plant to the last node using metre rule at 4, 6, 8, 10 and 12 WAS

3.2.7.3 ***Ear height*** **(cm):** Height of ear was measured in centimeters (cm) from the base of the plant to the node bearing the upper ear at harvest.

3.2.7.4 ***Stem diameter*** **(cm):** The stem diameter of each plant was measured using Vernier caliper.

3.2.7.5 ***Dead heart*****:** The number of plants showing the death of growing points (dead heart) was counted. The proportion of dead hearts was evaluated as in equation 3.1:

$$\text{Dead heart (\%)} = \frac{\text{Number of plants with dead heart}}{\text{Total number of plants inspected}} \times 100 \qquad (3.1)$$

3.2.7.6 ***Number of days to 50% tasseling*****:** The number of days from sowing to the time when 50 % of the plants have produced tassels was counted (IITA, 2012)

3.2.7.7 ***Number of days to 50% silking*****:** The number of days from sowing to the time when 50 % of the plants have produced silks was counted

3.2.7.8 ***Stem lodging*****:** The number or percentage of plants that suffered lodging was scored on a scale of 1-5, where 1=no stem lodging and 5= heavy stem lodging

3.2.7.9 ***Ear position*****:** The position of node where ear located on each plant was counted

3.2.7.10 ***Number of ears per plant*****:** The number of ears per plant was counted

3.2.7.11 ***Moisture content at harvest*****:** Grain moisture was taken by moisture tester at harvest in percentage.

3.2.7.12 ***Number of rotten ears*****:** rotten ear was rated on a scale of 1-5, where 1= little or no visible ear rot and 5 = extensive visible ear

3.2.7.13 ***Plant stand at harvest*****:** Total number of plants per pot obtained during harvest was counted.

3.2.7.14 ***Grain weight per plant*** **(g):** The weight of grains per pot was measured in g/plant.

3.2.8 Data Analysis

Analysis of variance (ANOVA) was performed using the General Linear Model (PROC GLM) of Statistical Analysis System. The significance of difference among the treatments

means were estimated using Duncan Multiple Range Test (DMRT) at 5% level of significance. Correlation coefficient was done to ascertain the relationship between stem borer severity and agronomic attributes of the maize genotypes. The data on dead heart, number of rotten ears, days to 50% tasseling, days to 50% silking, number of ears per plant, and grain weight were also subjected to cluster analysis to determine the relationships among the evaluated maize genotypes, using Unweighted Pair Group Method with Arithmetic means (UPGMA). Data analysis was done using the SAS statistical program (SAS, 2012).

3.3 Prediction of Attainable Maize Yield under Stalk Borer Infestation

The data on growth and yield parameters in section 3.3.6 were subjected to discriminant analysis. The discriminant functions were then used for prediction of the lodging status of maize genotypes. After the 7^{th} iteration of stepwise regression analysis, the optimal prediction was achieved as 73.7% (no lodging) and 77.7% for lodging. The model classification was evaluated using the prediction percentage. In all the three trials, the genotype, 12 measurable attributes were measured on each plant stand totaling 360 plant stands (40 x 3 x3). Of which 116 plant stands had no lodge with 85 stands were correctly classified as no lodge giving the model predicted of 73.3 %, while 188 out of 224 observations were correctly classified as lodging, which gave a predicted percentage of 77.7% for lodging. A stepwise approach was later used to estimate coefficients of the two discriminant functions; so that those variables that were significant at a pre-specified level (i.e. level of 1% probability in our case) were included in the final model. In each step, the value was calculated using the greedy Wilks (Rao, 1953) in the selection procedure. The coefficients of the two discriminant functions

were estimated. Four measurable attributes (stem diameter, number of days to 50% silking, moisture content, grain yield) were chosen and used in the discriminant models. Therefore, the two discriminant functions were given as shown in equations 3.2 and 3.3;

$Z_1 = -3.782 + 0.496\ X_1 + 0.079\ X_2 + 0.10\ X_3 + 0.091X_4$ (3.2)

$Z_2 = -2.364 + 0.127X_1 + 0.060X_2 + 0.028X_3 + 0.009X_4$ (3.3)

It was observed that group centroid for 'no lodging' was -0.424 while group centroid for 'lodging' was 0.889 using the discriminant model to classify the genotype lodging by cut-off form as in equation 3.4;

Cut off percentage (CO %) $= \frac{N_2(no\_lodge) + N_1(lodge)}{N_1 + N_2}$ (3.4)

$$= \frac{244 * (0.889) + 166 * (-0.424)}{166 + 244} =$$

Where N_1 =116, N_2 =244, I. e. 116 observations with plant stands had no lodge and 244 observations plant stands had lodging.

The data on growth and yield traits were also subjected to Cluster analysis to determine the relationships among the evaluated maize genotypes

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Cropping history of the surveyed farmlands

Farmers cultivated maize twice a year (early and late season) in Oyo and Kwara States while cultivated once in a year (wet season only) in Nasarawa and Niger States. Maize was sown in mixtures with other principal food and vegetable crops such as cassava, cowpea, millet, rice, okra, garden egg, sorrel and groundnut. The farmers interviewed stated that they usually buy seeds from the market or obtained seeds from previous harvest. Only a few of them obtained seeds from reliable sources like the research institutes, Ministries of Agriculture and Agricultural Development Projects (ADPs). Most of the farmers interviewed controlled weeds manually while few applied herbicides and insecticides were used to control weeds and insect pests respectively. Inorganic fertilizers such as NPK and urea were the main sources for soil improvement while few used both organic and inorganic manures. Information from various farmers met on the farms during field surveys of the various states and Local Government Areas about the knowledge of the occurrence of stalk borers was positive. They were aware of the presence and infestation of the pest, but no management strategy was attempted against it.

4.1.2 Incidence of stem borer infestation in surveyed field

The longitude, latitude, altitude and incidence of *Sesamia calamistis* in five locations (farmers' field) in four LGAs each of the four States surveyed is shown in Table 4.1. In Kwara State, the results indicated that the highest incidence (50%) of maize stem borers' infestation was obtained in Ilaji in Oyun LGA, followed by Ganmo oko (45%) in the same

Oyun LGA, while the lowest incidence (15%) was obtained in Ijanotan and Adeleke in Irepodun LGA as well as Osin in Edu LGA. In Niger State, the lowest incidence (10%) was acquired in Garatu in Bosso LGA while the highest (45%) was obtained in Lokogoma in Wushishi LGA.

In Nasarawa State, the highest incidence of 25% was found in Giza, Keana LGA followed by 23% incidence obtained in Wamba in Wamba LGA, while the lowest incidence (14%) was found in Keana, back of NSU (Nasarawa State University), Arikia and old barrack in Keana, Keffi, Wamba and Lafia LGAs respectively. Rook had the highest incidence (25%), followed by Alufa and Elemo (23%) in Akinyele, Atiba and Afijio LGAs of Oyo State, respectively.

Table 4.1.1: Incidence of stalk borer in states and Local Government Areas where farms were surveyed

State	LGA	Location	Long (^{0}N)	Lat (^{0}E)	Alt.(masl)	Inc.(%)
Kwara		Oyun	Ilaji	4.72	8.11	236	50
			Agbamu	4.65	8.10	241	35
			Ganmo oko	4.70	8.12	239	45
			Ilemona	4.71	8.12	301	20
			Arandun	4.68	8.08	332	20
		Irepodun	Ira	4.51	8.24	295	20
			Omugo	4.88	8.23	302	20
			Ijanotun	4.94	8.32	227	15
			Adeleke	4.80	8.26	315	15
			Oro	4.81	8.25	321	20
		Ilorin-East	Babanloma	4.72	8.61	298	30
			Oke oyi	4.77	8.62	310	34
			Iponrin	4.65	8.62	301	30
			Funti	4.76	8.62	273	30
			Arandun	4.77	8.62	214	35
		Edu	Shonga	5.15	9.00	197	30
			Lataworo	5.14	9.00	201	35
			Osin	5.14	9.00	234	15
			Ogudu	5.14	9.00	243	25
			Shaare	5.14	9.00	274	20
	Niger	Bosso	Garatu	9.58	6.14	207	10
			FUT, Forest	9.47	6.43	214	20
			Gidan-Kwano	9.52	6.85	213	13
			FUT,T& R	9.52	6.45	213	14
			Gidan-Mangoro	9.49	6.44	206	15
		Wushishi	Bankogi	9.80	6.15	137	25
			Lokogoma	9.82	6.16	138	45
			Pogo	9.81	6.16	122	20
			Zungeru	9.75	6.18	150	26
			Bogi	9.82	6.16	135	18

Table4.1.1Continue

State	LGA	Location	Long(^{0}N)	Lat(^{0}E)	Alt(masl)	Inc.(%))
	Paikoro	Bali	9.44	8.61	300	15
		Paiko-01	9.40	6.76	378	18
		Paiko-02	9.36	5.92	77	19
		Nikuchi	9.43	6.66	350	24
		Kaliko	9.36	6.60	300	37
	Gurara	Kwakuti - 01	9.40	6.94	473	25
		Kwakuti – 02	9.40	6.93	430	18
			9.34	7.00	395	23
		Zhigbedo-01	9.39	6.96	444	26
		Zhigbedo-02	9.40	6.88	370	25
Nasarawa	Keana	Keana	9.63	5.96	324	14
		Agaza	9.57	6.06	296	21
		Agundu	9.73	7.00	359	20
		Aloshi	9.81	6.35	321	21
		Giza	9.81	6.35	413	25
	Keffi	Uko	9.91	5.63	462	18
		Opposite NSU, Keffi Gate	9.83	6.03	365	16
		Back of NSU	9.78	8.51	410	14
		Arikin	9.76	7.15	403	21
		Tila	9.83	6.35	395	16
	Wamba	Dangi	9.53	6.07	325	21
		Arikia	9.64	5.61	283	14
		Wamba	9.69	5.73	321	23
		Shabu	9.79	6.02	263	21
		Gudi	9.57	5.66	411	22
	Lafia	Gandu	9.88	7.33	295	15
		Maraba	9.79	6.93	430	15
		Old Barrack	9.69	6.39	269	14
		Agode	9.79	5.98	362	17
		Ukwole	9.78	6.73	368	18

Table4.1.1Continue

State	LGA	Location	Long(^{0}N)	Lat(^{0}E)	Alt(masl)	Inc.(%)
Oyo	Egbeda	Egbeda	7.56	3.92	254	21
		Ayede	7.56	3.92	256	24
		Alapo	7.56	3.92	254	21
		Dawodu	7.56	3.92	256	20
	Akinyele	Rook	7.50	3.92	267	25
		Abatan	7.50	3.93	268	19
		Ajibade	7.57	3.93	289	10
		Akinyele	7.57	3.92	289	17
		Anifa	7.50	3.93	213	10
	Atiba	Ojakoso	7.93	3.91	281	13
		Abaoke	7.93	3.92	284	14
		Aboki	7.92	3.94	278	16
		Alufa	7.87	3.92	277	23
		Jobele	7.87	3.91	262	22
	Afijio	Akowe	7.75	3.92	284	10
		Fiditi	7.76	3.92	284	17
		Agudu	7.93	3.92	291	18
		Elemo	7.61	3.92	281	23
		Alado	7.76	3.91	284	21

KEY::masl = meter above sea level, Long. = longitude, Lat. = latitude, Alt = altitude, Inc. = incidence.

4.1.3 Severity of stalk borer infestation in surveyed fields

The severity of *Sesamia calamistis* in five locations (farmers' fields) in each of the four LGAs surveyed in Kwara State is shown in Figure 4.1.1. The results indicated that the highest severity (5.0) of maize stem borers infestation was obtained in Ilaji in Oyun LGA, Ogudu and Lataworo both in Edu LGA while lowest severity was obtained in Arandun and Ijan otun (2.0) both in Irepodun LGA. In Nassarawa State, the lowest severity of stem borers infestation was recorded in Agaza and Giza both in Kaena LGA and Gandu in Lafia LGA while the highest (3.0) stem borers' severity was found in Agundu in Kaena, Uko in Keffi LGAs, Dangi and Arikia in Wamba and Maraba in Lafia LGA (Figure 4.1.2).

Lokogoma and Bali, Wushishi and Paikoro LGA each had the highest (5.0) stem borers' severity of the infestation, while the lowest (1.0) stem borers severity was obtained in Kaliko (Wushishi LGA) (Figure 4.1.3). In Oyo State, Egbeda and Odooba (Egbeda LGA), Abatan (Akinyele LGA), Aboki and Abaoke (Atiba LGA) and Fiditi in Afijio LGA recorded the highest (3.0) severity while the lowest (1.0) stem borer severity was found in Ajibade and Anifa (Akinyele LGA), Ojakoso in Atiba LGA and Akowe in Afijio LGA (Figure 4.1.4). Finally, the highest (5.0) stem borers' severity was found in Kwara and Niger states compared to Nassarawa and Oyo had moderate severity (3.0) as their highest severity.

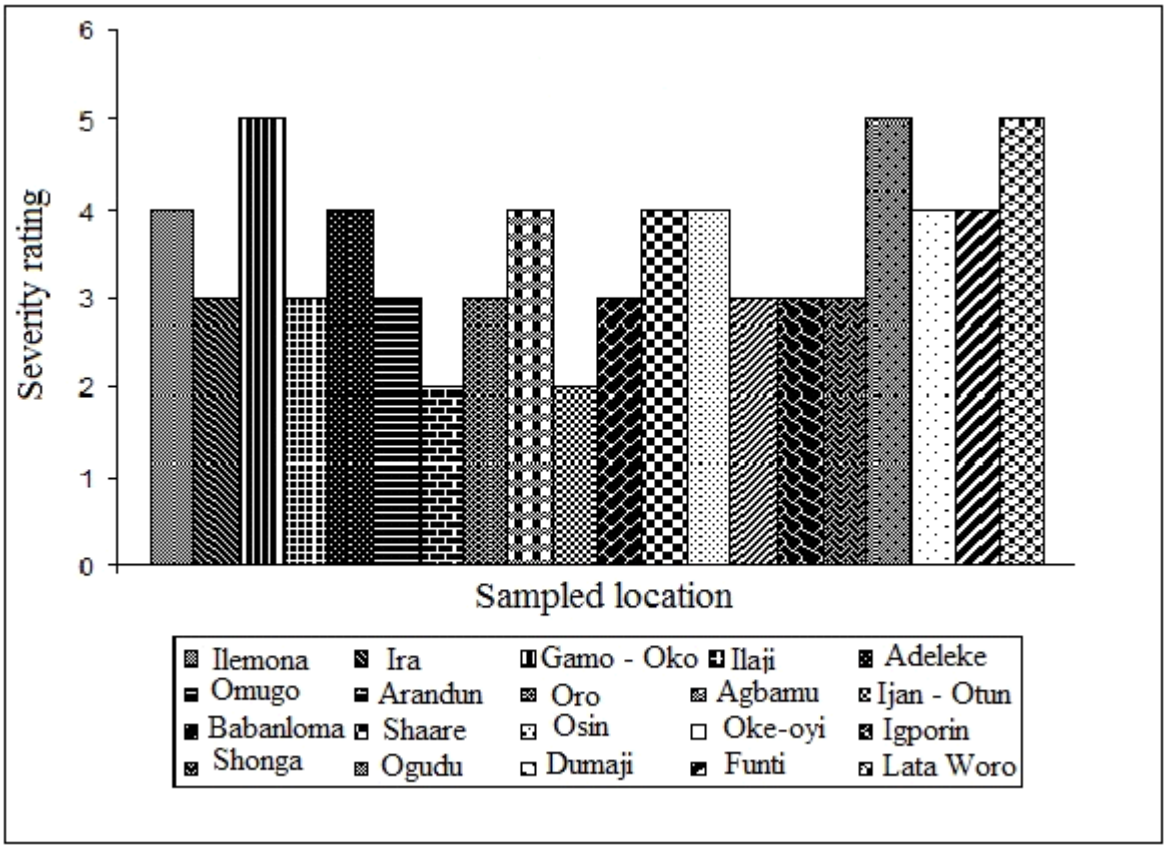


Figure 4.1.1: Severity rating of infestation by stalk borer in surveyed farms in Kwara State

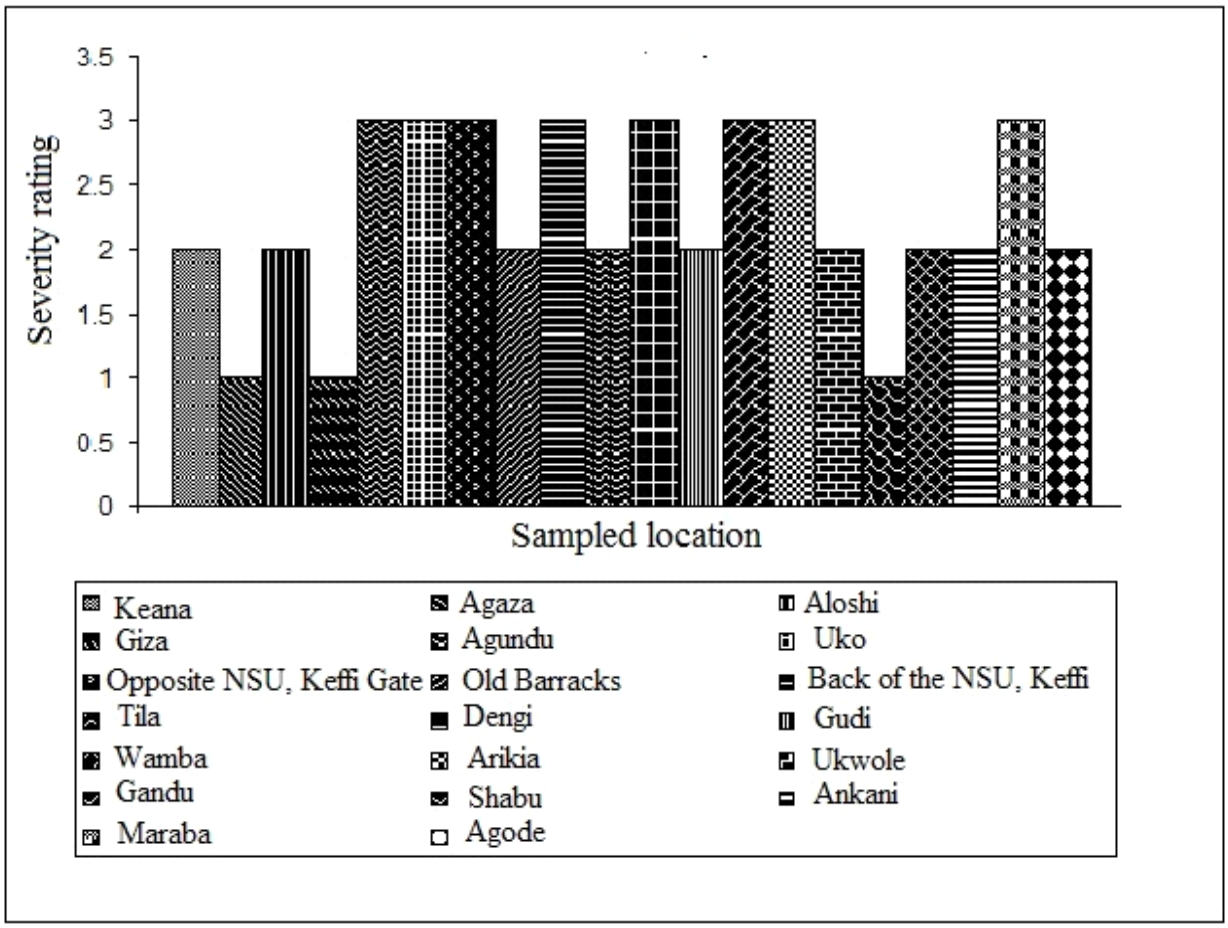


Figure 4. 1.2:Severity rating of infestation by stalk borer in surveyed farms in Nassarawa State

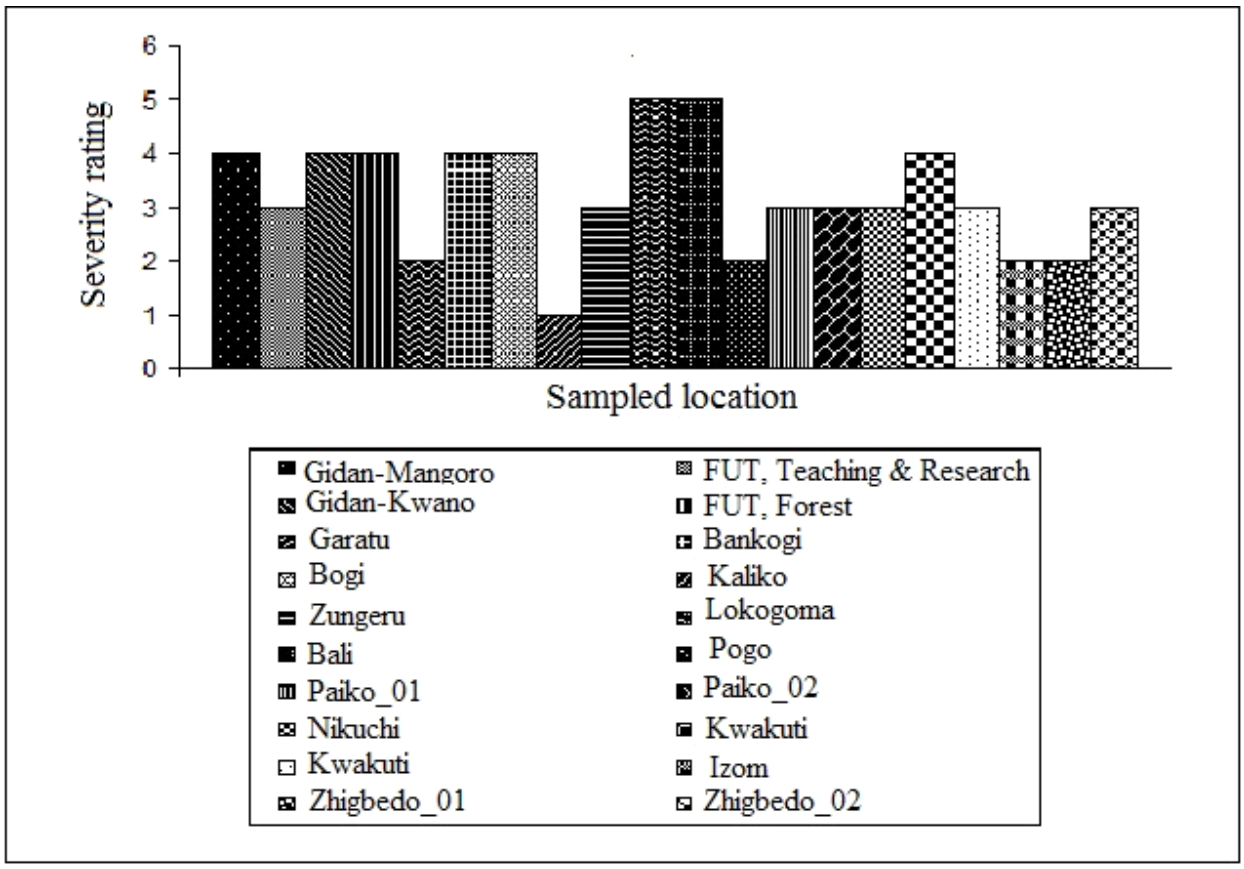


Figure 4.1.3: Severity rating of infestation by stalk borer in surveyed farms in Niger State

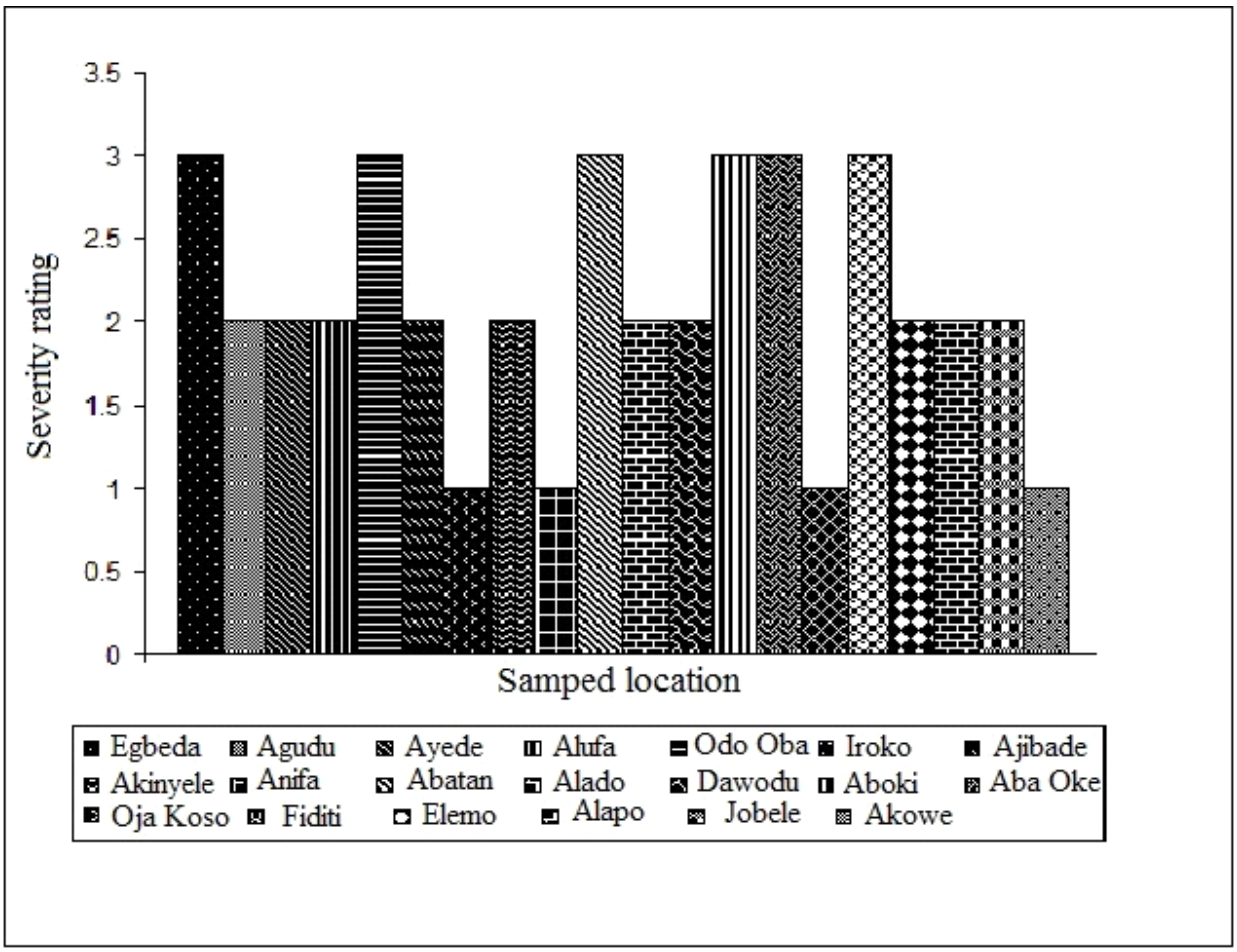


Figure 4.1.4: Severity rating of infestation by stalk borer in surveyed farms in Oyo State

4.1.3.1 *Sreenhouse experiment*

4.1.3.2 *Reactions of maize genotypes to Sesamia calamistis Infestation*

The damaging effect of stalk borers' infestation on maize genotypes (Table 4.1. 2) showed that genotypes M-G2, M-G5, M-G10, M-G15, M-G19 M-G40, M-G39, M-G34, M-G28, and M-G23 did not have a dead heart, while genotypes M-G1, M-G3, M-G4, M-G12, M-G13, M-G21 and M-G24 had higher percentage of dead heart. No significant difference was recorded among the maize genotypes for stem lodging effect of stem borers. The severity scale was significantly lowest ($p \leq 0.05$) in M-G8 compared to M-G5, M-G6, M-G12, M-G23, M-G13, M-G18, M-G19, M-G21, M-G23, M-G24, M-G33, M-G34, M-G34, M-G36 and M-G38 but were not significantly different from all other maize genotypes. Maize genotypes such as; M-G1, M-G2, M-G6, M-G24 and M-G33 recorded the least significant ($p \leq 0.05$) number of rotten ears compared to M-G7, M-G13, M-G17 and M-G39. Plant stand at harvest was higher in maize genotypes such as; M-G7, M-G22, M-G23,M-G26, M-G27, M-G40, M-G37, M-G32, M-G31, M-G30, M-G25, M-G28, M-G7, M-G17, M-G16 and M-G15, but no significant difference among the maize genotypes.

In Table 4.1.3, maize genotypes M-G39, M-G40 and M-G15 had significantly taller height than M-G17, M-G11, M-G10.While other genotypes were not significantly different from each other at 4WAS. At 6WAS, M-G15 recorded significantly ($P \leq 0.05$) taller height than M-G3, M-G4, M-G9, M-G10, M-G18, M-G19, M-G21, M-G26, M-G36 and M-G39. Other maize genotypes were not significantly different from each another. At 8WAS, M-G15 maintained the taller significant ($P<0.05$) plant height compared to other genotypes M-G6, M-G8, M-G9, M-G10, M-G11, M-G12, M-G17, M-G18, M-G19, M-G24, M-G26, M-G31, M-

G33 and M-G36. M-G15 remained the tallest significant ($P \leq 0.05$) among other maize genotypes such as; M-G15, M-G12, M-G36 and M-G40.

Table 4.1.2: Reactions of maize genotypes to *Sesamia calamistis* infestation

GENOTYPE	DHR(%)	SLG	SC	NRE	PSH
M-G1	67	1.00^{b}	5.00^{a-d}	0.33^{b}	0.33^{a}
M-G2	00	1.00^{b}	4.67^{a-d}	0.33^{b}	0.33^{a}
M-G3	67	0.67^{b}	4.67^{a-d}	2.00^{ab}	0.33a
M-G4	67	1.00^{b}	5.33^{a-d}	2.00^{ab}	0.67^{a}
M-G5	00	0.67^{b}	6.67^{abc}	2.00^{ab}	0.67^{a}
M-G6	00	1.00^{b}	7.33^{abc}	0.33^{b}	0.33^{a}
M-G7	00	1.00^{b}	5.00^{a-d}	5.00^{a}	1.00^{a}
M-G8	00	1.00^{b}	1.00^{d}	1.67^{ab}	0.33^{a}
M-G9	00	1.00^{b}	3.33^{bcd}	3.67^{ab}	0.67^{a}
M-G10	00	1.00^{b}	5.67^{a-d}	2.00^{ab}	0.67^{a}
M-G11	33	1.00^{b}	4.67^{a-d}	2.00^{ab}	0.33^{a}
M-G12	67	2.00^{a}	6.33^{abc}	1.67^{ab}	0.33^{a}
M-G13	67	1.00^{b}	7.33^{abc}	0.00^{b}	0.33^{a}
M-G14	33	1.00^{b}	5.00^{a-d}	0.67^{b}	0.67^{a}
M-G15	00	1.00^{b}	5.00^{a-d}	3.67^{ab}	1.00^{a}
M-G16	00	1.00^{b}	6.00^{a-d}	2.33^{ab}	1.00^{a}
M-G17	00	1.00^{b}	3.00^{cd}	5.00^{a}	1.00^{a}
M-G18	00	1.00^{b}	6.33^{abc}	0.67^{b}	0.67^{a}
M-G19	00	1.00^{b}	7.00^{abc}	0.67^{b}	0.67^{a}
M-G20	00	1.00^{b}	3.33^{bcd}	2.00^{ab}	0.67^{a}

Means in the same column with the same superscripts are not significantly different at $p \geq 0.05$ using Duncan Multiple Range Test (DMRT)

KEY: SLG = Stem lodging, DHR =Dead heart (%), SC = severity score, NRE = number. of rotten ear, PSH = plant stand at harvest,

Table 4.1.2.: Continued

GENOTYPE	DHR	SLG	SC	NRE	PSH
M-G21	67	1.00^{b}	7.67^{abc}	3.33^{ab}	0.33^{a}
M-G22	00	1.00^{b}	5.33^{a-d}	2.33^{ab}	1.00^{a}
M-G23	00	1.00^{b}	4.67^{a-d}	2.00^{ab}	1.00^{a}
M-G24	67	1.00^{b}	6.67^{a-c}	0.33^{b}	0.33^{a}
M-G25	33	1.00^{b}	3.67^{b-d}	3.33^{ab}	0.67^{a}
M-G26	00	1.00^{b}	9.00^{a}	1.00^{ab}	1.00^{a}
M-G27	00	1.00^{b}	3.67^{b-d}	1.00^{ab}	1.00^{a}
M-G28	.00	0.67^{b}	4.67^{a-d}	3.67^{ab}	1.00^{a}
M-G29	33	1.00^{b}	5.67^{a-d}	0.67^{b}	0.67^{a}
M-G30	00	1.00^{b}	5.67a-d	2.33^{ab}	1.00^{a}
M-G31	00	1.00^{b}	5.67^{a-d}	1.00^{ab}	1.00^{a}
M-G32	00	1.00^{b}	5.00^{a-d}	2.33^{ab}	1.00^{a}
M-G33	33	1.00^{b}	8.00^{abc}	0.33^{b}	0.33^{a}
M-G34	00	1.00^{b}	6.33^{abc}	1.00^{ab}	0.67^{a}
M-G35	33	1.00^{b}	5.33^{a-d}	2.00^{ab}	0.67^{a}
M-G36	33	0.67^{b}	8.33^{ab}	1.67^{ab}	0.33^{a}
M-G37	00	0.67^{b}	5.67^{a-d}	3.67^{ab}	1.00^{a}
M-G38	00	1.00^{b}	6.33^{abc}	2.00^{ab}	0.67^{a}
M-G39	00	1.00^{b}	4.67^{a-d}	5.00^{a}	1.00^{a}
M-G40	00	1.00^{b}	5.00^{a-d}	2.33^{ab}	1.00^{a}
SE+		0.26	2.56	1.99	0.45

Means in the same column with the same superscripts are not significantly different at $p \leq 0.05$ using Duncan Multiple Range Test (DMRT)

Table 4.1.3: Reactions of maize genotypes to *Sesamia calamistis* infestation

GENOTYPE	PLH4(cm)	PLH6(cm)	PLH8(cm)	PLH10(cm)	PLH12(cm)	SD(cm)
M-G1	81.00^{a-f}	89.33^{a-f}	99.00^{ab}	75.33^{abc}	75.33^{ab}	1.00^{a-d}
M-G2	85.00^{a-f}	90.00^{a-f}	134.67^{ab}	76.67^{abc}	76.67^{ab}	1.07 $^{a-d}$
M-G3	60.00^{c-h}	43.17^{d-g}	66.33^{abc}	100.00^{abc}	110.33^{ab}	1.37^{a-d}
M-G4	60.00^{c-h}	61.67^{b-g}	95.67$_{ab}$	106.33^{abc}	109.33^{ab}	1.63^{a-d}
M-G5	92.00^{a-e}	89.00^{a-f}	145.00^{ab}	160.67^{abc}	123.00^{ab}	2.03^{a-d}
M-G6	80.00^{a-f}	113.00^{ab}	63.33^{b}	67.33^{abc}	70.33^{ab}	1.13 $^{a-d}$
M-G7	89.67^{a-e}	92.67^{a-f}	126.00^{ab}	150.33^{abc}	151.33^{ab}	1.70 $^{a-d}$
M-G8	59.33^{c-h}	77.67^{a-f}	42.67^{b}	76.00^{abc}	104.00^{ab}	1.27^{a-d}
M-G9	64.67^{b-g}	60.67^{b-g}	55.33^{b}	86.33^{abc}	89.00^{ab}	0.83^{bcd}
M-G10	24.00^{gh}	46.33^{d-g}	52.00^{b}	109.00^{abc}	107.67^{ab}	0.53^{cd}
M-G11	42.67^{fgh}	36.00^{def}	28.67^{b}	55.33^{abc}	66.00^{ab}	0.30^{d}
M-G12	88.67^{a-f}	64.33^{b-g}	34.33^{b}	37.67^{bc}	16.67^{b}	2.15^{a-d}
M-G13	66.00^{b-g}	88.67^{a-f}	81.67^{ab}	71.67^{abc}	70.67^{ab}	1.50^{a-d}
M-G14	94.33^{a-d}	108.33^{abc}	122.67^{ab}	129.33^{abc}	135.33^{ab}	1.57^{a-d}
M-G15	121.67^{a}	128.00^{a}	205.67^{a}	208.00^{a}	208.33^{a}	2.70^{ab}
M-G16	87.00^{a-f}	82.17^{a-f}	148.33^{ab}	163.33^{abc}	169.67^{ab}	1.63^{a-d}
M-G17	45.67^{e-h}	31.67^{fg}	40.33^{b}	80.00^{abc}	83.67^{ab}	0.60^{cd}
M-G18	64.33^{b-g}	55.33^{c-g}	50.00^{b}	60.33^{abc}	59.33^{ab}	1.33^{a-d}
M-G19	68.67^{b-f}	60.67^{c-g}	64.67 ^{b}	85.67^{abc}	84.67^{ab}	0.83^{bcd}

Means in the same column with the same superscripts are not significantly different at $p \leq 0.05$ using Duncan Multiple Range Test (DMRT)

KEY: PLH = plant height, DHR =Death heart, SD = Stem diameter.

Table 4.1.3: Continued

GENOTYPE	PLH4(cm)	PLH6(cm)	PLH8(cm)	PLH10(cm)	PLH12(cm)	SD(cm)
M-G20	79.00^{a-f}	79.00^{a-f}	99.67^{ab}	77.33^{abc}	79.33^{ab}	1.03 $^{a-d}$
M-G21	72.67^{b-f}	66.33^{b-g}	74.33^{ab}	116.67^{abc}	121.67^{ab}	0.80^{bcd}
M-G22	101.67^{a-d}	77.67^{a-f}	127.33^{ab}	135.33^{abc}	132.67^{ab}	2.13^{a-d}
M-G23	105.33^{abc}	77.33^{a-g}	96.33^{ab}	104.67^{abc}	105.67^{ab}	2.33^{abc}
M-G24	58.00^{d-h}	17.33^{g}	47.67^{b}	68.67^{abc}	69.33^{ab}	0.47^{cd}
M-G25	82.33^{a-f}	77.33^{a-g}	77.67^{ab}	116.33^{abc}	120.00^{ab}	1.77^{a-d}
M-G26	19.33^{h}	30.67^{fg}	54.00^{b}	106.33^{abc}	142.33^{ab}	0.63^{cd}
M-G27	110.33^{ab}	94.67^{a-e}	166.33^{ab}	175.67^{ab}	174.00^{ab}	1.87^{a-d}
M-G28	89.00^{a-e}	81.67a-f	100.33^{ab}	117.33^{abc}	120.00^{ab}	2.70^{ab}
M-G29	89.67^{a-e}	86.67^{a-f}	160.00^{ab}	129.67^{abc}	127.67^{ab}	1.90 $^{a-d}$
M-G30	99.33^{a-d}	87.00^{a-f}	138.67^{ab}	132.67^{abc}	133.00^{ab}	2.23^{a-d}
M-G31	107.00^{ab}	100.83^{a-d}	90.33^{ab}	134.00^{abc}	134.67^{ab}	2.30^{abc}
M-G32	91.67^{a-e}	78.67^{a-f}	115.33^{ab}	115.33^{abc}	120.67^{ab}	1.77 $^{a-d}$
M-G33	80.67^{a-f}	77.33^{a-f}	43.67^{b}	59.00^{abc}	57.33^{ab}	0.47^{cd}
M-G34	95.67^{a-d}	77.33^{a-g}	95.67^{ab}	80.33^{abc}	85.67^{ab}	1.27^{a-d}
M-G35	81.00^{a-f}	89.00^{a-f}	87.00^{ab}	108.00^{abc}	112.00^{ab}	1.27^{a-d}
M-G36	57.00^{d-h}	55.33^{c-g}	33.67^{b}	33.67^{c}	14.00^{b}	0.57^{cd}
M-G37	80.67^{a-f}	66.33^{b-g}	64.33^{b}	68.33^{abc}	67.00^{ab}	1.23^{a-d}
M-G38	105.00^{abc}	121.67^{ab}	110.00^{ab}	97.00^{abc}	97.33^{ab}	2.07^{a-d}
M-G39	122.33^{a}	110.07^{abc}	162.67^{ab}	149.00^{abc}	168.00^{ab}	1.97^{a-d}
M-G40	120.17^{a}	122.00^{ab}	144.67^{ab}	195.00^{a}	200.00^{a}	2.80^{a}
SE±	22.92	29.95	67.70	78.29	82.40	0.96

Means in the same column with the same superscripts are not significantly different at $p \leq 0.05$ using Duncan Multiple Range Test(DMRT)

At 12WAS, the same maize genotype, M-G15 was the tallest maize genotype followed by M-G40 compared to M-G36 and M-G12, while other maize genotypes were also taller than each other but no significant difference was recorded. Significantly larger stem diameter was recorded in M-G40 than M-G34, M-G33, M-G26, M-G24, M-G21, M-G17, M-G14 M-G9, M-G10 and M-G11 while other maize genotypes did not have significant difference($p>0.05$) with each other.

Yield performance of maize genotypes under *Sesamia calamistis* infestation (Table 4.1.4) showed that M-G40 had significantly ($p\leq0.05$) higher position of ear than M36, M-G33 M-G24, M-G21, M-G20, M-G18, M-G13, M-G12, M-G10, M-G8, M-G6, M-G4, M-G3, M-G2 and M-G1. Similarly, the longest significant ($p\leq0.05$) ear height was recorded in M-G40 compared to M-G8 and M-G13. Highest significant ($p<0.05$) number of the ear was recorded in M-G39 followed by M-G34 compared to all other maize genotypes. M-G40 showed the significant higher ($p\leq0.05$) number of nodes than M-G6, M-G13, M-G19, M-G24, M-G29, M-G33, M-G34, M-G36 and M-G37. Moisture content was significantly ($p<0.05$) higher in M-G17 than M-G1, -G7, M-G9, M-G12, M-G18 M-G35, M-37and M-G40. The heaviest significant ($p\leq0.05$) grain weight (24.33 g/pot) was in M-G27 which was not significantly ($p> 0.05$) different from M-G2, M-G16,, M-G18, M-G22, M-G20, M-G23, M-G31, M-G36, M-G38 and M-G39.

Table 4.1.4: Reactions of maize genotypes to *Sesamia calamistis* infestation

GENOTYE	DTS(day)	DSK(day)	EP	EH (cm)	EN	NND	MC(%)	GW(g/plant)
M-G1	59^{a}	63^{a}	3.00^{b}	5.67^{abc}	0.33^{c}	6.33^{a-d}	0.40^{f}	0.33^{e}
M-G2	57^{a}	59^{a}	3.67^{b}	10.00^{abc}	0.67^{c}	6.67^{a-d}	10.07^{af}	13.93^{a-e}
M-G3	43^{a}	49^{a}	3.67^{b}	10.00^{abc}	1.00^{c}	9.67^{a-d}	9.83^{a-f}	1.40^{de}
M-G4	44^{a}	48^{a}	3.67^{b}	11.00^{abc}	1.00^{c}	8.33^{a-d}	6.97^{a-f}	3.63^{cde}
M-G5	39^{a}	42^{a}	5.33^{ab}	15.00^{abc}	0.67^{c}	8.33^{a-d}	9.27^{a-f}	1.50^{de}
M-G6	44^{a}	49^{a}	3.00^{b}	8.00^{abc}	0.33^{c}	5.00^{bcd}	5.40^{a-f}	5.30^{cde}
M-G7	58^{a}	61^{a}	5.67^{ab}	22.67^{ab}	1.00^{c}	14.00^{abc}	15.40^{af}	2.47^{cde}
M-G8	36^{a}	42^{a}	2.00^{b}	4.00^{bc}	0.67^{c}	7.00^{a-d}	3.07^{b-f}	0.07^{e}
M-G9	39^{a}	45^{a}	4.00^{ab}	12.33^{abc}	0.67^{c}	6.33^{a-d}	1.03^{ef}	0.53^{e}
M-G10	39^{a}	43^{a}	2.33^{b}	14.00^{abc}	0.67^{c}	9.67^{a-d}	22.47^{ae}	1.67^{de}
M-G11	35^{a}	42^{a}	4.00^{ab}	9.50^{abc}	1.00^{c}	7.33^{a-d}	5.70^{a-f}	0.94^{de}
M-G12	48^{a}	54^{a}	2.67^{b}	6.00^{abc}	0.33^{c}	7.33^{a-d}	2.17^{c-f}	0.70^{e}
M-G13	53^{a}	63^{a}	1.67^{b}	3.00^{c}	0.33^{c}	3.00^{cd}	4.03^{a-f}	0.53^{e}
M-G14	37^{a}	41^{a}	4.33^{ab}	12.67^{abc}	1.00^{c}	10.67^{ad}	8.60^{a-f}	3.93^{cde}
M-G15	57^{a}	65^{a}	7.00^{ab}	13.00^{abc}	1.00^{c}	16.00^{ab}	6.23^{a-f}	7.40^{b-e}
M-G16	53^{a}	59^{a}	7.67^{ab}	22.33^{ab}	1.00^{c}	11.33^{ad}	11.53^{af}	11.03^{a-e}
M-G17	61^{a}	65^{a}	6.00^{ab}	15.00^{abc}	1.67^{bc}	7.00^{a-d}	24.80^{a}	1.70^{de}
M-G18	39^{a}	44^{a}	3.00^{b}	7.87^{abc}	0.67^{c}	6.33^{a-d}	5.27^{a-f}	15.73^{a-e}
M-G19	39^{a}	44^{a}	5.00^{ab}	14.33^{abc}	0.67^{c}	5.0^{d}	5.80^{a-f}	4.03^{cde}

Means in the same column with the same superscripts are not significantly different at $p \leq 0.05$ using Duncan Multiple Range Test (DMRT)

KEY: DTS = day to 50 % tasseling, DSK =day to 50 % silking, EN = number of ears, EP = ear position, EH =ear height, NND =no. of node, MC = moisture contents, GW = grain weight

Table 4.1.4 Continued

GENOTYPE	DTS(day)	DSK(day)	EP	EH (cm)	EN	NND	MC (%)	GW(g/plant)
M-G20	34. 00^{a}	40.00^{a}	3.50^{b}	11.00^{abc}	1.00^{c}	5.00^{bcd}	19.25^{a-f}	11.70^{a-e}
M-G21	35.00^{a}	41.00^{a}	2.67^{b}	12.67^{abc}	0.67^{c}	6.33^{a-d}	24.23^{ab}	0.17^{e}
M-G22	51.00^{a}	60.00^{a}	7.33^{ab}	24.67^{ab}	1.00^{c}	10.33^{a-d}	6.40^{a-f}	17.17^{acd}
M-G23	60.00^{a}	63.00^{a}	4.67^{ab}	14.00^{abc}	0.67^{c}	10.00^{a-d}	10.20^{a-f}	18.20^{abc}
M-G24	47.00^{a}	50.00^{a}	3.00^{b}	8.33^{abc}	0.33^{c}	5.33^{bcd}	9.90^{a-f}	2.10^{cde}
M-G25	35.00^{a}	41.00^{a}	4.83^{ab}	10.00^{abc}	1.00^{c}	10.00^{a-d}	1.77^{def}	1.35^{de}
M-G26	57.00^{a}	78.00^{a}	6.00^{ab}	13.67^{abc}	1.00^{c}	12.33^{a-d}	23.07^{a-d}	3.03^{cde}
M-G27	57.00^{a}	67.00^{a}	7.67^{ab}	21.33^{ab}	1.00^{c}	15.00^{abc}	10.87^{a-f}	24.33^{a}
M-G28	60.00^{a}	65.00^{a}	6.00^{ab}	24.00^{ab}	1.00^{c}	8.33^{a-d}	24.40^{ab}	1.03^{de}
M-G29	36.00^{a}	43.00^{a}	6.33^{ab}	15.67^{abc}	0.67^{c}	12.33^{a-d}	18.47^{a-f}	8.60^{b-e}
M-G30	55.00^{a}	65.00^{a}	5.67^{ab}	20.67^{ab}	1.00^{c}	14.00^{abc}	12.33^{a-f}	1.42^{de}
M-G31	60.00^{a}	68.00^{a}	7.00^{ab}	22.67^{ab}	1.00^{c}	12.33^{a-d}	23.40^{abc}	18.23^{abc}
M-G32	54.00^{a}	63.00^{a}	6.33^{ab}	22.33^{ab}	1.00^{c}	11.67^{a-d}	4.03a-f	2.93^{cde}
M-G33	40.00^{a}	49.00^{a}	2.00^{b}	6.67^{abc}	0.33^{c}	3.67^{cd}	17.37^{a-e}	1.87^{de}
M-G34	54.00^{a}	65.00^{a}	5.00^{ab}	19.00^{abc}	1.00^{c}	6.00^{bcd}	12.93^{a-e}	6.00^{cde}
M-G35	36.00^{a}	43.00^{a}	4.33^{ab}	13.00^{abc}	0.67^{c}	9.00^{a-d}	1.53^{ef}	7.17^{b-e}
M-G36	52.00^{a}	60.00^{a}	2.00^{b}	4.67^{abc}	2.33^{b}	1.33^{d}	1.53^{ef}	9.57^{a-e}
M-G37	60.00^{a}	67.00^{a}	5.67^{ab}	13.67^{abc}	1.00^{c}	4.33^{bcd}	4.03^{a-f}	3.54^{cde}
M-G38	35.00^{a}	41.00^{a}	4.00^{ab}	10.67^{abc}	1.00^{c}	8.33^{a-d}	8.63^{a-f}	9.03^{a-e}
M-G39	54.00^{a}	63.00^{a}	7.67^{ab}	23.00^{ab}	3.00^{a}	12.00^{a-d}	19.30^{a-e}	22.47^{ab}
M-G40	48.00^{a}	56.00^{a}	10.67^{a}	25.33^{a}	1.00^{c}	18.33^{a}	10.10^{a-f}	1.50^{de}
SE±	24.92	29.61	3.38	9.74.	0.66	5.99	10.10	7.96

Means in the same column with the same superscripts are not significantly different at $p \leq 0.05$ by Duncan Multiple Range Test (DMRT)

KEY: DTS = day to 50 % tasseling, DSK =day to 50 % silking, EN = number of ears, EP = ear position, EH =ear height, NND =no. of node, MC = moisture content, GW = grain weight,

4.1.3.3 *Correlation coefficients of maize genotypes against Sesamia calamistis infestation*

Correlation Coefficients of Maize Genotypes against Stem borers' Infestation is represented in Table 4.1.5. The plant height at 4, 6, 8, 10 and 12 Weeks After Sowing (WAS) were positively and significantly correlated with one another. Using the cumulative plant height at 12WAS, it was negatively and significantly correlated with the following parameters; stem lodging (r = -0.551), dead heart (r = -0.331), severity score (r = -0.290) but positively and significantly correlated with the following parameters; stem diameter (r = 0.239), number of days to 50% tasseling (r= 0.544, number of days to 50% silking (r = 0.379) number of ear; (r= 0.340) and ear position (r =0.810).Furthermore, stem lodge showed positive significant relationship with dead heart (r=0.296) and severity score (r=0.349). They were negatively significant with variables such as; stem diameter (r= -0.290), number of days to 50% tasseling (r= -0.508), number of days to 50% silking (r= -0.372, number of ear (r= -0.159) and ear position (r = -0.584). Dead heart was also negatively significant correlated with days to 50% tasseling (r = -0.112), days to 50% silking (r =-0.257), number of ear (r =-0.113) and ear position (r =-0.322), but was positively non-significant with severity and negatively related with stem diameter (r = -0.058).

On the other hand, stem diameter was positively and significantly related to days to 50% tasseling (r S= 0.202) and ear position(r=0.274) but negatively non-significant with severity and days to 50% silking and positively and none significantly related to number of ear. Severity scaling exhibited negative and significant relationship with days to 50% tasseling (r=-0.243) but had positively significant with number of ear (r=0.259). Days to 50% tasseling was also positive and highly significant with days to 50 % silking (r=0.551), number of ear (r=0.414) and ear position (r=0.639). Days to 50% silking was positively and significantly related to number of ear (r=o.144) and ear position (r=0.414). Number of ear was also

positively and highly significant with ear position (r=0.537). Ear height had positive and highly significant relationship with plant height at 4 WAS (r= 0.396), 6 WAS (r=0.507), 8WAS (r= 0.664)10WAS (r= 0.680), 12 WAS (r=0.644) stem diameter (r= 0.237) days to 50 % tasseling (r= 0.480), days to 50% silking (r= 0.338), number of ear (r=0.400) and ear position (r= 0.711) but negatively significant with stem lodge (r=-0.465), dead heart (r=-0.323) and severity (r=-0.168). Similarly, number of rotten ear also showed positive and highly significant relationship with all other variables except for stem lodging (r=-0.299), dead heart (r = -0. 279) that were negatively significant but it was not significant with stem diameter (r = 0.057).

Number of nodes was negatively and highly significant related to stem lodging (r = -0.605) dead heart (r=-0.316) and severity (r=-0.248) but highly significant and positively related to all other variables. Plant aspect was positively significant with plant height at 6 WAS (r = 0.076), stem lodge (r=0.174), dead heart (r=0.067) stem diameter (r=0.171), days to 50% tasseling (r = 0.099) days to 50% silking (r =0.186) while negatively and significantly correlated with number of ear (r = 0.271) but not significant with ear position, plant height at 8 WAS (r=0.028), 10 WAS (r = -0.068) 12WAS (r = -0.055), severity (r=0.038) but positively not significant with plant height at 4 WAS. Plant stand at harvest was positive and highly significant with all variables except for stem lodge (r = -0.621 dead heart (r = -0.173) but not significantly related to severity. Grain weight was positively significant with plant height from 4 WAS to 12 WAS, days to 50% tasseling (r=0.318) days to 50% silking (r=0.206) ear position (r=0.394) and ear height (r= 0.349) while negatively significant with stem lodging (r=-0.297), dead heart (r=-0.086) and severity (r=-0.202) but not significant with stem diameter.

Ear height was positively related and highly significant with the number of rotten ear (r =0.521) number of node (r =0.674plant stand at harvest (r =0.591), moisture content (r =0.413) and grain yield (r =0.347) but not significantly related with plant aspect. The number of rotten ears was positively significant with the number of nodes (r =0.449), plant stand at harvest (r=0.556), moisture content (r =0.432) and grain yield (r =0.316) but negatively significant with plant aspect (r=-0.106. The number of nodes was positively and significantly related to plant stand at harvest(r=0.715), moisture content (r=0.527) and grain yield (r=0.278)but not significant with the plant aspect. Plant aspect showed a positively non-significant relationship with plant stand at harvest, negatively non-significant with moisture content but negatively significant with grain yield(r=-0.152). Plant stand at harvest, on the other hand, exhibited a positive and highly significant relationship with moisture content (r=0.486) and grain yield (r=0.339). Lastly, moisture content was positive and significantly related to grain yield (r=0.272).

Table 4.1.5: Pearson correlation coefficients for maize genotypes traits against *Sesamia calamistis* infestation

VAIABLE	PLH4	PLH6	PLH8	PLH10	PLH12	SLG	DHR	SDM	SC	DTS	DSK	EN	EP
PLH4	1.000ns	0.7001***	0.523***	0.428***	0.312**	-0.425***	-0.297**	0.247*	0.035ns	0.3090**	0.296**	0.304**	0.441***
PLH6		1.000ns	0.802***	0.734***	0.647***	-0.602***	0.453***	0.220*	-0.169*	0.373***	0.401***	0.235*	0.630***
PLH8			1.000ns	0.957***	0.874***	0.592****	-0.385**	0.257*	-0.228*	0.550***	0.435***	0.385***	0.816***
PLH10				1.000ns	0.919***	-0.609***	-0.361**	0.240*	-0.294*	0.606***	0.436***	0.392***	0.823***
PLH12					1.000ns	-0.559***	-0.331**	0.239*	-0.290*	0.544***	0.379***	0.340**	0.810***
SLG						1.000ns	0.296**	-0.279*	0.349**	-0.508**	-0.372**	-0.159*	-0.584**
DHR							1.000ns	0.058ns	-0.017ns	-0.112*	-0.257**	-0.113*	-0.322**
STD								1.000ns	0.010ns	0.202*	-0.005ns	0.031ns	0.274**
SC									1.000ns	-0.203*	-0.354**	0.259*	-0.243**
DTS										1.000ns	0.551***	0.414***	0.639***
DSK											1.000ns	0.144*	0.414***
EN												1.000ns	0.537***
EP													1.000ns
EH	0.396***	0.507***	0.664***	0.680***	0.644***	-0.465***	-0.323**	0.237*	-0.168*	0.480***	0.338**	0.400***	0.711***
NRE	0.398***	0.492***	0.509***	0.460***	0.4492***	-0.299**	-0.279*	0.057ns	0.292**	0.338**	0.192*	0.510***	0.640***
NND	0.372***	0.598***	0.802***	0.821***	0.774***	-0.605***	-0.316**	0.300**	-0.248*	0.609***	0.408**	0.373***	0.812***
PLA	0.015ns	0.076*	-0.028ns	-0.060ns	-0.055ns	0.174*	0.067*	0.171*	-0.038ns	0.099*	0.186*	-0.271**	-0.023ns
PSH	0.429***	0.588***	0.728***	0.753***	0.680***	-0.621***	-0.214*	0.293**	-0.244*	0.684***	0.431***	0.545***	0.765***
MC	0.248*	0.368**	0.407***	0.459***	0.480***	-0.387**	-0.173*	0.173*	0.019ns	0.340**	0.262*	0.285*	0.551***
GY	0.201*	0.294**	0.352**	0.362***	0.335**	-0.297**	-0.086*	0.025ns	-0.202*	0.318**	0.206*	0.394***	0.349**

KEY: * =p<0.05 (moderately significant at 5%),*** =p<0.01(highly significant at 1%), PLH = plant height, SLG = Stem lodging, DHR =Dead heart, SDM = stem diameter, SC = severity score, DTS = Day to 50% tasseling, DSK =Day to 50% silking, EN = number of ear, EP = ear position, EH =ear height, NRE = no. of rotten ears, NND =no. of node, PLA = plant aspect, PSH = plant stand at harvest, MC = moisture content, GW = grain weight

Table 4.1.5 continued

VARIABLE	EH	NRE	NND	PLA	PSH	MC	GW
EH	1.000ns	0.521***	0.674***	-0.067ns	0.591***	0.413***	0.347**
NRE		1.000ns	0.449***	-0.106*	0.556***	0.423***	0.316**
NND			1.000ns	-0.034ns	0.745***	0.527***	0.278**
PLA				1.000ns	0.035ns	-0.018ns	-0.152*
PSH					1.000ns	0.486***	0.339***
MC						1.000ns	0.272**
GY							1.000ns

KEY:* =p<0.05 (moderately significant at 5%), *** =p<0.01 (highly significant at 1%), **n**s = non-significant, EH =ear height, NRE = no. of rotten ear, NND =no. of node, PLA = plant aspect, PSH = plant stand at harvest, MC = moisture contents, GW = grain weight

4.1.3. 4: *Cluster Analysis of Selected Traits*

Cluster 1 was made up of 21 genotypes (52%), (M-G10, M-G11,M-G12, M-G14, M-G18, M-G19, M-G20, M-G21, M-G24, M-G25, M-G29, M-G3, M-G33, M-G35, M-G38, M-G4, M-G40, M-G5, M-G6, M-G8, and M-G9). The mean dead heart, number of rotten ears, days to 50% tasseling, days to 50% silking, number of ears per plant, and grain weight was 0.3%, 2, 39 DAS, 45 DAS, 1, and 3.9 kg, respectively (Table 4.1.6 and Figure 4.1.9). Cluster 2 was made of 7 genotypes (17.5%), (M-G1, M-G13, M-G15, M-G17, M-G26, M-G28, and M-G7). This group had a mean 0.2%, 2, 46 DAS, 54 DAS, 1, and 2.9 kg for dead heart, number of rotten ears, days to 50% tasseling, days to 50% silking, number of ears per plant, and grain weight, respectively. The genotypes in Cluster 3 were also 7 (17.5%), M-G30, M-G31, M-G32, M-G34, M-G36, M-G37, and M-G39, with a mean dead heart, number of rotten ears, days to 50% tasseling, days to 50 % silking, number of ears per plant, and grain weight of 0.1 %, 3, 47 DAS, 64 DAS, 1, and 5.6 kg, respectively (Table 4.1.6 and Figure 4.1.9). Cluster 4 consisted of only 5 genotypes (12.5%) (M-G16, M-G2, M-G22, M-G23, and M-G27) and contained M-G27, which exhibited the highest grain weight. The cluster had a mean of 0% dead heart, 2 rotten ears, 45 days to 50% tasseling, 63 days to 50% silking, 1 ear per plant, and 10.7 g grain weight per pot (Table 4.1.6 and Figure 4.1.6).

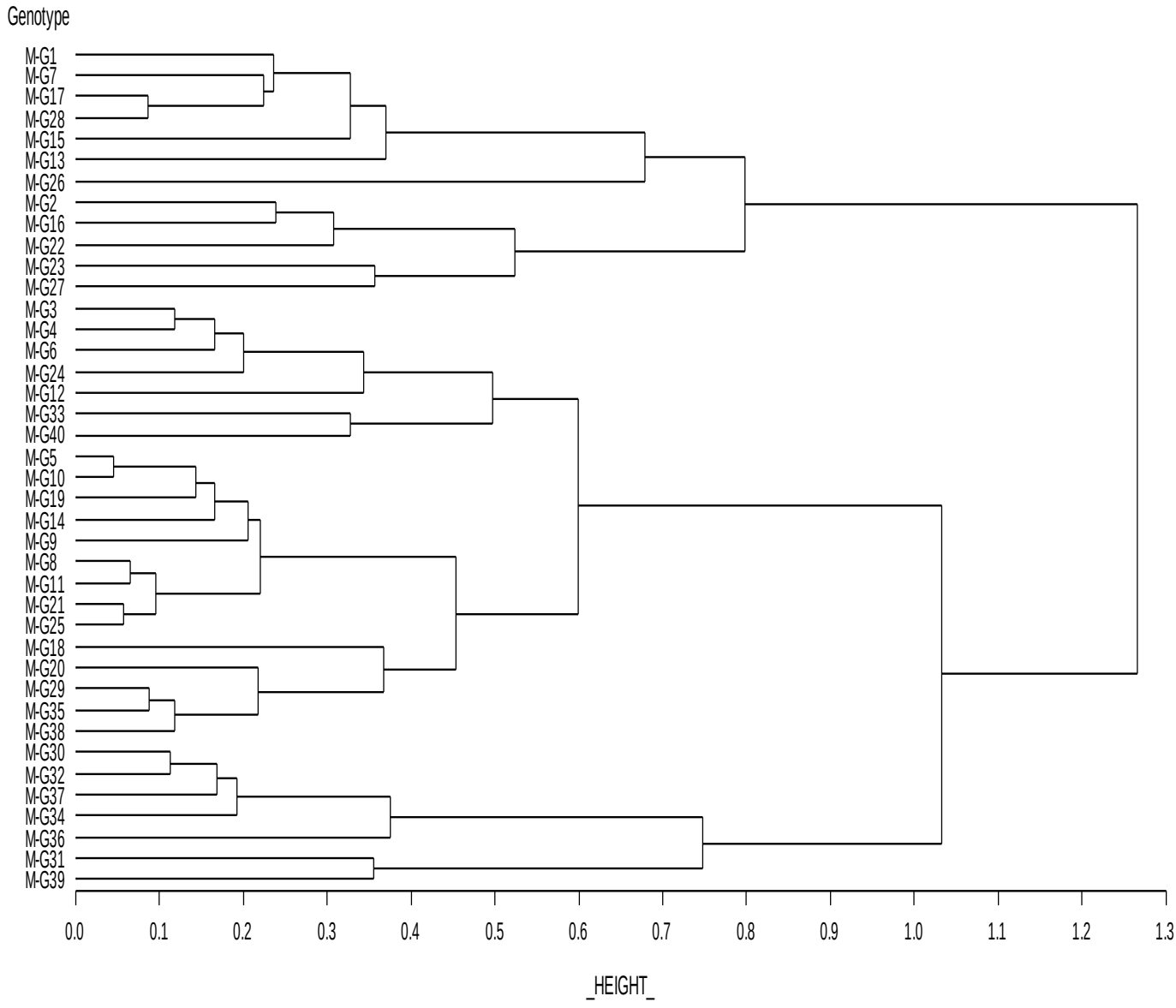


Figure 4.1.5: Dendrogram of the forty maize genotypes inferred from qualitative traits

Table 4.1.6: Distribution of 40 genotypes of maize in different cluster

Genotype	Dead heart	Number of rotten ear	Days to 50% tasseling	Days to 50% silking	No. of Ears per plant	Grain weight
			Cluster 1			
M-G10	0.0	2	39	43	1	1.7
M-G11	0.3	2	35	42	1	0.9
M-G12	0.7	2	48	54	1	0.7
M-G14	0.3	1	37	41	1	3.9
M-G18	0.0	1	39	44	1	15.7
M-G19	0.0	1	39	44	1	4.0
M-G20	0.0	2	34	40	1	11.7
M-G21	0.7	3	35	41	1	0.2
M-G24	0.7	0	47	50	0	2.1
M-G25	0.3	3	35	41	1	1.4
M-G29	0.3	1	36	43	1	8.6
M-G3	0.7	2	43	49	1	1.4
M-G33	0.3	0	36	49	0	1.9
M-G35	0.3	2	36	43	1	7.2
M-G38	0.0	2	36	41	1	9.0
M-G4	0.7	2	44	48	1	3.6
M-G40	0.0	2	36	56	1	1.5
M-G5	0.0	2	39	42	1	1.5
M-G6	0.0	0	44	49	0	5.3
M-G8	0.0	2	36	42	1	0.1
M-G9	0.0	4	39	45	1	0.5
Mean	0.3	2	39	45	1	3.9
			Cluster 2			
M-G1	0.7	0	59	63	0	0.3
M-G13	0.7	0	53	63	0	0.5
M-G15	0.0	4	57	65	1	7.4
M-G17	0.0	5	61	65	2	1.7
M-G26	0.0	1	57	78	1	3.0
M-G28	0.0	4	60	65	1	1.0
M-G7	0.0	5	58	61	1	2.5
Mean	0.2	2	46	54	1	2.9

Table 4.1.6 continued

			Cluster 3			
M-G30	0.0	2	36	65	1	1.4
M-G31	0.0	1	36	68	1	18.2
M-G32	0.0	2	36	63	1	2.9
M-G34	0.0	1	36	65	1	6.0
M-G36	0.3	2	36	60	2	9.6
M-G37	0.0	4	36	67	1	3.5
M-G39	0.0	5	36	63	3	22.5
Mean	0.1	3	47	64	1	5.6
			Cluster 4			
M-G16	0.0	2	53	59	1	11.0
M-G2	0.0	0	57	59	1	13.9
M-G22	0.0	2	51	60	1	17.2
M-G23	0.0	2	60	63	1	18.2
M-G27	0.0	1	57	67	1	24.3
Mean	0.0	2	45	63	1	10.7

4.1.3.5 *Stem Borers' Predictions*

Table 4.1.6 presents the overall means across the maize genotypes varying group members for differentiating the varietal lodging status (lodging and no lodging). It was shown that the mean stem diameter (cm) was 3.14 for no lodging plant stands, which was higher than 1.43 for the lodging. The same trend was observed for other attributes such as number of days to 50% silking, number of ears, ear position, ear height, number of nodes, and plant stand at harvest.

On the contrary, days to 50% tasseling and moisture content were lower for no lodging maize stands than lodging. The P-value associated was less than 0.01 for stem diameter (SDM), the number of days to 50% silking (DSK), moisture content (MC) and grain weight (GW) with the associated F-values as 45.15, 32.95, 38.88, and 39.37 respectively.

The coefficients of the two discriminant functions were estimated. Four measurable attributes (stem diameter, number of days to 50% silking, moisture content, grain weight) were chosen and used in the discriminant models. Therefore, the two discriminant functions were given as:

$$Z_1 = -3.782 + 0.496\ X_1 + 0.079\ X_2 + 0.10\ X_3 + 0.091X_4 \quad (4.1.1)$$

$$Z_2 = -2.364 + 0.127X_1 + 0.060X_2 + 0.028X_3 + 0.009X_4 \quad (4.1.2)$$

It was observed that group centroid for 'no lodging' was -0.424 while group centroid for 'lodging' was 0.889 using the discriminant model to classify the genotype lodging by cut-off form;

$$\text{Cut off percentage (CO \%)} = \frac{N_2(No.lodging) + N_1(lodging)}{N_1 + N_2} \quad (4.1.3)$$

$$= \frac{244 * \ (0.889) + 166 * (-0.424)}{166 + 244} =$$

Where N_1=116, N_2=244, I. e. 116 observations with plant stands had no lodging and 244 observations plant stands had lodging.

Table 4.1.7 Means of attributes used for stem borers prediction

Attribute	No Stem Lodging	Stem Lodging
SDM	3.14	1.43
DTS	47.65	40.99
DSK	54.59	47.16
EN	1.03	0.93
EP	5.58	4.66
EH	41.91	39.55
NRE	3.12	1.95
NND	10.44	8.65
PAS	1.4	2.52
PSH	0.87	0.68
MC	5.63	10.4
GW	72.1	40.81

KEY: SDM = stem diameter, NRE = no. of rotten ear, PSH = plant stand at harvest, DTS = days to 50% tasseling, DSK =days to 50% silking, EN = number of ears, EP = ear position, EH =ear height, NND =no. of node, GW = grain weight

4.2 Discussion

The farmers interviewed stated that they usually sourced seeds from the market or previous harvest or both, except a few that obtained their seeds from agro-stores and/or research institutes. This revealed that most of the farmers were not planting certified and hybrid seeds. The cropping system practiced by most farmers in the areas encouraged a favourite breeding environment for the survival and infestation of stem borers because most farmers intercropped maize with sorghum, millet and pearl millet which serves as alternative hosts for stem borer species. This corroborates the findings of Fajinmi and Odebode (2010), who stated that a reduction of pest incidence with intercropping of non-host plants should be carefully adopted. The cultivar of interest, sources of seed and fertilization method adopted by farmers all played a significant role in the spread of these stem borers infestation in the study area.

The highest (5.0) stem borers' severity was found in Kwara and Niger States. Similarly, the highest stem borers' incidence was obtained in Kwara State, this was because most farmers intercropped maize with sorghum, millet and pearl millet which served as alternative hosts for stem borer species. compared to Nasarawa and Oyo that had a moderate severity and lowest severity scores of 3.0 and 1.0 respectively

Identification revealed that *S. calamistis* was the most abundant borer species in the studied location (Southern Guinea savanna of Nigeria). This agrees with the findings of Obhiokhenan *et al*. (2002) who reported higher percentage of *S. calamistis* in the mangrove and rain forest zones. Similar observations have been made in the studies carried out in Southwestern Nigeria by Balogun and Tanimola, (2001). However, Simon *et al*. (2015), reported that *B. fusca* was the most predominant borer species recorded in the guinea agro-ecological zone. Okweche *et al*. (2010) reported that *B. fusca* was the most predominant borer species in the guinea

savanna agro-ecological zone of Nigeria followed by *S. calamistis, E. saccharina, C. ignefusalis and C. partellus* in early and late-planted maize

Although Balogun and Tanimola (2001), reported that *A. ignefusalis* was among the five major stem borers of maize in Nigeria. This study contrarily revealed that *A. ignefusalis* was not found in all the LGAs surveyed. This observation confirms the report by Polaszek (1998) that *A. ignefusalis* is not a primary pest of maize and is also restricted to certain areas and suitable habitats. Youm (1990) also reported that *A. ignefusalis* was a major pest of pearl millet and was not predominantly found in maize. Also, sugar cane is the main crop host of the African sugarcane stalk borer and a relatively minor pest of maize, sorghum and rice (Youm *et al*., 1993). In time, *B. fusca* became eliminated to the advantage of *S. calamistis* since *B. fusca* was more susceptible to high mortality at higher temperatures than *S. calamistis*. Ekoja *et al*, (2015) reported that the difference in population between the two borer species was due to the feeding habit of the borer.

For the reactions of maize genotypes to *S. calamistis* infestation, maize genotypes; M-G39, M-G15, M-G27, M-G30, M-G32, M-G12, M-G16, M-G2, M-G37, M-G19, M-G18, M-G24, M-G28, M-G6, M-G13, M-G23, M-G7, M-G5, M-G34, M-G8, M-G9, M-G28, M-G17, M-G10, M-G22, M-G31, M-G38 were tolerant to dead heart, M-G11, M-G14, M-G10, M-G29, M-G28, M-G35 and M-G36 were moderately susceptible, while M-G1, M-G3, M-G4, M-G12, M-G40, M-G21 and M-G24 were susceptible. M-G12, maize genotype was highly susceptible to stem lodging. Genotypes such as M-G39, M-G15, M-G17, M-G29, M-G30, M-G32, M-G14, M-G12, M-G3, M-G2, M-G1, M-G37, M-G19, M-G18, M-G4, M-G24, M-G11, M-G10, M-G6, M-G13, M-G23, M-G7, M-G21, M-G35, M-G34, M-G8, M-G9, M-G17, M-G40, M-G10, M-G22, M-G31, M-G28, M-G38 were moderately susceptible to stem

lodging effect of stem borers infestation except few such as M-G5, M-G16, M-G28, M-G34 and M-G37 that were moderately tolerant. Even though the genotype did not show extreme resistance to stem borers' infestation, it significantly reduced borer damage. The performance of these maize genotypes agrees with finding of Bamaiyi and Oniemayin, (2011) who stated that some maize varieties including Sammaz 14 and Flint have been reported to be tolerant to stem borers in Nigeria.

M-G8, M-G9, M-G17 and M-G28 were highly resistant to the severity damage effect of stem borers' infestation. M-G1, M-G4, M-G7, M-G11, M-G14, M-G15, M-G16, M-G19, M-G22, M-G23, M-G28, M-G32, M-G35and M-G40 were moderately resistant. M-G6, M-G13, M-G39, M-G17, M-G29, M-G30, M-G12, M-G16, M-G2, M-G37, M-G18, M-G24, M-G11, M-G10, M-G5, M-G34, M-G31 and M-G38 were susceptible While M-G21, M-G23, M-G28 and M-G34 were highly susceptible. The number of rotten ears was lowest (0.00) in M-G13. M-G15 recorded the tallest (208.00cm) plant height and the tallest had been maintained from initial, 4WAS till 12WAS while M-G40 recorded the thickest (2.80cm) stem diameter. Plant stand at harvest was completed in some maize genotypes. M-G27 had the lowest (0.33) plant aspect compared to other maize genotypes. In the case of yield and yield components, M-G28 had the lesser number (34.33) of days to 50% tasseling and shortest number (40.00) of days to 50% silking. The longest (25.33cm) maize ear was obtained from M-G40, while the highest number (3.00) of the ear was recorded from M-G39. The highest number (18.33) of a node was recorded from M-G40. Moisture content was highest (24.80 %) in M-G17 while M-G27 had the highest (24.33g/pot) grain weight, followed by M-G39, M-G23, M-G31, M-G22, M-G18, M-G2, M-G20 and M-G16 which also showed potential high grain yield.

Characterization of the maize genotypes into four groups was in line with previous works of Gomez *et al*. (2004), Tadesse and Bekele (2003) and Upadhyaya, (2003). Cluster analysis indicated that the genotypes in each discriminate group had similar performance as opposed to genotypes in different groups. Therefore, maize genotypes in each group could commonly be used for stem borer resistant screening programs with regards to the mean value of the desirable characters. The positive correlation existed between grain yield and other traits (components) agreed with the findings of Malik *et al*. (2006). This implies that selections aimed at increasing grain yield would invariably select for resistant maize genotypes to stem borers' infestation. The results of this study were in accord with Karasu *et al*. (2002) who reported that crop yield variations are strongly influenced by growth and yield parameters. Thus the correlation estimation in this study clearly defined the contribution of various other traits such as number of ears, ear height, moisture content, number of the rotten ear. The highest and lowest grain yield level attained by the genotypes were mostly due to the genetic makeup of the individual maize genotype to tolerate the pressures imposed by stem borer infestation.

Characterization of the maize genotypes into four groups was in line with previous works of Gomez *et al*. (2004), Tadesse and Bekele (2003) and Upadhyaya, (2003). Qualitative cluster analysis indicated that the genotypes in each discriminate group possessed similar genetic relationships as opposed to genotypes in different groups. Therefore, maize genotypes in each group could commonly be used for stem borer resistant screening programs with regards to the mean value of the desirable characters.

In the estimation coefficients of the two discriminant functions (lodging and no lodging), four measurable attributes (stem diameter, number of days to 50% silking, moisture content, grain yield) were chosen and used in the discriminant models. After the 7th iteration of stepwise regression analysis, the optimal prediction was achieved as 73.7% (no lodging) and 77.7% for the lodging. In all the three trials,116 plant stands had no lodge with 85 stands were correctly classified as no lodging giving the model predicted of 73.3%, while 188 out of 224 observations were correctly classified as lodging, which gave a predicted percentage of 77.7% for lodging.

More importantly, the grain yield for no lodging was obtained as 72.1k/pot, while 40.81 g/pot for lodging indicating the grain yield recorded for no lodging maize stands was almost twice higher than the lodging maize stands. This indicated that stem lodge would significantly reduce the growth characteristics (i.e. stem diameter). Furthermore, the grain yield for no lodge was 72.1kg, while 40.81kg for lodge indicating the grain yield recorded for no lodge maize stands was almost twice higher than the lodged maize stands. This indicates that these four characters (SDM, DSK, MC and GW) were significant and they are included for discriminating capacity of the genotypic variables. Thus, there was evidence to suggest that the group centroids were significantly different from one another and that the discriminant function was, therefore, able to significantly discriminate between groups.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The highest *Sesamia calamistis* incidence was found in Kwara State while the highest severity of *Sesamia calamistis* was obtained in Kwara and Niger states. The lowest stem borers' severity was obtained in Oyo State resulted from the cropping system practiced by most farmers in the areas and inability of most farmers to cultivate certified and hybrid seeds which encouraged a favourite breeding environment for the survival and infestation of stem borers. *Sesemia. calamistis* was the only borer species found in the studied location (Southern Guinea savanna of Nigeria).

The highest number of ears was acquired from M-G19, M-G39 and M-G40. M-G23, M-G28 and M-G33 had shortest days to 50% tasseling while M-G24, M-G28 and M-G33 had shortest days to 50% silking. The highest grain yield was recorded from M-G27. The aforementioned maize genotypes that performed distinctively in various aspects of maize production could be used in the selection for resistant genotypes against stem borers' infestation. Traits such as number of ears, moisture content, and plant stand at harvest, number of days to tasseling and silking which showed a positive significant correlation with grain yield can be used as selection indices in grain yield improvement and production. Out of the forty (40) maize genotypes evaluated for tolerance against the stem borers' infestation, genotypes; M-G34, M-G27, M-G23, M-G39, M-G28, M-G31, M-G8, M-G11, M-G21 and M-G28 were identified by the analytical tools as the overall best for grain yield as compared to the grand mean

performance of the genotypes. The total contribution (direct and indirect) of number of days to 50% tasseling, number of ears, ear position, moisture content and stem diameter were positively correlated to grain yield. The genotypes M-G31, M-G23 and M-G8 were found moderately tolerant to leafy damage. M-G34, M-G23 and M-G16 were highly tolerant to dead hearts while M-G9 and M-G13 were resistant to ear rotten. M-G34 and M-G27 maize genotypes for high grain yield.

The maize genotypes in each cluster group could commonly be used for stem borer resistant screening programs with regards to the mean value of the desirable characters. Cluster 4 consisted of genotypes that had resistance to dead heart under artificial infestation of *Sesamia calamistis* with mean value of 0.0. M-G2, M-G16, M-G22 and M-G23 belonged to the same cluster with M-G27 that produced the highest grain yield (24.33g/pot) under artificial infestation of *Sesamia calamistis*

The grain yield recorded for no lodging maize stands was almost twice higher than the lodging of maize stands. The implication is that the stem lodging symptom in maize genotypes as a result of stem borers' infestation caused a reduction in yield to as low as almost what it should have been without stem lodging.Stem lodging symptom in maize genotypes as a result of stem borers' infestation could be used for forecasting (predicting) grain yield in maize production.

5.2 Recommendations

1. Farmers should source their planting materials from seed companies and/or research institutes for certified and hybrid seeds that are resistant/tolerant to maize stem borers' infestations.
2. Farmers should adopt cropping system(s) such as; destruction of crop residues, manipulation of planting date and tillage method that discourage breeding and survival of stem borers.
3. Annual and/ or biennial farm survey for incidence and severity of maize stem borers should be encouraged.
4. Selection of maize genotypes such as M-G31, M-G23, M-G8, M-G17, M-G28, M-G9, M-G16, M-G5, M-G28, M-G34, M-G37, M-G27, M-G19, M-G10, M-G23, M-G38, M-G13, M- G4, M-G34 and M-G6 are recommended for possible maize stem borers- tolerant genes evaluation.
5. The maize genotypes in each cluster group could also be used for stem borer resistant screening programs with regards to the mean value of the desirable characters.

5.3 Contribution to knowledge

a. *Sesamia calamistis* was the only stem borer species militating against maize production in Southern Guinea Savanna of Nigeria.
b. Incidence of stem borer was higher in Kwara than Niger, Nasarawa and Oyo States, while severity of stem borer was higher in Kwara and Niger States than Nasarawa and Oyo States because of cropping system practiced by the farmers.

c. Maize genotypes that showed high level of tolerance to damage attributes such as severity, stem lodging, ear rotten and low yield were recommended for selection in breeding for maize improvement.
d. Stem lodging symptom in maize genotypes as a result of stem borers' infestation caused a reduction in yield.

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APPENDICES

Appendix 1: Data Collection Sheet

Survey of Stem Borers in Southern Guinea Savannah Ecology of Nigeria

Date: _____ Season: _____

State: LGA: _____ Name of Village:

_____

Latitude: _____ Longitude: _____ Elevation:

_____

Gender of Farmer: Male ( ) Female ( ) Age of Farmer: _____

Highest Educational Background: ( ) Primary ( ) Secondary ( ) Tertiary ( )Non-formal

Maize farming experience (Years): _____ Size of the Maize farm: _____

Age of plants: _____

Purpose of cultivation: (A) Consumption (B) Sale (C) Consumption and Sale

Source of Seeds: (A) ADP (B) Research Institutes (C) Agro Shops (D) Friends (E) Previous Harvest (F) Market

Do you practice intercropping? (A) Yes (B) No

If Yes, with what crop(s)? _____

Do you practice Crop rotation? (A) Yes (B) No

What crop do you rotate with Maize? _____

What is the length of rotation? _____

Do you experience insects on the maize plants? (A) Yes (B) No

What growth stage do you notice the insects? _____

Use of Insecticides: (A) Yes (B) No

How often? _____

If yes, what type? _____

Use of Fertilizer: (A) Yes (B) No

If yes, what type? _____

Use of Manure: (A) Yes (B) No

If yes, what type? _____

Use of Herbicides: (A) Yes (B) No

If yes, what type? _____

What type of crops surrounds your farm? _____-

What variety of maize do you plant? _____

Why are you interested in that variety? _____

Which season of the year do you grow maize? (A) Dry season (B) Wet season (C) Dry and Wet season

Scale for scoring stem borer leaf damage from seedling to whorl stage in maize

Numerical Score	Visual ratings of plant damage	Reaction to resistance
0	No damage	Probable escape
1	Few pin holes	Highly resistant
2	Few pin holes on older leaves.	Resistant
3	Several shot holes on leaves (<50%).	Resistant
4	Several shot holes on leaves (>50%) or	Moderately resistant

	small lesions (<2 cm long)	
5	Elongated lesions (> 2 cm long) on a few leaves.	Moderately resistant
6	Elongated lesions on several leaves.	Susceptible
7	Several leaves with elongated lesions or tattering.	Susceptible
8	Several leaves with long lesions with severe leaf tattering	Highly susceptible
9	Plant dying due to death of growing points (dead-hearts)	Extensively sensitive to damage

Source: CIMMYT, 2011

Appendix 2; Damage on maize plants caused by stem borers' infestation

Appendix 3: Empty cobs caused by stem borers' infestation

Appendix 4: Damage to cobs and grains by stem borers' infestation


A

B


C

: A=. Larva B & C = pupae

Appendix 5: Larva and pupae on maize plant in screenhouse

ANOVA Table

Appendix 6: Analysis of Variance for Plant height at 4 Weeks After Sowing

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	67599.78125	1733.32772	<.0001
Rep.	2	7388.58750	3694.29375	0.0016
Error	78	40967.9125	525.2296	
Total	119	115956.2813		

Appendix 7: Analysis of Variance for Plant height at 6 Weeks After Sowing

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	77936.07925	1998.36101	0.0013
Rep.	2	7477.16067	3738.58033	0.0191
Error	78	69976.6660	897.1367	
Corrected Total	119	155389.9059		

Appendix 8: Analysis of Variance for Plant height at 8 Weeks After Sowing

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	225255.5917	5775.7844	0.1918
Rep.	2	41931.1167	20965.5583	0.0132
Error	78	357468.8833	4582.9344	
Total	119	624655.5917		

Appendix 9: Analysis of Variance for Plant height at 10 Weeks After Sowing

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	214618.6583	5503.0425	0.6382
Rep.	2	57397.1167	28698.5583	0.0120
Error	78	478090.2167	6129.3618	
Total	119	750105.9917		

Appendix 10: Analysis of Variance for Plant height at 12 Weeks After Sowing

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	225255.5917	5775.7844	0.7531
Rep.	2	41931.1167	20965.5583	0.0139
Error	78	529687.3333	6790.8632	
Total	119	807570.9917		

Appendix 11: Analysis of Variance for Stem Lodging

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	225255.5917	5775.7844	0.1918
Rep.	2	41931.1167	20965.5583	0.0132
Error	78	5.21666667	0.06688034	
Total	119	9.96666667		

Appendix 12: Analysis of Variance for Death Heart

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	8.59166667	0.22029915	0.0132
Rep.	2	0.51666667	0.25833333	0.1263
Error	78	9.48333333	0.12158120	
Total	119	18.59166667		

Appendix 13: Analysis of Variance for Stem Diameter

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	53.87364583	1.38137553	0.0628
Rep.	2	4.38912500	2.19456250	0.0979
Error	78	71.5025417	0.9166993	
Total	119	129.7653125		

Appendix 14: Analysis of Variance for Severity Score

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	292.4583333	7.4989316	0.3011
Rep.	2	24.6166667	12.3083333	0.1595
Error	78	510.7166667	6.5476496	
Total	119	827.7916667		

Appendix 15: Analysis of Variance for Days to 50% Silking

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	32900.32500	843.59808	0.5423
Rep.	2	2945.21667	1472.60833	0.1930
Error	78	68369.4500	876.5314	
Total	119	104214.9917		

Appendix 16: Analysis of Variance for Number of Ear

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	66.12500000	1.69551282	<.0001
Rep.	2	1.01666667	0.50833333	0.3132
Error	78	33.6500000	0.4314103	
Total	119	100.7916667		

Appendix 17: Analysis of Variance for Number of Rotten Ear

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	214.6333333	5.5034188	0.1141
Rep.	2	0.2166667	0.1083333	0.9732
Error	78	311.1166667	3.9886752	
Total	119	525.9666667		

Appendix 18: Analysis of Variance for Number of Node

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	1631.591667	41.835684	0.2812
Rep.	2	279.150000	139.575000	0.0247
Error	78	2804.183333	35.951068	
Total	119	4714.925000		

Appendix 19: Analysis of Variance for Plant Stand at Harvest

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	8.92500000	0.22884615	0.2982
Rep.	2	1.11666667	0.55833333	0.0669
Error	78	15.55000000	0.19935897	
Total	119	25.59166667		

Appendix 20: Analysis of Variance for Ear Position

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	467.7661064	11.9940027	0.4158
Rep.	2	83.8000000	41.9000000	0.0299
Error	77	877.866667	11.400866	
Total	118	1429.432773		

Appendix 21: Analysis of Variance for Ear Height

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	4718.740580	120.993348	0.1829
Rep.	2	374.109392	187.054696	0.1463
Error	73	6919.72394	94.79074	
Total	114	12012.57391		

Appendix 22: Analysis of Variance for Moisture Content

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	5814.302304	149.084674	0.0806
Rep.	2	647.462294	323.731147	0.0476
Error	73	7439.72271	101.91401	
Total	114	13901.48730		

Appendix 23: Analysis of Variance for Grain Weight

Source of Variation	DF	SS	Mean Square	Pr > F
Genotype	39	5192.394968	133.138333	0.0029
Rep.	2	179.027738	89.513869	0.2500
Error	76	4818.12260	63.39635	
Total	117	10189.54530		