UNIVERSITY FOR DEVELOPMENT STUDIES

EFFICACY OF LEMON BASIL (*OCCIMUM BACILICUM*) IN THE CONTROL OF FALL ARMYWORM-*SPODOPTERA FRUGIPERDA* (J.E SMITH)

BY

ABDUL-RAHAMAN AMADU DOHBIA (BSc AGRICULTURE TECHNOLOGY)

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DECLARATION

I hereby declare that this thesis is the result of my own original research and that it has neither in whole nor in part been presented for another degree elsewhere. Works of others which served as sources of information have been duly acknowledged by reference to the authors.

Abdul-Rahaman Amadu Dohbia	**…. ………………….**	**...…………….**
(Student)	**Signature**	**Date**

Supervisors

Dr. Frederick Kankam	**………………….**	**.........................**
(Principal Supervisor)	**Signature**	**Date**
Dr. Samuel Adu-Acheampong	**…………………**	**…………………..**
(Co-Supervisor)	**Signature**	**Date**

ABSTRACT

The spread and prevalence of diseases and insect pests are generally influenced and facilitated by large-scale monoculture. Techniques like intercropping relay and rotation can significantly improve disease and pest management. The many unknowns about insect pest and pathogens, such as their dynamics during the cropping season, pose a challenge to evidence-based pest control efforts. Pest control of any kind frequently comes at a financial and environmental cost, as well as some health implications, particularly when synthetic chemicals are used. Local botanicals have been proven to be a safe and environmentally friendly. This study determined the effects of the botanicals prepared from lemon basil –*Ocimum basilicum* on Fall Armyworm (FAW) overall damage levels in maize during the 2020 cropping season in the Guinea Savannah Ecological zones of northern Ghana. Prior to the botanical experiment a surveys of one hundred farmers were conducted during the 2020 cropping season. Based on the survey the study further applied processed various formulations of lemon basil material for the control of the fall armyworm because it was found to be the most dominant pest in the study area. According to the survey results, the majority of farmers practice continuous cropping, with maize being the most dominant crop in the area. The study also revealed that FAW is the most common economically destructive crop pest in the area. The study further revealed that a large proportion of farmers do not follow any safety protocol when handling chemicals, putting the health and safety of farmers, consumers, and the environment at risk. Furthermore, the application of a locally prepared extract of lemon basil on maize resulted in a positive effect on the FAW. There was no significant difference between the four treatments. The results also indicated that the soaked preparation has superior performance because there was no sign of pests attack on plants treated with the soaked solution plots during the seven-day application

period. Extracts of lemon basil have chemical properties that proved to have positive effects on the control of FAW which was identified as major insect pest on maize from the surveys. Further studies on the application rates and the need to explore the oil components of lemon basil for the control of FAW will be helpful in the search for botanicals alternatives in the insect pest's management.

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I also thank the farmers who assisted me in the administration survey questionnaire and also giving insight to some traditional uses of botanical materials and also colleague students who assisted during the data collection most especially during the fall armyworm data analyses.

DEDICATION

This thesis is dedicated to Almighty, my late father; Abdul –Rahaman Iddrisu Dokurugu, my mother; Salamatu Tidow Abdul-Rahaman, my dear wives and all teachers (present and past) for making me who I am today.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Intercropping has increased crop variety, which has been a convenient and effective way of minimizing pest and disease population and magnitude levels among farmers (Seran and Brintha, 2010). The age long indigenous practices in agriculture such as mixed cropping and Intercropping are among ways used in various agricultural regions to control disease and pest infestations (Abate *et al*., 2000; Chhetry and Balbahri, 2009).The majority of people in northern Ghana make their living by farming. Food crop cultivation is widespread among subsistence farmers and is the primary source of income and livelihood in the five northern regions. The most commonly grown crops include soybean, pepper, maize, yam, cassava, rice, sorghum, millet, cowpea, groundnut and tomatoes. Which crops are grown are determined by physical and biological agro-ecosystem characteristics, as well as socioeconomic factors.

Yield losses due to arthropods, diseases, and weeds are estimated to account for approximately 35% of major crop yield losses globally. In developing countries where pest control options are limited, losses may exceed 50% (Oerke, 2006; Aruna *et al* 2019). Arthropod pests consume enough food to feed an additional billion people (Birch *et al.*, 2011). Herbivore pests consume 13% of annual crop production in the United States, at a cost of $18.77 billion (Judith Myers and Sarfraz 2016). Reduction in maize yield by FAW is estimated to be between 8 and 16 million metric tons in Africa. This is translated in monitory terms to be between 2400 and 4800 Million United State Dollars per annum (Hans, 2018).

Measuring the efficacy of lemon basil in the control of Fall Armyworms (FAW) aims to provide an alternative to the use of synthetic chemicals, which come with high risks to the user, the environment, and the residues in farm produce (Aktar *et al.*, 2009). Sweet lemon basil belongs to the Lamiaceae plant family and can be used either fresh or dry in food seasoning. It grows in a variety of climates around the world. Basil is well-known as a plant with folk medicinal value, and as such, it is officially recognized in several countries. The use of pesticides, biological and cultural controls are all strategies that have been proposed for management fall armyworm. However, it does appear that in dealing with FAW in large scale farms where the invasion is severe; all these proposals can provide effective and responsive check. Furthermore, cultural or biological techniques are difficult to implement and necessitate the use of well-trained farm owners.

Lemon basil has long been used as a flavoring agent in food, as well as in perfumery and medicine (Telcia *et al*., 2006). Parts of the plant including the flowers and the leaves are medicinal against many ailments used by people (Sajjadi, 2006). Recent study has looked into the potential of using the oils from the plant as antioxidants and (Suppakul *et al*., 2003; Lee *et al*., 2005; Wannissorn *et al*., 2005 Politeo *et al*., 2007;;). The origin or location as well as the colour of the flower and leaf of the plant determine the chemical composition (Da-Silva *et al.*, 2003; Sajjadi, 2006).

1.2 Problem statement

Over the years, due to increased human population, land use for agriculture purposes has correspondently increased across Northern parts of Ghana. As a result, there is continuous cropping with much greater land use intensity. Agriculture, on the other hand, is expected to meet rising food and fiber demand. These demands have led to increased competition for land all over the world, putting agricultural intensification at the forefront (Seran and Brintha, 2010). Pressure on agriculture lands has led to encroachments on wet lands and other land originally meant for other purposes to be converted to farm lands and this has created issues of environmental degradation. (Seran and Brintha, 2010). The pressure on farm lands come with other adverse effects on the environment due the use of agro chemicals and its associate run off on water bodies. (Matson *et al*., 1997; Tilman *et al*., 2002).

Crop intensity values as high as 0.9 have been reported in the Upper East Region in particular.

Thus, one of the issues looked at is the attention of the in the increased in population pressure on agricultural land in the northern part of the country. The study specifically looks at the efficacy of lemon basil (*ocimum basilicum*) in the control of fall armyworm (*Spodoptera frugiperda*). In the last six decades, the most influential insect pest management tool has been the use of synthetic insecticides (Guedes *et al*., 2016). This pest management option has increased crop productivity by lowering crop loss and providing food commodities with high cosmetic qualities (Oerke 2006). However, the misuse of the synthetics -insecticides has led to increase in resistance in pest management, elimination of rather some beneficial organisms such natural plant enemies. (Chagnon *et al.*, 2015; Guedes *et al.*, 2016). Farmers, particularly subsistence farmers, have been confronted with the use of synthetic agro-chemicals in the aftermath of the emergence of fall armyworms in Ghana since June 2016 (MOFA), with the attendant effect on the farmers' lives; its residual effect on farm produce and the environment at large. This work investigated on a locally known and available plant extract – lemon basil, a herb with low insect resistance development, no or minimal effect/harm to the user, farm produce, and the environment.

Long before the advent of modern technology which brought about synthetic chemicals, Plant-based materials were used for pest control. Synthetic pesticides were quickly adopted due to their quick response to some emerging issues as blight and rust management. As a result, the use of natural plant-based products declined gradually and not long the human and environmental safety issues posed by the use of the synthetic chemical came handy. Food products from natural production sources are preferred all over the world as they are deeming safe for consumption. The use of organic material- plant base extracts is once again widely used in organic farming due to the fact that the synthetic chemical residues in crop plant produce are poisonous and therefore unsafe. This has led to the restrictions in the use of some chemicals for farming purposes. (Nayana and Ritu, 2017) Data from empirical subsistence studies Farmers' perspectives, expertise, and fall armyworm control are hazy, and reports are incomplete, implying that farmers could devise coping strategies for managing and dealing with the fall armyworm threat in a way that influences the pest's status (Francis *et al*., 2018). In order to meet farmers' demands, it is critical to consider farmers' perceptions, knowledge, and pest management strategies when planning and developing agendas, formulating extension strategies, and proposing research (Damalas *et al*., 2015; Fliert and Braun, 2002)To develop long-term integrated pest management strategies, farmers' socioeconomic factors, knowledge, and perceptions, as well as their existing management practices and potential fall armyworm control limitations, must all be understood.

The effect of the fall armyworm in recent years has not only increased the stress on low yields but also reduce farmer's income due to cost of controlling the pest. The use of synthetic chemicals by farmers especially in the Tamale Metropolis and Tolon District is increasing in the wake of the fall armyworm invasion. However, a survey conducted in these two areas shows a rather low level of knowledge and understanding of the risks associated with the use of the synthetic chemicals in pest control. Majority of the farmers applied these chemicals without adherence to any of the rules in the protocols, such as no protective clothing, not washing after using the chemicals. The survey reported that sixty nine percent (69%) of the people in the survey were reported not to be following any protocols in application of pesticides.

1.2 Significance of the study

Due to the risks associated with most pesticides of synthetic origin, environmentally safe methods mainly from microbial and botanicals sources are gaining attention and been promoted

(Bateman *et al.*, 2018). Production of Maize in Africa is usually done at the level of the subsistence farmer and the systems of cropping are mostly varied depending on the units of land area, the cultivated crop, land use consistency among others, not similar to the American large scales mono-cropping designs and the use of pesticides are minimal in Africa compared to other parts of the world.(Ramankutty and Foley, 1998; Ebanyat *et al.*, 2010)

Botanical pesticides or botanicals are also called herbal pesticides (Kumar B. *et al.*, 2013) are known natural substances for the management pests occurrences via other mechanisms either than toxicity, and the fact that it is not clear as to the veracity of the ability of botanicals control of pests situations in a nontoxic means or action, a committee has been set up to assess the efficacy criteria standard against bio pesticides by Environmental Protection Agency (EPA)

(Mazid, *et al.,* 2011, Schumutterer, 2013). Over 6000 plant species have been identified that possessing insecticidal properties. In insect pest management, a number of plant products derived from neem, custard apple, tobacco, pyrethrum, etc. have been used as safer insecticides (Singh *et al*,. 2005; Nawaz *et al* 2o16 and Shivkumara, 2019). Botanical pesticides have environmentally friendly characteristics such as volatile nature, low environmental risk compared to current synthetic pesticides. Due to minimal residual activity; predation, parasitism, and the number of pollination insects would affect smaller and compatible with IPM programs (Jeffries. *et al*.,2011)

At present however, there is limited information on biocontrol data for fall armyworm in Ghana and the effect of botanical insecticides on the activities associated with FAW. There is, therefore, the need to document baseline information on available botanicals and their potentials for biopesticides interventions, and the effects of bio-rational insecticides on their activities. Also to evaluate alternative options of pest control strategies such as the use of botanicals such as neem extracts and oil among others and most importantly a new product which is known to be used locally but with no scientific evidence to back it as in the case of lemon basil.

1.4 Main objective

To reduce production cost through the use of cost effective botanical pest management strategy with little risk of chemical exposures to the farmer, the environment and residual effect on the produce by evaluating the potential of local plant material, lemon basil.

1.4.1 Specific objective

To determine the dominant crop insect pest and the common control measure used by farmers.

To determine the efficacy of lemon basil in the management of fall armyworm in maize field.

CHAPTER TWO

2.0 LITERATURE REVIEW

Intercropping has increased crop variety, which has been a convenient and effective method of reducing pest and disease severity and density (Trenbath, 1999 and Seran and Brintha, 2010) . Mixed cropping and intercropping crop varieties are indigenous agricultural methods that have been used for centuries in various agricultural regions to control disease and destructive pest infestations (Ramert *et al.*, 2002). Plant elements of farming systems are not shown simultaneously, but rather for a significant portion of their growth periods, depending on crop arrangement; however, a significant portion of their growth periods, depending on crop arrangement, plays a critical role in their development and the ecological environmental goal of intercropping (Trenbath, 1999). Strip intercropping, mixed planting crops, relay intercropping, and row intercropping are common pest and disease management crop arrangement patterns.

2.1 Historical cropping pattern in the Northern Region

The most common crop cultivation pattern in many parts of northern Ghana is intercropping (Benneh,1973). Cereal-legume intercropped cereal-legume intercropped cereal-legume intercropped cereal-legume intercropped cereal-legume intercropped cereal-legume intercropped cereal-legume intercropped cereal-leg (Francis and Stern, 1987). Individual land holdings in most areas of the Upper East region have shrunk due to population pressure on lands, and are no longer large enough for the cultivation of many crops. More than 80% of the region's population cannot obtain a land holding of 2 hectares in and every square kilometer holds 125 people in terms of density as compared to the 72 people as national average (Anang and Asante, 2020). Cereal intercropped cultivation is generally common around Sawla areas in the now Savannah region whereas legumes crop intercropped are done in Upper East, a densely populated area. Cereals make up the majority of households' diets in these areas, resulting in higher production levels (Diao *et al.*, 2007).

MacCarthy *et al.*, 2014 in citing Abatania and Albert, 1993 reported that natural vegetation conversion to agriculture land has increased in the last two decades. An estimated annual rate of decline of close forest area is 0.4 and 0.5 percent for the savannah and forest areas respectively (Forestry Department of Ghana, 1998). This is in respond to the increase in demand of agricultural land as a result of food demand due to the rising population. This has led to an alarming rate of soil degradation due to the fragile nature of soils in the area according to (MacCarthy *et al.*, 2014) in citing Vlek *et al.*, 1997. In supporting this accession, Braimoh and Vlek 2004 research found that soil in northern parts of Ghana for the past two decades has been on the decline.This situation is as a result of the methods of land management practices which includes continuous cropping, burning the vegetation, overgrazing and others , and the resultant soil fertility decline is one of the most pressing concern in communities around the savannah and parts of the transitional zones. In attempt to address these issues, farmers use animals dropping to augment the field soil fertility within the compound fields (Wood, 2013). Crop residue are carried from the farms for other purposes such fodder and burdens in pents and in the process enriching soils with the compound fields. MacCarthy *et al* 2014 in citing (Wopereis *et al.*, 2006) stated that grazing by livestock mainly in the bushes during the day is nutrient mining in the bush fields, and the eventual dropping mainly in the night at home enriches soils within homes. Nutrient gradient is therefore created between compound farms (fields within home) and ‘bush farms’ (fields outside home) (Zingore *et al.*, 2007))

Cropping patterns in these areas are largely based on cereals. Intercropping based on roots and tubers typically predominates in the Bimbilla area, which is located in the northern region's south-eastern corner. Legume-Cereals, Cereal-Tuber/root, Cereal-Cereal are the most common crop combinations used in cropping patterns (Khalid *et al*.,2021). Patterns arrangements depends on the nature of the soil and the soil crop relationship. When compared to bush fields, compound farms have less intercropped (Okigbo and Greenland, 1976; Gaba *et al.*, 2015). Maize and Tobacco are the main crops grown in compound farms with maize dominating. The fertility requirement of maize in higher comparatively and averagely the available organic matter within the compound fields due the household organic waste materials, animal droppings and absence of bush burning is more compared with 'bush' fields. Bush farms are those that are more than three kilometers away, and some are more than twenty kilometers away (Owusu *et al.*, 2011). Farmers grow solely maize in these fields in order to get the most grain out of them. Animals are confined or tethered by all animal owners in communities where community compound farms are cultivated because crops grown on compound fields are attacked by the animals, destroying the crop and thus the yield. Tobacco, on the other hand, is not normally eaten by animals, and some farmers prefer cultivating Tobacco in their compound parcels according to Integrated Research System for Sustainability Science. In Modern agricultural development techniques, the trend has been more on intensive monoculture (Kentie *et al*, 2015)

2.2 Crop diversity patterns

2.2.1 Crop rotation

In the management of soil related diseases , rotation of crops which is sequencing of different crows on a particular parcel of farm land in different time periods is one of the effective methods used (Oros *et al.,* 2013). Pathogens population and or their action and other undesirable effects are minimized if not curtailed due to the absence of the host specifity. The biomass of plants does not only add to the organic matter but also deter some pathogens actions. (Hoitink and Boehm, 1999). The pathogen's inoculai are significantly reduced in a situation when the period of non-host is prolonged (Garret and Cox, 2006). The rotation scheme influences how specific pathogens are managed (Krupinsky *et al*. 2002). Crop rotation, for example, influences root occupation by archaea and bacteria in upland maize and wetland rice (Breidenbach *et al*.). Furthermore, most research works proposed the cultivating of multiple crops using agrodiversity would have a positive impact on a specific parcel of land in a locality (Seran and Brintha, 2010). Crop residue diversity and crop diversity Hoitink and Boehm have an impact on the microbial population in plants and soil, which in turn has an impact on pests, weeds, and plant diseases (Garbeva *et al.,* 2004). Crop rotation is an effective way to control a wide variety of pathogens.

2.2.2 Intercropping

Cultivating more than one crop within a specific piece of land as the same time is said to be Intercropping. (Ofori and Stern, 1987). Crops grown in alternating rows, growing crops in alternating strips (strip intercropping), relay intercropping and mixed intercropping are the various types of intercropping (row intercropping). The primary reason for intercropping's to ensure that more significant crop interactions and biological take place. The main benefits of intercropping are biological and economic consistency, fewer weeds, more efficient use of available resources, and, most importantly, increased yields (Brooker *et al*. 2015; Vandermeer, 1989). The technique is in used in most tropical regions of the world for over a century, and to some extent some temperate regions such as China (Vandermeer 1989). However, the introduction of monoculture has taken the center stage in the last century due to mechanization thereby putting intercropping in a decline in many temperate regions (Francis, 1986). Numerous research works have been conducted, particularly beans and cereals and cereal and pea intercropped in some temperate regions and crop disease is generally suppressed by intercropping (Vandermeer, 1989; Boudreau, 2013). In Western Kenya, a recent study discovered that intercropping with a legume effectively inhibited cassava brown streak disease (Ememwa *et al*., 2017). A variety of integrated management schemes were used over seven seasons to investigate the inconsistency of primary and late leaves spots of groundnut (Boudreau *et al*., 2013). As disease pressure in intercropping fields has decreased, groundnut yields have increased significantly. Early leaf spot effects on maize intercropped was investigated, and the infection influenced pathogen dispersal, resulting in disease reduction. Because of the low levels of early leaf spot (ELS), the most effective intercropping scheme used cotton strip patterns with limited fungicide managements (Han-ming, *et al*., 2019)

2.2.3 Cover cropping

Crops refers to every ground cover living tissue that is planted alongside or after the most recent crop and is frequently destroyed and incorporated into the soil for the succeeding crop to be planted (Hartwig and Ammon, 2002). It was first used before 1945 and consists of two cropping's into a sole key crop to enhance soil amendments while reducing weeds, erosion and pest. Cover cropping styles include relay cropping, overseeding, and interseeding (Hartwig and Ammon 2002). This type of cropping system may be appealing to vesicular-arbuscular mycorrhizae, which aids in weed suppression (Jordan *et al*., 2000). Herbicides and artificial fertilizers have significantly reduced the use of those systems (Hartwig and Ammon, 2002). In Manitoba, Canada, research concerning the use of cover crops in cereals revealed that this didn't result in significant grain in crop yield losses (Martens *et al*., 2015, Han-ming *et al*., 2019,) and can prevent disease spores from spreading in crop field *(*Schoeny *et al.*, 2010).

2.2.4 Origin and distribution of Fall Armyworm

Fall armyworm (FAW), a native of the terra firma's tropical and subtropical regions, it's now a serious and major insurgence pest maize crop (*Zea mays* L) . FAW has spread all over Africa and Asia within a shortest time. Variety of food crops, including maize cotton (Gossypium hirsutum L.; Malvaceae), sorghum (*Sorghum bicolor* [L.] Moench; Poaceae), pasture Grasse and (Zea mays L.; Poaceae) faces FAW as one of the main insect pest in recent times. FAW is cosmopolitan in United State of Americas (Adamczyk, 1998) and has of late assumed a major African pest (Goergen *et al.,* 2016*;* Nagoshi *et al.*, 2017). In assess of 23 families with over 80 species of FAW which have been reported, appeared to affect a wide range of food crops (Pashley, 1988). Maize, rice, sorghum, cotton groundnut and some grass, are among the plant species affected. However, C4 plants example as corn, sorghum, and Bermuda grass are preferred over C3 crops like soybean and cotton (Luginbill 1928, Buntin 1986, McCarty and Nagoshi *et al*., 2007). Fall armyworm is said it originates from both the tropics and sub-tropics of America antrum is a major maize pest, particularly in Brazil and Central America (De Groote *et al.,* 2020). It is primarily the main serious maize and other cereals production issue in pest management (Montezano *et al.*, 2018), and it has recently infiltrated many maize growing areas in Africa and Asia is at hand (Day *et al.*, 2017). S. frugiperda entered West Africa through Benin, Nigeria to Togo in 2016 (Durocher-Granger *et al.,* 2021), and the first occurrence in Ghana was in April 2016 in the Eastern Region (MoFA 2017). The fall armyworm is now present in all ten regions of Ghana and has caused damage to several hectares of maize farm lands across the country, with the monetary value of yield losses due to fall armyworm infestation estimated at US $164,000,000.00 as of April, 2016 (SARI 2017).

However, as shown in a report from the Ghana Atomic Energy Commission (GAEC), research to help regulate the invasion of farms across the country by fall armyworms is still in its early stages.

The species does not diapause, and the pest can produce many generations completely even during off-season and in irrigated areas if the host crops available, thanks to the conducive environmental conditions prevailing in many parts of the African continent. Significant losses in mostly cereals and maize in particular by FAW in Africa have been published where no action has been taken by way of management and with no natural enemy. Fall armyworm was first reported in Kenya's western region in 2017, but by early 2018, the disease had spread to more than 42 counties across the country (Sisay *et al.*, 2018) At the larval stage, this new pest exhibits frequent interactions with the stem borer community in the use of maize resources (Sakami, 2017). The rapid spread of the virus has continued, and 44 African countries are now affected. So far North Africa has not reported a case. There have been no reports from North Africa, but FAW has made its way to the Indian Ocean islands, including Madagascar. According to environmental suitability modeling, the majority of FAW-suitable areas in Sub-Saharan Africa are now infested. It is unlikely that they will spread directly across the Sahara. However, if FAW establishes itself in the few suitable areas in North Africa, it may pose a threat to Europe through migration.

According to Nagoshi and Meagher (2004a, 2004b) and Chapman *et al.* (2015), an increase in the general FAW incidence during spring is followed by a rather fast extended reduction by midyear surveys reports in maize farms in southern Florida, appears to reflect the pest's yearly relocation northward. Following the mid-year decrease in the south, FAW populations begin to increase in agricultural areas in the fall and winter, coinciding with the late-year maize cropping season (Nagoshi and Meagher, 2004b).

The FAW upsurge period usually coincide with favorable climatic situations for southward movement, prompting the recommendation of a north-to-south return migration in advance of winter freeze (Garreaud *et al.,* 2009). Occasional 10 observations of FAW using sex pheromones in eight areas from French Guiana northward to Canada over two years indicated a regular movement of fall armyworm within the southernmost areas of the Americas into Canada (Nagoshi et al., 2006, 2007a).. Territory-wide management programs aimed at influencing FAW number fluctuation in these areas can essentially change the extent of northward movement (Nagoshi and Meagher, 2004b). Apart from the idea that FAW moves long distances, knowledge of the mode of FAW migration from one crop field to another is critical for developing an effective management strategy (Adamczyk, 1998). Nagoshi *et al*. (2006,) discovered significant genetic factor drift amongst FAW populaces collated in cotton and maize farms in Brazil. Because of the spatial and transient covering of cotton and maize plants in certain regions, FAW movements amongst various crop fields and the host, necessitates the need for crop protecting strategies for the control FAW in order to minimize pesticide resistance occurrence (Assefa and Ayalew, 2019). Furthermore, Nagoshi *et al*. (2006, 2007a), discovered the FAW strain that attacks cotton in Mississippi are migrants from the maize growing regions in the north since the cotton invaded stains were coming from maize and that maize was a source of shelter for cotton attacking strain hence the late season occurrence in Mississippi dalta. The ability of a generation to migrate over long distances of about 480 km (Adamczyk, 1998), made it possible for the FAW's seemingly limitless distribution in the Western Hemisphere (Nagoshi *et al.*, 2007b). This sporadic movement of FAW could be caused by regular changes in precipitation, temperature, and host plant planting (Westbrook *et al.*, 2016). Furthermore, during the spring, prevailing breezes and frontal systems with their converging air movements are said to perform an important part in determining the range and route of FAW adult movement (Rainey, 1979). The presence of fall armyworm in Africa is shown in Figure 1 below where countries affected marked red.

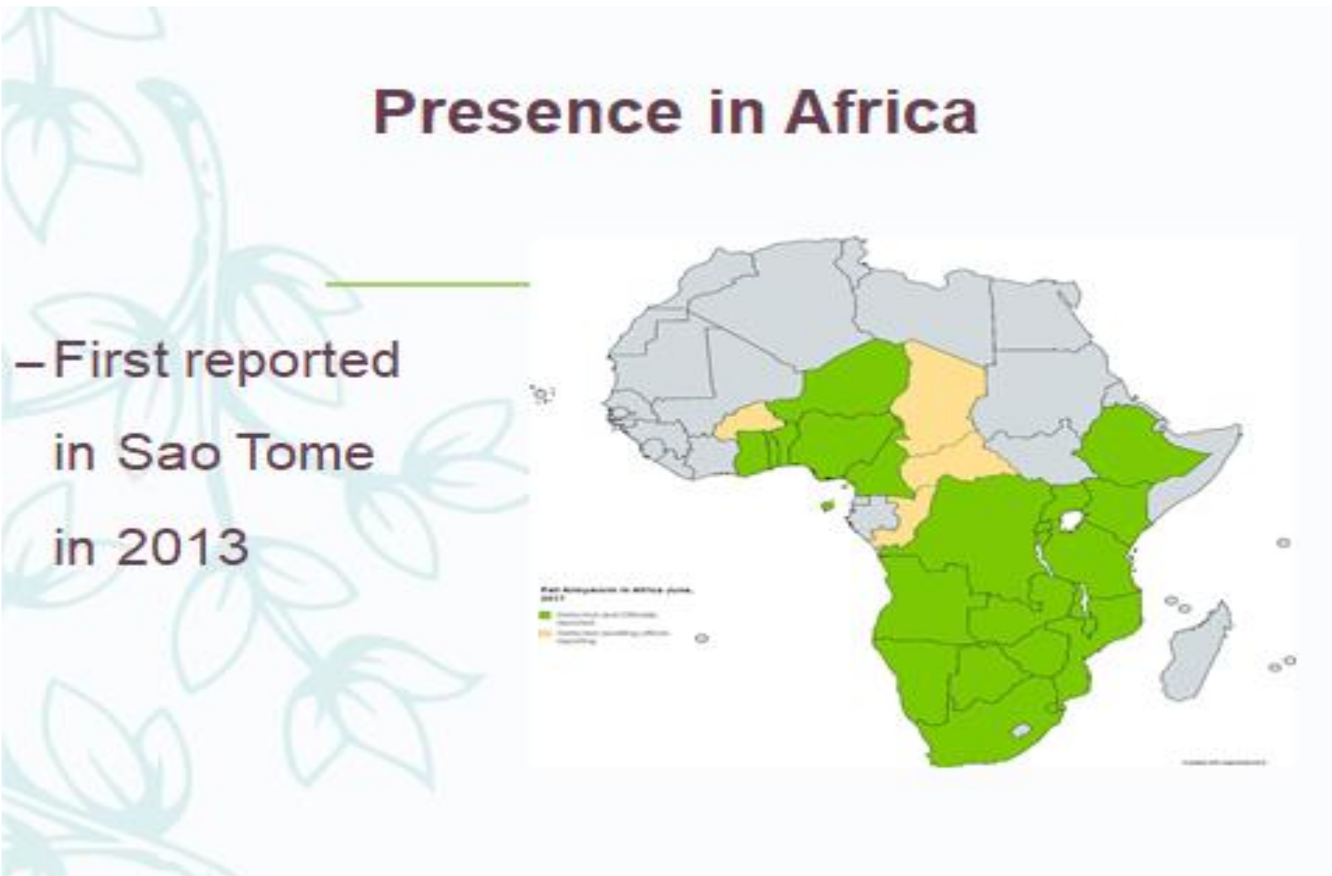


Figure 1: Presence of *S. frugiperda* in Africa

2.2.5 Biology of fall armyworms

In Latin America, the FAW use 30 days to completes its life cycle (at temperatures around 28 ° C) in the hot summer months and 60 to 90 days in colder temperatures (FAO, 2017). The life cycle of FAW consists of an egg, six stages of larval development (instars), a young and a moth. FAW life cycles do not go through a diapause (a period of biological rest) under permanently favorable conditions (as in many sub-Saharan countries without winter) and where FAW populations are rather endemic. Migratory FAW occurs when environmental conditions are favorable, and there may be only one generation before extinction locally in areas where FAW is not endemic. An average egg production of female FAW ranges from 1,500 to 2,000 and over in its life time with 100 to 200 at a time (FAO, 2017). During the hot summer months, the egg phase lasts about two to three days. FAW larval instars usually have six stages. The larvae usually hide in the brightest part of the day, so they are called nocturnal. The larval phase lasts 14 to 30 days contingent on the ambient temperature, from hot to cold. The larva is buried in the ground at a depth of 2 to 8 cm to pupate. It creates a protective structure known as the cocoon by combining soil particles with silk. There may be poplars in the game if there is no soil in the area. The pupa stage lasts about eight to nine days, after which the adult moth emerges (Sharanabasappa et al., 2018). Adult males and females are nocturnal and can be distinguished by the color of their front wings. Most of the eggs are laid within four to five days of the adult females their lives after preovippsition moths usually lay the majority of their eggs within the first four to five days of their lives after three to four days of preovipposition, but other oviposition can occur within three weeks. An adult FAW has an average lifespan of about ten days(Sharanabasappa *et al*., 2018). Fall armyworm feeds on over 80 plant species, and therefore said be one of the many polyphagous and harmful pests of plants. Larvae feed on the leaves, living holes om the leaves and tearing along the edges. If a leaf is missing, feeding with cornstarch can result in a slew of identical "shot" holes. Constant feeding within the vegetative stage can cause heavy window curls filled with larva frass, striped leaves and sometimes total defoliation of the entire stalk. Fall armyworm is known to cause significant damage to economically important weed cultivars such as corn, cotton sugar, cane sorghum and vegetables as well.

The pregnant female lays eggs in masses of 55 to 888 on the bereaved or upper portion of the maize leaf, under leaf base and curl parts of the leaf. The eggs are dorso-ventral flat, light green at first, turning golden yellow in one day, and finally blackening before hatching. Females hide within egg mass, giving her the appearance of mold. The incubation period lasts between 2-3 days, with an average of 2.50 days (Sharanabasappa *et al.*, 2018). The first instar larvae are green with a black head, while the second instar larvae are green-brown. The third instar is brownish, with three white lines running down the dorsal and lateral sides. There are brownish black, light side lines with three white dorsal lines on the body of the fourth and sixth intar stage of the larva. Black tuberculosis run across the body around the spine. In front, a white inverted "Y" is found on the head (Sharanabasappa *et al.*, 2018). About 40% of larva deaths that occurs when maize field is infested with two to four fourth instar larvae in three days through Cannibalism (Chapman *et al*., 2015). Unlike the African worm (Spodoptera exclusivea), this behavior is encouraged when the larvae are introduced in an environment where feed is limited (Chapman *et al*., 2015). The cause of the death as a result of the larvae population density dependence is unclear (Chapman *et al*., 2015), but it could be a significant factor in reducing the severity of some occurrences. although African knowledge shows that this is not clearly stated.

Cannibalism may be reduced once populations are low due to the high reproductive capability of newly emerged larvae (Pannuti *et al.,* 2016). The square behind the hind end of the abdomen distinguishes it from FAW larvae (CABI, 2017b). On the back of the body, there are raised spots that are sometimes black and have thorns (CABI, 2017b; Capinera, 2000). The host plant leaves on which the laid eggs are attached is the primary food source for the newly incubated larvae, but as they mature, they spread gradually to neibouring plants (CABI, 2017c).Primary and secondary stages of the instars then follow and move to the opposite side of the leaf, they leave holes due the their feeding on the leaf as the grow. The color and width of adult FAW moth wings vary (32 to 40 mm). The forewings of the adult FAW appeared brown and grey characterized with a triangular whitish spots around the larva tapering tip and the middle. The distinguishable feature of the female is the presence of unclear marks that appears gray-brown to light gray-brown spots. Female and male hind wings glow silvery white with a narrow black border. Because of its migratory nature, Spodoptera frugiperda (J. E. Smith) is classified as an occasional plague. This species does not migrate north across the United States every year during warmer climates as in South Florida, the Caribbean, South Texas, Mexico, and coastal areas. South Georgia, Alabama, Mississippi, and Louisiana are all affected. (Knipling 1980; Adamczyk, 1998). Every year, FAW migration causes problems among various crop plants. The occurrence of FAW and the subsequent destruction of plants can be unpredictable. Plant reproductive structures are destroyed, resulting in high yield losses.

2.3 Life stages of fall armyworm

2.3.1 Egg

Fall armyworm eggs are "flat spherical", measuring 0.39 mm and 0.47 mm in length and diameter respectively (Adamczyk, 1998). The color of newly laid eggs is initially green-gray, but gradually darkens with age. The eggs of the worms appear to be brown and black 12 hours after settling, before the larval eclipse (Sisay et al., 2018). Eggs are sometimes wrapped in a "hairy" material (thick shell shell) to protect them from moths. Oviposice arrives early in the evening. Eggs are normally laid in groups / clusters, with the clump containing anywhere from a few to hundreds of eggs and hatched within 4 days provided environmental conditions. The egg / clump weights are shown in Figure 2 below.

Figure 2: *S. frugiperda* egg mass with little or no covering of scales (A); egg mass covered with scales (B); and egg mass nearing larval exclusion (C).

2.3.2 Larva

The color of the larvae from white to yellow during the first instar (L1) is closed, with black-headed capsules and small black spots where the main setae appear. The larvae usually darken when they feed and grow, which gives them a greenish appearance (Luginbill 1928). The color of the other two larval instars (L2 - L3) is similar to the previous instars immediately after milling the first instar, but darkens before milling to the next instar. The color patterns of the last three stars (L4 - L6) are mostly dark, but this is affected by diet and other factors. The capsule on the head is traditionally black, from brown to black. Advanced instars (L4 - L6) are smoother and lack primary setae (Sharanabasappa *et al.,* 2020). The color of the old larvae varies from light green to brown to black, a discontinuous white line in the middle of the dorsal area, as well as yellow and red "flecking" ventral marks (stomach). In the eighth part of the abdomen, the larvae have a clear pattern of four "dots". Autumn worm bites have tooth-like protrusions. The orange brown color of the pupal case has width of 0.314 for the first inster and 2.72 for the sixth instar. Figure 3 below shows the life cycle of eel (Spodoptera frugiperda)

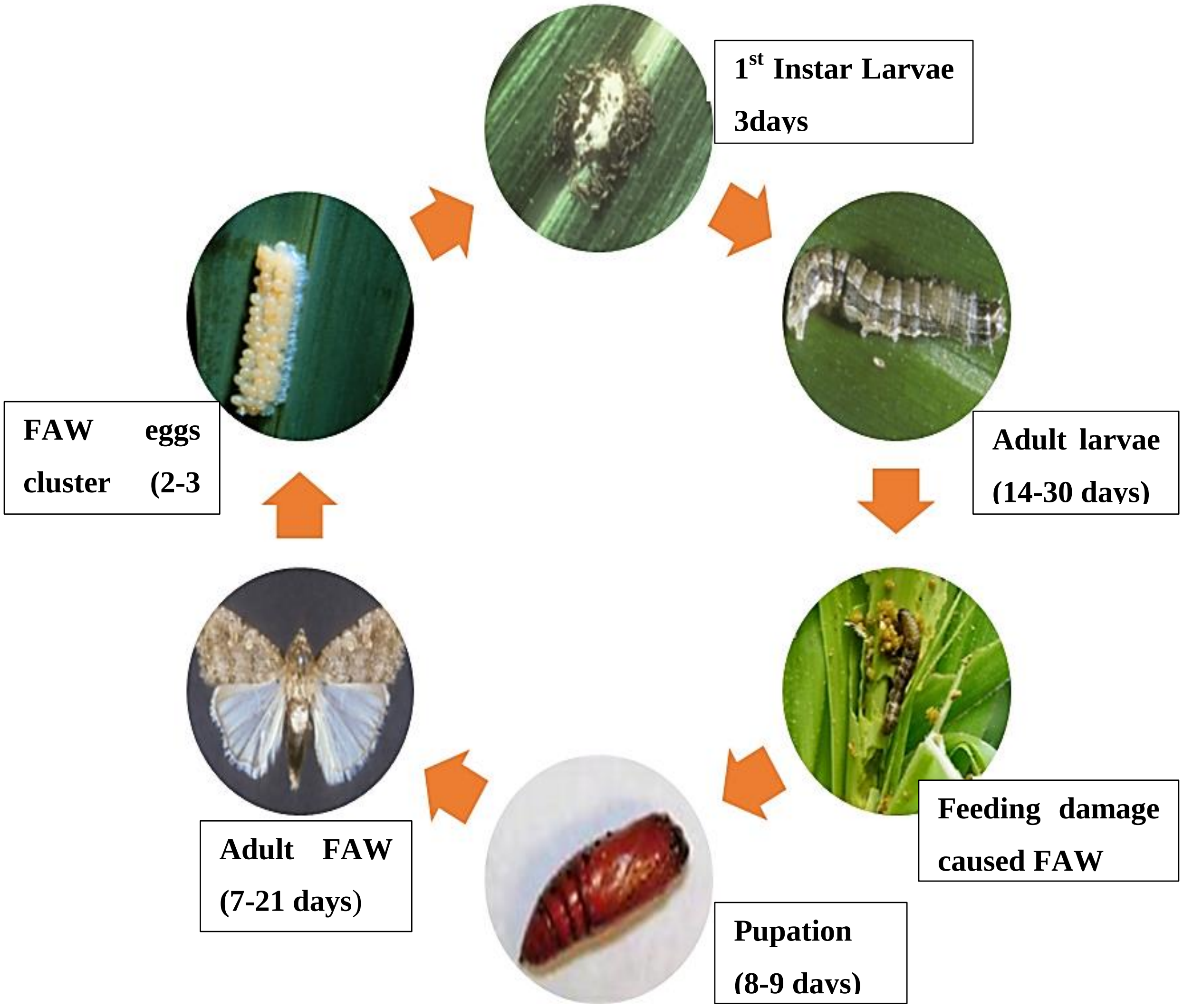


Figure 3: Live cycle of *S. spodoptera*

2.3.3 Adult

The adult worm (moth) has 3.81cm wingspan. The upper wings are dark gray with a distinct white area near the dorsal tip or apex of the wing, while the lower front wings are light gray to brown (Oliver and Chapin, 1981). The rear wings are light gray to white. Adult males resemble Spodoptera ornithogalli commonly called Guinea worms. Compared to male fallow deer worms, adults with yellow stripes on the front wings have crescent-shaped features, which lead to greater variability in color shades. Adult female army worms are sometimes confused with Spodoptera exigua (Hübner) . Adult beet female worms have an oval dark central round spot, while adult FAW have a paler base color with a light round spot (Todd and Poole, 1980). The parachute worm moth has filamentous (like wire) antennas that are common to the Noctuids. The moths are nocturnal by nature (Sharanabasappa *et al*., 2018).

2.4 Host strains behavior

The two different FAW strains are morphologically similar in nature making FAW is complicated by the these presence of two different strains that are morphologically similar. These strains are called "host-specific" because they prefer host-specific plants. These are commonly known and named as C-strain for corn strain and R-strain for rice strain Quisenberry 1991, Nagoshi and Meaghe,r 2004). Hitherto, the population of armyworms were classified as sister species as tribes (Pashley, 1986). R-strain FAW feed on rice, bermudagrass, Pers. and some species of Graminaceae and C-strain feed on maize preferably. The carbon isotope ratio in adults indicates that strain C comprises the majority of the eel subpopulation in the cotton environment. Compared to strain R, strain C develops in greater numbers (Nagoshi *et al*., 2007). Crossbreeding occurs between the two tribes, but there is a difference in willingness to rent. A varied population is produce when C-strain males crossed the R-strain females; meanwhile, there is an incompatibility between R-strain male and C-strain females as they do not produce when crossed (Whitford *et al*., 1988).

Genetic markers and variants of allozyme are often used to identify these two strains (Nagoshi and Meagher, 2004). Due to the differences between the two strains in life history, strain identification has a resonant effect on plant protection strategies. Variations in larval development in host plants, copulation behavior, feeding method, insect control and vulnerability in plants expressing Bacillus thuringiensis (Bt) proteins have some influence. in managerial tactics.

2.5 Damage caused by *S. frugiperda*

Female FAW moths prefer 1 to 2 feet tall young corn plants to lay eggs, and young caterpillars can be found feeding on young maize leaves. In contrast, adult larvae enter the throat (whorl) and feed on the stem day and night. It was not previously recognized as a budworm due to its eating habits in the throat of a corn plant (S. exigua Hbn.). Fall armyworm larvae damage host plants by ingesting leaves, and only a single surface of the leaf in feed on by the first instar without affecting the inverted epidermal layer. The second or third instar, on the other hand, eats on both sides of the leaf, which causes it to open (Sisay *et al.*, 2018). Fall armyworm larvae usually begin to feed at the edges of the leaves and progress to the middle ribs. When the larvae eat the corn cobs, clear holes are formed. As FAW larvae feed on stuffed leaves, holes are made in the framed leaves as they grow, and large holes appear in three or four rows through the leaf. Due to their cannibalistic nature, when the larvae feed close to each other, fallow deer larvae almost always have one or two larvae on each plant. Feeding old larvae will result in extensive rot, after which only the ribs of the leaves and stems or the hard and prickly nature of the corn will often remain. Invasion of S. frugiperda maize causes further damage at the V10 stage, according to Rea *et al*. (2002). Fall armyworm larvae tunnel to plant growth points (buds, whorls, etc.) and destroy the plant's ability to grow. In maize, they also burrow through the ear and eat up the kernel, much like Helicoverpa zea (Sisay *et al.*, 2018). However, unlike the corn earworm, S. frugiperda tunnels via the cob husk structure. The damage caused on leaves by FAW and maize ear worm looks similar. In any case, a detailed inspection can conclude a particular species is accountable for the destruction, because FAW holes have smooth edges, while earworm holes edges are raged (Vickery, 1929; Sisay *et al*., 2018).

2.6 Economic impact of fall armyworms

The FAW outbreak is a major impediment because it is the primary cause of extensive damage to maize crops, which are the primary source of food for over 300 million African farmers (Day *et al*., 2017; Wossen et al., 2017). According to available estimates taken from 12 countries Africa, 4.1 to 17.7 million tons of maize is loosed as a result of FAW annually (Rwomushana et al., 2018). An estimated range of 22 to 67% loss in yield at field level have been reported in Ghana and Zambia (Day *et al*., 2017), The fall armyworm causes damage to over eighty different crops across sub Saharan Africa and the main staple crops like maize is most affected that feeds over three hundred (300) million individuals (Abrahams *et al.,* 2017;). There hasn't been much research into small-holder farmers' perspectives, the ideas and methods to use to take care of FAW. If appropriate, applicable, and massively manageable measures are not implemented, the pest's consequences will continue to cause widespread harm to maize, worsening the already precarious food security and residing situations of hundreds of thousands of smallholder farmers worldwide. In Ethiopia, FAW is a major threat to the food security of 9.6 million maize-producing smallholders. FAW has infested a quarter of the 2.9 million ha of maize-planted land, resulting in a loss of more than 134,000 tons of maize produce, according to current reports. Such losses could have fed approximately 1.1 million people. 1 In addition to cost savings, the United States of America has spent a significant amount of money on insecticides and monitoring. During the 2017 cropping season, for example, the United States of America spent approximately US$4.6 million on 277,000 liters of pesticides and surveillance equipment to trace and song pest infestations. Such emergency spending has the potential to stymie various development efforts by diverting resources away from more productive investments. Furthermore, in addition to yield losses and pest control costs, other FAW-induced monetary effects can include decreased earnings due to decreased maize sales; decreased meals consumption due to decreased food availability from both plants and livestock, as crop residues are a primary livestock feed supply in rural areas; increased medical treatment fees for people exposed to insecticides; and environmental harm due to insecticide contamination (Denberg and Jiggins, 2007; Midingoyi *et al*., 2018). Furthermore, other stakeholders in the agriculture sector forming the value chain namely; processors, aggregator's agro-inputs overall performance are equally affected as long as maize production is affected. FAW (Spodoptera frugiperda) is an insect pest that feeds on over 80 crop species, causing damage to commercially important cereal crops such as maize, rice, and sorghum, as well as legumes, vegetable crops, and cotton. The adult moth can travel over one hundred kilometers per night and is native to the Americas' tropical and subtropical regions. It lays its eggs on plants, from which the larvae hatch and begin to feed. Infestations can cause significant yield loss. Farmers in the Americas have managed the pest for many years, but at a high cost. FAO (2017).

In a new household surveys in Ghana and Zambia, 98% of farmers indicated FAW infestation in maize , and solely 2-4% stated harm to sorghum, millet or Napier grass,. Farmers in Ghana and Zambia pronounced a common maize loss of 26.6% and 35% respectively. This is a lot lesser than the figures in 2017. Yield reduction should be decrease owing to climatic factors, build-up of natural enemies, and or extended management practices. Farmers are better off in FAW management and are higher at estimating FAW damage. Deducing from these losses nationally offers an estimation of US$177m misplaced price of the every year maize crop in Ghana and

US$159m in Zambia. Greatest parts lands in Ghana and Zambia are very tons appropriate for FAW and so countries developing maize with less susceptible to the pest would possibly be in all likelihood suffer less damage. But the relationship between environmental suitability and harm has not been established. According to current estimates from 12 African countries, FAW causes an annual loss of 4.1 to 17.7 million tons of maize (Rwomushana *et al.,* 2018). Farm-level estimates from Ghana and Zambia indicate a yield loss of 22–67 percent (Day *et al.,* 2017), 47 percent in Kenya and 9.4 percent in Zimbabwe (Baudron *et al.,* 2019). If bold and potent management strategies are not implemented, the pest will continue to wreak havoc on maize and aggravate the already precarious food security and livelihood requirements of hundreds of thousands of smallholder farmers in many SSA countries. FAW poses a significant risk to Ethiopia's 9.6 million maize-producing smallholders. According to recent reviews. Such losses could have fed about 1.1 million individuals.1 In addition to yielding reductions, the united states has additionally incurred full-size bills on pesticides and monitoring costs. For instance, in the 2017 cropping season, the US spent about US$4.6 million to buy 277,000 liters of insecticides and tools for surveillance work to hint and track pest infestations. Such emergency funding can undermine various improvement efforts by diverting resources away from more productive investments. There are ripple and trickle effects such as decreased in income due to reduce quantities for sale by farmers, reduced residue as pasture for livestock in most rural areas, increased cost of production in the poultry industry due to cost of maize all as a result of loss in maize yields and cost of FAW control.

Fall Armyworm was discovered in many African countries in early 2016 (Durocher-Granger *et al*., 2021), marking its first appearance in the Eastern Hemisphere (Nagoshi *et al*., 2017). The Fall Armyworm's ability to disperse quickly throughout the hemisphere, rapacious feeding habits, and long-distance flight behaviors make it a serious danger and threat to maize production in particular in Africa (Nagoshi *et al.* 2017., 2018). According to the Centre for Agriculture and Bioscience International (CABI), for the 2017–2018 maize production season in some Sub-Saharan African countries, FAW threatened 13.5 million tons of maize, or more than 20% of total maize manufacturing for the region, valued at US$3 billion. Agriculture is one of Ghana's most important financial sectors, accounting for a sizable portion of the country's Gross Domestic Product (GDP) (ISSER, 2010) and employing approximately 44.7 percent of the country's human labor force aged 15 and up. Although fall armyworm was present in 2016, a significant outbreak of the pest was discovered at the start of the cropping season in 2017. The new pest caused widespread damage to maize crops, whose demand for higher yields rises year after year due to population growth Maize consumption has risen from 38.4 kg per capita in 1980 to 45 kg in 2015. (MoFA 2010, 2012, 2016, 2017) Between 2000 and 2009, maize used in the production of poultry feed by industry was estimated to have grown at a rate of 10% per year, with the potential to exceed 540,000 million tons (Hurelbrink and Boohene, 2011). This has become a major project for maize production, as well as a serious threat to the country's food security, and will have a direct financial impact. Training of some MOFA personnel by both the government and various stakeholders are among various strategies undertaken in order to mitigate the losses and maintain productivity and to ensure food security. The fall armyworm's migratory behavior, combined with its high dispersal capability, make the pest able to spread faster across a wide area of crop fields within a shortest possible time ran. Seasons dictates the life cycle of FAW in some geograpycal regions. Whereas the life cycle takes between 80 to 90 days during winter, about 60 days in spring and autumn, the life cycle is completed in about 30 during the season of summer (Tendeng *et al.*, 2019). The fall armyworm is considered the second most damaging agricultural pest, with annual losses ranging from $39 to $297 million (Sparks 1986). It is also suggested that FAW is the most detrimental and economically significant pest of maize fields in Brazil (Omoto *et al.*, 2016). The pest causes massive financial losses in Brazilian maize. In Brazil, the use of insecticides is now regarded as a significant component of the IPM employed by farmers, and insecticide abuse has resulted in the development of resistance by the FAW (Matova *et al.*,2020). Spodoptera frugiperda is a major pest of maize in Nicaragua, where infestation stages can reach 100%, resulting in a yield limit of 45 percent if left untreated (Pretty and Bharucha, 2015). 25 Maize is the most widely cultivated crop in Africa and a staple for roughly half of the continent's population. It is grown in a number of agro-ecological zones (AEZs) where more than 200 million people rely on the yield for food safety (Day *et al.*, 2017). According to the assessments, the achievable effect of FAW on continental maize production figures are in the range of 8.2 to 20.5 million tons in a year of the overall expected production of an average of 38 million tons within a year, and monitory losses between US$ 2,480 million and US$ 6,188 million per year of absolute predicted estimation of US$ 11,590 million each year for the major maize producing nations in Africa taken collectively, and excluding any appropriate manipulate gauges (CABI, 2017a ; Kebede, 2018). Centre for Agriculture and Biosciences International (CABI) division in charge of Sanitary and Phytosanitary (SPS) predicted that fall armyworm would cause $3 billion in damage to Africa's maize crop the following year if strong control measures were not put in place. Experts estimate that the FAW has cost Africa more than $13 billion, and they warn that the pest is here to stay (Banson *et al.*, 2019). According to agricultural experts from the USAID Bureau for Food Security, the continued presence of fall armyworm is major food security threat, farmer wages, and agricultural exchange across the continent (Kassegn, *et al.*,2021). The loss will be 13 billion US dollars across Africa, resulting in a 9% cap on the continent's GDP (Gakpo, 2017). On going assessments of maize yield losses ranging from 20 to 50 percent in Africa support severe financial consequences (Kassie *et al.*, 2020). FAW may also have an impact on accepted exchange. Trade poses the risk of introducing the pest to countries where it does not yet exist – shipment of food and agricultural products is a specific risk. As a result, countries in North Africa, Asia, and 26 Europe will prefer to deal with this threat by increasing production or imposing additional requirements and conditions on trade from FAW-infested countries, which will have a cost impact on exporters. The first shipment of FAW-polluted roses from Africa was intercepted in Europe in June 2017. (Day *et al*., 2017).

2.7 Fall armyworm response so far

In April 2017, the Plant Protection and Regulatory Services Directorate (PPRSD) collaborated with CABI and different partners to design a short, medium, and long-term layout for dealing with fall armyworm in the country. In all districts across the country, an education session for a large number of agricultural employees on how to notice the presence of FAW in a farm as early as possible, and how to control/manage the pest, has been completed. MoFA, in collaboration with the United States Agency for International Development (USAID), was able together acquire 1,000 knapsack sprayers for farmers in the five northern regions, as well as provide education on how to use them. On May 10, 2017, MoFA fashioned an outstanding team of sixteen individuals comprised of experts from MoFA, a range of Ministries, as well as creating companions and various stakeholders, to work collaboratively towards the abolition of the FAW. Since its inception, the group has done a range of tasks related to pest management, which includes the recognizable proof of numerous chemicals (biological and synthetic) in mild of their technique of undertaking that is appropriate for controlling the fall armyworm. The team was also tasked to education farmers on how to recognize the presence of FAW as early as practicable in order to manage the pest before it motives monetary harm. Other obligations are monitoring and surveillance, looking for resources and funds timely intervention in medium to long time, the implementation of FAW prevention and manage measures and the investigation of long-term measures to fight the pest via organic control. The Minister for Food and Agriculture introduced a memorandum to parliament in search of approval for the release of GHS 15,857,281.00 to entire quite a number workout routines such as preparing their body of workers for early detection, collaboration and coordination, sensitization, developing and printing of fact sheets, surveillance at the neighborhood and national levels, looking at manipulate and administration activities, and procuring a crucial grant of insecticides, among others. So far, the Ministry has received 72,774 litters of liquid pesticides and 4,320 milligrams of powdered pesticides for use in the affected areas (MoFA, 2017). Due to the fall armyworms' bizarre obliteration tendency, farmers must exert all efforts to ensure that their fields are now not destroyed through the FAW larvae. Among the many manage options, insecticide is one of the most broadly used; in the Americas, farmers use pesticides on their farms on each day groundwork when necessary. Another option is to plant early in the spring to keep away from a growing in FAW numbers as the season progresses. Moat farmers in South Africa usually use pheromone lures combined with Dichlorvos block traps to tarp and kill male armyworms in order to disrupt mating cycles. A collaborative effort is underway with a range of governments and communities to fight the pest assault through the USAID feed the future program. USAID, through the feed the future initiative, is main the US government's efforts to fight the fall armyworm with a 29-strong coalition of partners that includes the private sector, colleges, donors, lookup institutions, and national governments (Tamakloe, 2018). Among the quite a number measures adopted by way of MoFA to manage the pest are the distribution of pesticides to all district workplaces in the united states of America where farmers can reap them in the tournament of FAW invasions, as well as the corporation and education of 'Nnoboa' Spraying Teams in farming. Ghana has begun the search for natural enemies of the FAW, which will be reared and used as biological manage retailers against the FAW once identified, according to the Director of Plant Protection and Regulatory Services Dr Mrs. Felicia Ansah (GNA -16 / 04/2018)

Pesticide application is the most frequent method of control. Pesticides are used by using more farmers in Ghana than in Zambia, but fewer farmers used pesticides in 2018 than in 2017. Since 2017, the percentage of Zambian farmers the usage of usual techniques or not controlling FAW has increased. In Ghana, the proportion of farmers who use no manage approach has been cut in half. The elevated use of biopesticides in Ghana due to the fact that 2017 has been a giant change. This displays a country wide coverage that encourages and subsidizes their use. Bacillus was once the most generally used lively ingredient. There is huge settlement that Integrated Pest Management (IPM) is the fantastic way to manipulate FAW. Monitoring FAW affords information to useful resource decision-making.. Field scouting determines whether remedy is rewarding with the aid of scoring the proportion of plant life affected, however choice thresholds have yet to be determined in Africa. Pheromone traps are being used to display FAW, but the relationship between lure seize and population measurement is uncertain for the more than a few types of trap and pheromone being used. FAO has created an Android app (FAMEWS) for amassing records from area scouting and pheromone traps. Remote sensing, computerized entice counting, image evaluation of bugs and damage, and radar research will all improve monitoring and make a contribution to a higher understanding of FAW biology, as well as provide opportunities for forecasting. Pesticides are widely used via farmers and are exceedingly encouraged with the aid of governments. Many are fine when used correctly, however they are frequently used except sufficient protection precautions. Some farmers are the usage of pretty hazardous chemicals illegally. Reports of pesticide ineffectiveness are most likely the result of improper application. Farmers could also develop strategies and take measures on their own to mitigate the effects of FAW abundance. In developing research plan and in the design of extension delivery strategies to meet farmer's needs, it is important to tap into farmers own knowledge and understanding, their perceptions and management capabilities for managing pest (Khan and Damalas 2015). Knowledge on farmers' socioeconomic dynamics, farmer's viewpoint, and current management practices, as well as potential fall armyworm manipulation constraints are crucial and must be taken into consideration in fashioning a multifaceted approach in dealing with the FAW menace.

2.8 Management strategies for *S. frugiperda*

2.8.1 Monitoring and surveillance

Monitoring refers to an effort to successfully track the presence, population, and movement of a pest within a specific geology (Lavandero *et al*., 2004). Monitoring exercises can be composed and carried out on a variety of scales – most often by governments, through educated specialized personnel who systematically collect data to educate policymakers and professionals about the presence and severity of the pest over a given area. However, more localized measurements, such as records from farmers ready to scout their fields, can also be collected and integrated into larger, formal monitoring plans (Prasanna *et al*., 2018). Monitoring is also important in terms of Insect Resistance Management (IRM), which refers to the continuous, repeated evaluation of an insect pest's susceptibility to a specific poison (for example, a traditional pesticide or an insecticidal protein expressed in genetically engineered crops) (Andow, 2008). Surveillance refers to the unintentional, passive detection of pest problems as they emerge. To put it another way, this methodology does not successfully search for a specific pest; rather, it may also note when a problem occurs (Prasanna *et al*., 2018). Reconnaissance is typically carried out by farmers at the farm level and necessitates no special education or method (Feder *et al*., 2004). Surveillance's importance should no longer be underestimated. Farmers are frequently among the first to detect emerging issues, and when a mechanism is in place to collect and track surveillance reports as they emerge, the collective feedback of hundreds of farmers can provide invaluable information about the dynamics of pest infestation (Prasanna *et al*., 2018). The detection and assessment of a pest's population density is critical for the timing of management strategies (Trematerra, 2013). In research and integrated pest management, insect traps are useful tools for determining pest population densityTraps can help track attacks by novel pest species, the start of regular pest action, the range and strength of pest pervasions, and changes in pest populations, all of which aid in informed pest management decision making.

Fall armyworm monitoring should be possible with the use of dark mild and pheromone traps to catch the flying moths (Rojas *et al*., 2004). Pheromone traps are more productive than backlight traps; they should be suspended at the cover top at the whorl stage in plants like maize (Sisay *et al*., 2018). Trap catches can determine the presence or absence of a pest, but they are no longer reliable indicators of density. Local FAW monitoring is proposed to track the pest's presence, population, and movement within a predefined topography (Prasanna *et al*., 2018). This is normally led by trained specialized personnel across a country or district, but it can also be localized at the farmer level for both smallholder farmers and town-level dynamic farmers. In each case, monitoring is entirely based on pheromone traps placed near farms to capture adult male moths. The total number of FAW moths caught in snares is recorded and used to illuminate gorgeous endeavor (regularly announcing the information to gorgeous professionals to assist them in making management decisions) (Prasanna *et al*., 2018). Monitoring and surveillance are based on lure selection, trap placement and configuration, and lure checking (CABI, 2017b).

2.8.2 Field scouting and action thresholds

Monitoring, surveillance, and scouting are necessary workout routines for the successful implementation of compelling IPM programs (Ausher, 1997). Predicting when a pest invasion will occur and then surveying the extent and severity of an invasion allows for well-timed problem mitigation through the use of the least and most invulnerable interventions to correctly and economically guard against yield loss while protecting required organic machine advantages and limiting environmental harm. Scouting refers to a movement led by a skilled person – often a farmer – through science-based protocols, organized at the farmer subject school, and looking at their own farms for pests (Neder *et al*, 2006). Sc.outing enables farmers to evaluate pest stress and crop performance in the field with certainty (Prasanna *et al*., 2018). Scouting is done on a regular basis to assess both the damage that pest invasion will cause and the viability of management strategies within a farm, with the goal of bringing forth management choices at the individual farm level (Castle and Naranjo, 2009). Localized scouting records, in any case, can be accumulated and integrated into formal monitoring plans at large geographic scales. Practical advice on the best way to identify FAW and when to start controlling the pest promotes more focused and positive pesticide use (Glaser and Matten, 2003). Specification and skillful coordination's of the various control measures namely chemical, biological and cultural will benefit both the elite and smallhoder in the villages in many ways;

- Effective and efficient method of treatment application saves money.
- Protects FAW's natural enemies, which may also be harmed via insecticides
- Manages insecticide resistance, assisting in the long-term viability of present chemical control options.

Scouting is dependent on pest and crop agroecosystem knowledge, as properly as an perception of intervention triggers and mitigation tools (Way and Van Emden, 2000).

It is no longer easy to locate FAW in maize. Field scouting is a quintessential element of integrated pest management, and it is used to look at all elements of crop manufacturing in order to achieve most yield. free of cost For example, searching via a maize area of 50,000 flora at a price of 5 seconds per plant would value approximately 70 hours of labor. Conditional Action Thresholds based on plant improvement stage are added based totally on African and global specialist opinion. More formal Economic Thresholds will be developed by means of the lookup neighborhood over time (Prasanna *et al.,* 2018). There are two sorts of farmers regarded – smallholder farmers and village-level modern farmers – and separate Action Thresholds are hooked up for each of these two groups. Smallholder farmers and village-level revolutionary farmers scout their fields in similar ways. Because of the smallholder farmers, greater time can also be required to clarify Action Thresholds, sampling, and pesticide use (Settle *et al*., 2014). Furthermore, extra conservative alleviation strategies are suggested for smallholder farmers, as they frequently lack the practice and shielding hardware required to safely and efficaciously use a variety of pesticides (Reichenberger *et al.*, 2007). Ordinarily, pesticide spraying selections are primarily based on the determined Economic Threshold and Economic Injury Level. There are no archived Economic Thresholds primarily based on African country-level estimates, however

FAW has greater than a hundred years of journey in the Americas. In this case, in accordance to Expert Opinion, plant improvement stage-based provisional Action Thresholds is used (Prasanna *et al.*, 2018).

➢ Scouting procedures

When the maize improvement segment has been identified, pattern the area the usage of the splendid scouting protocols.

The goal of scouting is to become aware of insects as early as possible; the smaller the insect, the less difficult it is to control.

Scouting must start quickly after seedling development (VE; Early Whorl) in best conditions. Because FAW larvae assault seedlings in the first generation and complete their existence cycle in 30-40 days, fields are checked at the seedling and Early Whorl stages every week

Scouts should look for signs of FAW egg hatching and feeding by early-instar larvae instead of the small FAW larvae itself. Leaf damage, ear openings, and feeding frass are examples of such indicators.

Neonate (newly hatched) as well as first larvae are small, about 1 mm in length, and can be difficult to find. Farmers, on the other hand, with a little practice, can become very adept at detecting even the smallest pinhole indications of FAW feeding. When FAW larvae are large enough to recognize with anything other than a hand lens, they are difficult to manage (Prasanna *et al.*, 2018).

When a moth is identified, it is a good idea to look for eggs and larvae. Examine 20 plants in 5 areas or 10 plants in 10 areas to determine the proportion of infestation (Capinera, 2005). Van

Huis (1981) proposed that asset farmers rely on the number of damaged whorls in 20 consecutive vegetation at 5 randomly selected locations. Thus, Andrews (1988) proposed examining 20 flowers from 5 websites and using a maize infestation of 40% as a criterion in Honduras. When larval population sizes are low or larvae are still young, a large sample measurement is required to determine larval density in a field. In the field, inspecting is done on foot from four sides of the sampling zone, using a rectangular foot metallic quadrant to follow the diagonals of the sampling region. The threshold for using remedies is reached when larval densities per rectangular foot reach at least three. Thresholds are expressed as a percentage of plant life displaying typical FAW damage/injury signs, as shown in Table 1.

Table 1. Fall armyworm action threshold

Maize Crop Stage	V. Stage	Action Threshold for smallholder farmer	Action Threshold for village level progressive farmer
Early Whorl Stage	VE-V6	20% (10-30%)	20% (10-30%)
Late Whorl Stage	V7-VT	40% (30-50%)	40% (30-50%)
Tassel & Silk Stage	R1-R3	No spray unless low-toxicity and supportive of conservation biological control	20% (10-30%)

Source: Prasanna et al. (2018).

2.8.3 Cultural management

A key component of an FAW pest management strategy is cultural control. Fields with mono-cropped maize in highly susceptible for FAW to thrive. FAW can ideally be managed using both chemical and cultural methods (Bahiru Setegna personal conversation on June 18, 2017). Late plantings should be avoided because maize ears will be attacked more aggressively by a larger FAW outbreak than early plantings. Using a non-host crop like beans as an intercropped with rotating maize and rotating a non-host with maize is of the cultural means of reducing FAW attack (FAO, 2018). Many smallholder farmers in Africa no longer use pesticides to manage pests on maize; instead, they use cultural methods and techniques like maize intercropped that prevent or kill insect pests in their farms, manual picking and larvae killing, and the application bushes ashes in plant whorls (Abel *et al.*, 2000). According to a research carried out in both Kenya and Ethiopia, 14 and 39 percent of farmers, respectively, used cultural techniques (such as manual picking) to manage FAW (Kumela *et al*., 2018). The use of mechanical means by farmers in pest management saves up to 54% of their time (Fentahun, Personal Communication, 26 October 2017).

2.8.4 Biological management

Sustainable long term plant and environmental protection requires an important alternative management strategy, one such is biological management. The background knowledge of adaptations and the arrangements of the various biological manipulation Understanding the adaptation and grouping of biological manipulation outlets used within a given agricultural ecosystems is critical for organic control success. In agricultural systems, arthropod biocontrol and microbial pathogens sellers have already been used successfully (Pilkington, Messelink, van

Lenteren, and Le Mottee, 2010). Because they usually come in a form; as nematodes, bacteria, fungi, the cost of production in recent years have significantly decreased (Mahmoud, 2016). Even though organic manipulation is no longer a viable alternative to traditional pesticides, both the adult and larvae stages of FAW attacked by various pathogens, predators and parasitoids

Because of the FAW's migrant action, natural enemies' effectiveness is reduced. A variety of insects have been discovered to parasitize FAW caterpillars and eggs. Ashley (1979) isolated and identified 53 parasitoids derived from both the larvae and eggs of FAW. While 21of these parasitoids were from central and South America, 18 were found in North America, with the remaining 21 found were in Central and South America. Apanteles marginiventris, Eiphosoma vitticole, Rogus laphygmae, Ternelucha spp., and Ophion spp., were among parasitoids identified (imported) from the survey conducted by Ashley (1989) on the effect of one imported parasitoid and eight indigenous parasitoids on FAW in South Florida. Despite the fact that these species parasitized 63% of the first four larval instars, the researchers determined that this was not effective and could not be relied on because FAW was capable of reproducing in access to outnumber and undo the effect of the parasitoids. The most common parasitoid in Kenya was Archytas marmoratus, a tachinid fly that accounted for 12.5 percent of parasitism. Tanzania and Kenya recorded ranges of 4 to 8.3 and 6 to 12 percent parasitism rates respectively for Charops ater and Coccygidium luteum (Barzman *et al.* 2015).

Eleven districts in Ethiopia have recovered three parasitoids from the larvae of FAW (Siazemo, 2020): Palexorista zonata (Diptera: Tachinidae), Charops ater (Hymenoptera: Icheneumonidae), and Cotesia icipe (Hymenoptera: Braconidae). Parasitism by Charops ater a tachinid fly, Palexorista zonata recorded the lowest of (6.4 proportion) of parasitoids   and the highest and commonest was Cotesia icipe discovered parasitoids within the surveyed areas of Jimma and

Hawassa both in (Southwestern Ethiopia) and Awash Melkassa. Parasitism ranged from 33.8 to 45.3 percent in Awash Melkassa and Jimma. Parasitism by a tachinid fly, Palexorista zonata, and Charops ater, on the other hand, was once extremely low (6.4 proportion). Host adaptation of indegenous parasitoids to FAW and recruitment gave a strong indications that controlling pest by biological means was possible. A prolong suppressed population and mortality have been reported by some research works **on** invasive pest conditions in situations when an indigenous parasitoid shifted eventually to a new host. (Vercher *et al*., 2005).

Given the importance of maize in all regions, FAW has emerged as one of the continent's most serious food security threats. The yield losses associated with the use of FAW vary and depend on a variety of factors, but in Brazilian plantations, they can range from 19 to one hundred percent (Gharde *et al.,* 2018). Following a severe FAW outbreak in Africa, fall armyworm control has relied heavily on the use of synthetic chemical insecticides. However, using organic control as a long-term management method is an especially important administration option for controlling this pest. The success of any organic control is heavily reliant on factors such as incredible biological, ecological, and population research of the species involved. Natural enemies of FAW have been studied in the United States (Ashley 1986; Meagher *et al*. 2016), Mexico and Central America (Castro and Pitre 1989; Molina-Ochoa *et al*. 2003), and South America (Molina-Ochoa et al. 2003; Beserra *et al.,* 2002) . Although some species are found throughout the Western Hemisphere, the dispersal of the majority of species is generally described by the ability of their geographical areas (Ashley, 1979) Because FAW is new in Africa, it is unknown which native natural enemy species will be used as a host, despite the fact that some search for recognized parasitoids has been decided by some countries in East Africa (Sisay *et al*. 2018). The biological handling management strategies that include more than one species of natural enemies can be completely profitable (Riggin et al. 1993; Wyckhuys and O'Neil 2006, 2007).

A survey of registered biopesticides in 30 countries identified biopesticides suitable for FAW control in Africa. Eight lively components have indeed been prioritized, and subject testing for several of them is currently underway, including insect viruses, Bacillus thuringiensis (Bt), neem products, and pheromone-based mating disruption. Biological manipulation has both immediate and long-term benefits. Several indigenous natural enemies (predators and parasitoids) have been discovered, with parasitism rates reaching up to 70%. Conducting research on the conservation, encouragement, and enhancement of natural enemies is critical. Natural enemies are being researched in Latin America in preparation for possible introduction into Africa. FAW infestations can be reduced through a combination of agronomic and cultural practices. According to new research, intercropping maize with legume crops (beans, soybeans, and groundnuts) reduces damage. It has also been demonstrated that the use of associated flora (repellents and lure crops) can reduce FAW damage in Africa. Work is needed to ensure that companion flora is not invasive and that it can be obtained and grown at a low cost. Insect-resistant maize has been discovered, and 5 promising hybrids are expected to be available within the next two to three years. FAW can be controlled to some extent, according to preliminary results from genetically modified maize trials. Few African countries have legalized the use of genetically modified crops.. Farmers are experimenting with both standard and novel pest management methods, such as various repellent and insecticidal resources and plant extracts. There have been reviews of strategies for encouraging natural enemies. Some companies are testing these methods, which have the benefit of being low priced and regionally available (Hajek *et al.*, 2004).

Reports on yield losses due to FAW especially situation cereal crops, mainly maize, which is a key meals crop in the unique foci of the pest in Central and South America, the United States, and recently affected components of Africa. Researchers and farmers in the Americas have realized how to control FAW the use of a variety of chemical and other methods, and yield losses are usually minimal. However, yield losses are severe when FAW invades previously uninfected areas. Estimated maize yield losses in these conditions range between 25% and 50%, with some reviews as low as 12% and as excessive as 70% depending on the percentage of vegetation infested and the stage of crop development. Sugarcane yield losses have been pronounced to be in the 15% to 20% range. There is little information handy on yield losses in different cereals, and nearly none on non-cereal crops (Araus *et al*., 2008).

2.8.5 Botanical pesticides

Botanical pesticides are promoted as a safer alternative compared with the widely used synthetics which are toxic and include; organophosphorus and pyrethroids that also cause environmental disruptions, individual costs, resulting in development of pest resistance and resurgence situations (Arya and Tiwari, 2013). Botanicals have been used by many farmers in the developing countries for the management of insect pests for many years in a self-disciplined vegetation and saved merchandise due to its affordability, accessibility and above all environmentally friendly and safer tools to use (Schmutterer, 1985). Any insect pests have been managed with great success using extracts of plant life such as Jatropha curcas, Croton macrostachyus, Nicotina tabacum, Phytolacea docendra, Azadirachta indica, Chrysanthemum cinerariifollium and Milletia ferruginea, and (Schmutterer, 1985), (Silva *et al.* 2015) published excessive deaths among larvae population. In cutting-edge research, report of starvation in larvae population resulting in mortality in FAW and slow larvae growth due to the application of an ethanol extracts extracted from Argemone ochroleuca (Papaveraceae)

Even though many plant extractions have been confirmed of its insecticidal properties against FAW (Batista-Pereira *et al.,* 2006), not much have been done on the certification for commercial purposes. Azadirachtin (derived from neem) and pyrethrins and a neem product – azadirachtin, are the widely used plant base extracts across Latin America are the most commonly used products in Latin America (derived from pyrethrum). Some globally accepted registered plant base products includes; quassia, nicotine, rotenone, ryanodine and garlic. (Isman, 1997). These materials can be prepared in the dust formulation, mixed in water to get extract solutions and application is done just like in the case of chemical applications.

Azadirachtin, an extract product from neem comparatively have very low residual existence within the environment as it breaks down easily or isomerizes in sunlight due to its high photosensitivity. Additionally, neem base products have no accepted standardized way of preparation and as such lucks propriety. (Assefa, 2018). The protocols used for testing the efficacy of conservative insecticides in no longer reliable for extracts from neem because when one percent liquid solution of neem extract was used, FAW mortality recorded was low value in three days but after ten days it was high. Botanicals are plant secondary metabolites that provide an appealing and conducive substitute for pest management (Lydon and Duke, 1989). According to scientific literature, plant secondary metabolites are frequently involved in plant interactions with different species, most notably in the plant's defense response to pests. Thus, botanical secondary compounds are a significant source of chemical compounds with pesticidal activity (Lydon and Duke, 1989). Normally, this beneficial resource is no longer used to make pesticides. Botanical pesticides have many advantages, such as rapid degradation via sunlight and moisture or with the assistance of detoxifying enzymes, target specific nature, and low phytotoxicity, which encourages researchers to use botanicals in pest management. Secondary metabolites produced by larger flowers include, lignans, phenolics, alkaloids and their glycosides These metabolites play an important role in the plant defense system by providing a variety of structural proto-types for the development of lead molecules, which are typically used as new pest manipulators. (Lydon and Duke, 1989)

Information on a pest of which a specific plant is resilient can help predict which pests may also be managed using a secondary metabolite produced by a specific plant species. This method has aided in the discovery of many commercial pesticides, particularly pyrethroid insecticides. Botanicals include herbicides, nematicides, fungicides, insecticides, rodenticides. And molluscides. These pesticides function in a variety of ways. Some are toxicants or storylands, while others are antifeedants/repellants or behavior modifiers. Botanical pesticides have a more difficult discovery method than artificial pesticides, but the reduced environmental load caused by the resource of botanical pesticides makes them an attractive alternative. Despite relatively minor prior efforts in the enchantment of botanical pesticides, botanicals have had a massive influence on the insecticide challenge. Herbicides, nematicides, rodenticides, fungicides, and molluscicides have had varying degrees of success (Lydon and Duke, 1989).

2.8.6 Chemical control

FAW control is typically accomplished properly using the artificial pesticides (Blanco *et al.*, 2016,), however, this comes at a high cost, the tendency of contamination of the environment, pest developing resistance to chemicals as well as pests resurgence possibility (Crowe and Booty, 1995). In Ethiopia, the known wide range chemicals namely; the organophosphates, the pyrethroids and the carbamates are in use and currently there are no commercially certified FAW chemical elements. FAW is known to be of the nocturnal insect and are only active in the night, therefore spraying at certain period of the day, when the larvae are deeply hiding inside plants whorls will not be effective. (Day *et al*., 2017). There is the risk of crop destruction, human health issues, environmental degradation and chemical resistance development because of the improper use of chemicals instead of the use of threshold stages to determine the selection of chemicals and application rates. (Togola *et al.*, 2018).

Treatment of seed with Thiamethoxam was no longer effective in preventing FAW invasion (Assefa, 2018). Treating soya seed with chlorantraniliprole and cyantraniliprole has the tendency to reduce FAW preference for soya foliage according to Thrash *et a*l. (2013). There was a reduction in vegetative damage by FAW in laboratory tests using clothianidinand thiodicarb, and no reduction when chlorpyrifos, thiamethoxam and fipronil (Camillo *et al.*, 2005) and kerosene (Portillo *et al*., 1994) was used. There is the option of applying the pesticides directly to the soil during planting but this may not be effective as compared to the seed treatment. Van Huis (1981) came to this conclusion through research.

Application of trichlorfon sand mixtures, in a granular or powdery formulations directly into the plants whorls is not considered appropriate use of the smallhoder farmers resource in Ethiopia and Kenya (Kumela *et al*., 2019), whereas required pesticides quantities reduced by 20% without a change in effect and influence when mixtures of saw dust and chlorpyrifos was used (Kumela *et al.*, 2019; Kumela *et al*., 2019; van Huis 1981)

2.9 The Lemon basil

Lemon basil leaves are small to medium in size, averaging 5 centimeters in length, and have an elliptical to elongated, oval shape that taper to a wonderful point on the non-stem end. The leaves are green, flat, and smooth,, with veining and notched edges. The crisp, succulent leaves, which grow in pairs on both sides of the square, fuzzy stalks, have a sweet, citrus-forward aroma. Lemon basil has a distinct herbal, sweet, and tangy flavor with lemon and anise undertones. In late summer, the flowers also generate lemon-scented, small white flora that grow naturally on long, mild inexperienced bracts.

Lemon basil is boasted by way of the physique as a leafy plant with therapeutic (healthy) properties. This medicinal plant is a member of the mint family and is also acknowledged as Saint John's Worth. The plant occurs in many varieties, which frequently differ in properties such as taste, aroma and taste. These special houses manifest due to the critical oils it contains. The plant fragrance can be candy or fragrant. Lemon basil makes available nutrition in the form of vitamin A, vitamin D, vitamin K, calcium, iron and manganese. With these nutrients, you can add lemon basil to your meal as a sauce. Sometimes ample is enough to add to a meal just to provide vitamin K as the solely vitamin. Touching basil as a self-made recipe is surely the secret of proper food. It is recognized by many common names, such as lemon basil, hairy basil, Thai lemon basil or Laotian basil **(**Makri *et al*.,2008)

2.9.1 Economic importance of Lemon basil

Lemon basil is associated with the goddess Tulsi in some parts of Asia (Nazim *et al.*, 2009), is a common traditional medication in India (Beatovic *et al.*, 2015), and is used for each medicinal and non-secular orthodox Christian rituals. (Jelacic *et al*. 2011). Traditional uses of this plant embody flavoring marketers in the food industry, dental and oral products, and fragrances. (da Silva Gündel *et al*., 2018). It is widely grown in Iran and has been used as medicinal tincture as well vegetable Its seeds are used as a source of diet fiber in Asian drinks and cakes, as well as in standard pharmaceuticals (Hajmohammadi *et al.*, 2016). Coughs, headaches, worms, diarrhea, and skin infections are also treated with it (Labra *et al*., 2004). It is also an issue with Mediterranean diets, which are typically found in southern Europe, such as Italian and Greek cuisines (Kaefer and Milner, 2008). In traditional Chinese medicine, polysaccharides from lemon basil is been used for cancer treatment (Zhan *et al.*, 2020) and are now widely used in everyday life. It has also been used to treat belly aches, coughs, constipation, anxiety, arthropod stings, pyrexia, infections, and headaches. It can also manipulate and limit blood glucose, with anti-diabetic and anti-spasmodic properties; and (Mousavi *et al*., 2018) anti-oxidant anti-fungal, and anti-bacterial activities.

In diabetic rats, an ethanol extract of lemon basil leaves can lower blood glucose and advanced glycation give up products. Lemon basil leaves are used as an antispasmodic, carminative, and stomachic in ethnic medicine. Lemon basil leaves contain saponins, flavonoids, tannins and alkaloids, as essential oil compounds (Al-Maskari *et al* 2012). Lemon basil essential oil has anti-oxidant, anti-inflammatory, and antimicrobial properties (Al-Maskari *et al* 2012). Lemon basil leaves are stomachic, antipyretic, antispasmodic and diuretic. Low production costs, Hydrophilicity, appropriate film formation, biocompatibility, appropriate film formation, viscoelastic and edibility, properties are just a few of the benefits of basil seed mucilage. Lemon basil polysaccharides have anti-aging , anti-oxidant, and anti-tumor properties, as well as anti-bacterial, anti-atherosclerotic, and immunity-boosting properties, and they are extremely beneficial in the treatment of diabetes mellitus (Shahrajabian *et al*., 2020).

2.9.2 Phyto chemical properties of Lemon basil

It is well regarded that special basil cultivars have the genetic potential to produce one of a kind chemical compounds, ensuing in distinct chemical profiles (Avetisyan *et al*., 2017). Nonetheless, most research to date have focused specifically on the volatile compound profile, demonstrating the existence of a broad vary of chemotypes within the identical species of the Ocimum genus (Wesolowska and Jadczak, 2016). However, the chemical composition of the plants' extracts beyond volatiles, as properly as their bioactive properties, have received little interest for most *O. basilicum* cultivars and quite a few other *Ocimum* genus species. While many studies on O. *basilicum* have been conducted, solely a few references to the cultivar *O. basilicum 'Cinnamon'* or the herbal hybrid *Ocimum citriodorum Vis*, have been found. It is properly acknowledged that specific lemon basil cultivars have the genetic capacity to produce specific chemical compounds, resulting in distinct chemical profiles (Avetisyan *et al.*, 2017). Despite the interest in and vast use of both species, as in the past stated, there is still a scarcity of facts on the plants.

Lemon basil leaves are used in people medicine as a tonic and vermifuge, and a cup of hot basil tea can assist with nausea, flatulence, and dysentery. The plant's oil is beneficial for treating mental fatigue, colds, spasms, rhinitis, and as a first-aid remedy for wasp stings and snakebites (Ismail, 2006). *Ocimum* is a genus in the Lamiaceae (Labiatae) family that consists of at least 60 species and several varieties. It is a full-size supply of essential oil, which is used in food, perfumery, and cosmetics. Some *Ocimum spp*. are used in traditional medicinal drug for a range of purposes, specifically in many Asian and African countries. The routine polymorphism helps determine a giant range of subspecies, varieties, and types that produce integral oils with various chemical compositions; some have an excessive camphor content, whilst others have central, geraniol, methyl chavicol, eugenol, thymol, and so on (Khalid *et al*., 2006).

2.9.3 Insecticidal properties of lemon basil

Origin of the plant In assessment to chemical compounds, pesticides have been tested to be precise in action in opposition to target insects and are non-toxic to the ecosystem and man (Nathan *et al*., 2006). Plant phytochemical compounds have the potential to kill and repel bugs whilst also performing as deterrents to different insects; this is also envisioned as a next-generation alternative for mosquito manage and intervention applications (Chalannavar *et al*., 2013). Botanical extracts have been proven to have insecticidal pastime in opposition to a number of mosquito species, together with Aedes, Anopheles, and Culex, however their adulticide motion on the entire mosquito lifestyles cycle is nevertheless unknown (Chalannavar *et al*., 2013). *Ocimum spp*. (Tawatsin *et al*., 2001), Eucalyptus species (Collins *et al*.,1993), Vitex rotundifolia (Grayson, 2000), Curcuma sp. (Pitasawat *et al*., 2003), A large proportion of the world's human population, about 80%, depends heavily on vegetation for disorder control, each infectious and non-infectious (Nazarov *et al*., 2020). Because of their non-toxicity, specificity, and safety to the surroundings and ecosystem, plant extracts are gaining acceptance in presenting alternative majors in vector manage of ailments and arboviruses (Ormancey *et al*., 2000).

Lemon basil oil, extracted from the leaves and distinct components of the plant life via steam distillation, is used to flavor diets, oral and other dental confectionaries, and as a heady scent in regular rituals and tablets (Simon *et al*., 1990,). The oil contained in Lemon basil insecticidal repellant (Keita *et al*., 2001,), (Tawatsin *et al*. 2001), fungistatic (Reuveni et al. 1984), or antimicrobial substances (Chang *et al.*,2009). These residences are regularly attributed to quintessential oil components like methyl chavicol (estragole), methyl eugenol, linalool, camphor, and methyl cinnamate (Baritaux *et al.,* 1992).

Plant vital oils (EOs) have organic functions towards larger different crop insect pests and can perfumed as contact insecticides, fumigants, antifeedants, repulsive, and, or can have an impact on insect pest growth, reproduction, and behavior (Harwood *et al*., 1990; Isman 2000; Isman *et al.,* 2008). Furthermore, the toxicity of Eos inn mammals I lower comparatively and their fast break down within the atmosphere give the EOs attractive alternatives to the regular pesticides (Isman, 2000).

The imperative oils (EOs) of mint species (Mentha spp.) have adulticidal, larvicidal, make bigger and replica inhibitory, as well as makes repellent pastime closer to a range of saved product from vectors and pests (Rajendran and Sriranjini 2008 and Pitarokili *et al.,* 2011). Moreover they are extremely toxic to inexperienced house pests like Trialeurodes vaporariorum, Tetranychus urticae and relatively few aphid species (Kimbaris *et al.,* 2010). Lavender EOs have there are fertility inhibitory, fumigant poisonousness, properties contained inLavender EOs, and bean weevil, Acanthoscelides obtectus repelled and obstruction (Papachristos and Stamopoulos 2002a, b, 2004), they are not only toxic repellents but also restrict oviposition of T. urticae and Eutetranychus orientalis (Papachristos and Stamopoulos, 2004). (Refaat *et al*., 2002). Citrus fruit resistance to the Mediterranean fruit fly can be traced to the presence of EOs of citrus, (Papachristos *et al*., 2009). They also have fumigant and contact insecticidal material for the control of different pests in stored product, some pests vectors and other agricultural pests (Kimbaris *et al.,* 2010). EOs of lemon basil,. have been examined completely against a variety of insect and mite pests of flora and stored produce, exhibiting interaction and fumigant toxicity that impacts the improvement and conduct of insect pests (Refaat *et al.*, 2002 and Chang *et al.*, 2009).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

The research was carried out in ten communities the Tamale Metropolis and Tolon Distrct located in the northern Ghana of Guinea Savannah Agro-ecological Zone during the main cropping season of 2020. The Guinea savannah zone encompasses the Northern, Savanna and North east Regions, as well as parts of the Upper East and Upper West Regions, which are primarily Sudan savannah (MoFA-GTZ, 1992). This has bimodal seasonal patterns (wet and dry regimes). The wet season typically begins from April/May and ends in October/November, with the remainder of the year being dry. The rainfall amounts range from 100-200 mm/h, with a yearly mean of 900-1000 mm and a peak in September. (GMet). Both staple and commercial crops production is done in rainy season, the rainy season is therefore the most critical aspect of the weather in northern region. Generally temperatures are higher in the north than in the south. Throughout the harmattan period, extreme temperatures of (about 40°C) and the lowest temperatures of about (about 18°C) are the figures usually recorded in March and (December and January) respectively,(EPA, 2002).

The Guinea savannah zone is dominated by ground cover of grasses and shrubs of varying heights, the usual broad leaved deciduous trees which are fire resistant are scattered at the margins of the forest. Towards the Sudan savannah, this grade shifts into more open grassland with generally spread out short trees (Adu, 1986; Gyasi *et al.*, 2006). Ghana's savannah ecosystem is mostly rich in several species of plants and animals, and these are more important agriculturally and ecologically for the livelihood of the people. For the production of annual food crops and cash crops, the Guinea Savannah relies on a single rainy season.

3.2 Experimental procedure

The experiment was conducted in two folds; a social survey and an on-field experiment conducted to assess the control of fall armyworm using lemon basil.

3.3 Survey on use of pesticides and cropping patterns

In order to determine and establish some common cultural practices as well as the major crops and insect pests prevalence in the area, a questionnaire was designed and administered among one hundred farmers in the two areas.

3.3.1 Response of cropping patterns and pest control methods

The purpose of the survey was to get information on cropping pattern in the two areas as well as the common pest and control methods used. The idea was to find a more suitable way of pest management for the farmers having observed the way and manner the farmers handle the synthetic chemicals. The survey took place between 10th April and 25th may 2020' in nine community and one farmer organization involving 100 farmers

The farmers were randomly selected from the communities as follows; Kpalsogu; 10 responders, Lingbunga; 12 responders, Kpeindua; 8 responders. Tibogu; 6 responders and kpalgun; 8 responders representing Tolon District. Gukpegu-Tua; 13 responders, Nanton-Changnaayili; 10 responders, Pagazaa; 10 responders, Dakpemyili; 13 responders and Northern Farmers Association; 10 responders, in the Tamale Metropolis. A questionnaire was administered to ascertain the cropping pattern, the common pest and control measures and the chemicals used.

The questionnaire also sought to know the local materials used in the control of pest within the two Areas thus Tamale Metropolis and Tolon Districts.

Among some local materials usually used in the study area included neem, pepper, Ash and Lemon basil among others.

Based on the local materials mention, no much information on the lemon basil was known as compared to the others mentioned where several people have worked on neem, Ash, and pepper even though the material was available and common in all the communities across the two areas. However, curiously, the lemon basil which is a local herb common in the northern Ghana is traditionally medicinal and locally used in several ways for various purposes. Paramount among is the used of the herb during the preparation of a dead body for burial among Dagombas generally. Information from the traditional buriers is that the pungent smell of the herb takes care of the usual odour from the dead when use to wash the hands and clothing stained by the body of the decease. It is also believed to have some spiritual cleansing of the environment of the dead such that the stains and the secretions from the dead which is considered poisonous is neutralized by washing with the herb, according to MA Bili Naa a leader of the burier team in Yoggu in Tolon traditional area.

The herb is also known to be used for scorpion stinks locally and some literatures have also corroborated this assertion (Khair-ul-Bariyah *et al.*, 2012). The herb is commonly seen in the surroundings within homes and rarely seen in the farms. This herb is used mostly by traditional herbalist for treatment of most ailments. The lemon basil is locally available in the compounds of all the communities in the two districts where the study is targeted. Due to the availability and accessibility of the plant within the localities, the idea is to use it in order to determine its efficacy in the control of FAW which was identified as the dominant pest destroying the common crop – maize in the two areas.

3.4 On-field research

3.4.1 Experimental design

The experimental lay out was in a Randomized Complete Block Design (RCBD) with four replications of the treatments and a control. Each experimental plot measured 5 m × 5 m with an alley of 1.5 m and 3 m between plots and replications respectively. All the treatments were randomly assigned to the various experimental plots. The treatments are sun dried powder (SUDP), sun dried soaked (SUDS), shade dried powder (SHDP) and shade dried soaked (SHDS).

3.4.2 Land preparation and planting

The experimental field was ploughed and disc-harrowed to fine soil tilt using tractor. The land was then levelled and with the help of tape measure, a hoe, garden line pegs and a cutlass were used manually to prepare the various plots. All plots were labelled prior to sowing. A planting distance of 40 cm × 50 cm was used. The planting was three seeds in a hill and later thinned after germination to two plants per stand. Missing plants stands were replaced one week after planting. The planting distance and the rate targeted plant population since yield was not part of the parameters to measure the efficacy of the Lemon basil on the control of the Fall Armyworms, but rather available plant surface area for the attack of the FAW and the application of the Lemon Basil extract to the surface in order to determine effect of the extract on the plant surface area against the FAW attack.

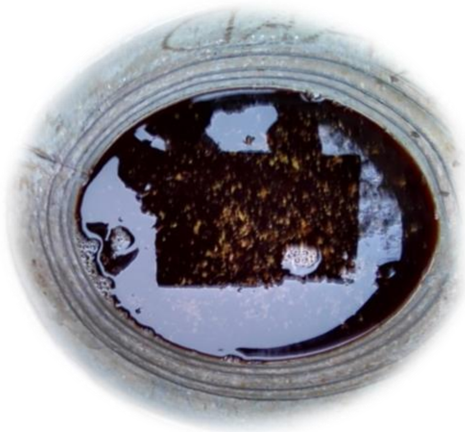
3.4.3 Crop husbandry

All cultural practices were employed as and when needed. Herbicides were applied a day after planting with both pre-emergence and post-emergence herbicides. The herbicides were applied at a rate of 300ml per 15L knapsack. Weeds were later controlled manually after seedlings emerged from the soil and at 14, 28, 42 and 56 days after emergence (DAE).

3.4.4 Preparation of botanicals

The selection of the botanical –lemon basil was based on the survey conducted on the types of local materials been used for the control of pests in the two areas and some literature available on the some of the common herbs used and efficacy of those herbs as well as the environmental impacts of the botanicals.

Collection of the lemon basil herb was done in six communities in the two Districts namely: Gbambaya, Nanton-Changnayili, and Gukpegu-Tua in the Tamale Metropolis; Kpalsugu, Tali TibogNaayili and Lingbung Gundaain in the Tolon District. The material parts used for the project included the leaves, seed and flower. The material- lemon basil was divided in two parts, one part was sun dried (SUD) and the other part shade dried (SHD) and obtain a constant weight. Each part, that is the (SUD AND SHD) was pounded to get a smooth material and each was subdivided into two equal parts to get four parts thus SUD becomes sun dried powder and sun dried soaked (SUDP AND SUDS) and SHD becomes shade dried powder and shade dried soaked (SHDP AND SHDS). Both the SUDP AND SHDP was further ground to get a fine smooth powder and further sieved through a clothing material. The powder solution and the soaked solution are shown in the plates 1 and 2 respectively below.



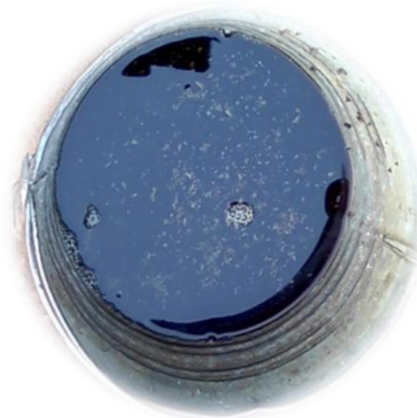


Plate 1: lemon basil powder solution **Plate 2: lemon basil soaked solution**

3.4.5 Application of treatments

The powdered ones were used directly by diluting the 250 grams of material into a 15 liter knapsack sprayer for the application on the maize whiles the soaked ones of same quantity of 250 grams were soaked for 24 hours, the content decant and sieved into the knapsack sprayer through the sieve of the knapsack sprayer.

The application was carried out in twelve rounds in duration of 8 days intervals in the evenings. The data was taken on every other day in the mornings giving only a day interval giving four days data in each round and application had done on the eighth day evening after data is taken in the morning.

Each of the treatments from the two main forms -the sun dried and the shade dried applications was based on the processed form that is either powdered or soaked. The powder was applied directly at a rate of 250 grams per 15 liter knapsack water. Same rate of the soaked was processed by soaking it in water for 24 hours, after which the soaked water is decanted and filter to get the solution for application.

3.5. Data collection

The data collected was basically about the attack of the armyworms on the plant leaves after the emergence of the maize using the parameters of its presence in the window panes, the presence of fall armyworms, and the presence of the frass, the chewed parts and perforations/holes on the leaves.

3.5.1 Scouting for signs and symptoms

Scouting was done after one week using Plant Protection and Regulatory Services Directorate – PPRSD quick sample method of X W Z. With this method, one of the letters -X was used by drawing this letter on the field with a rope and choosing four spots on the drawn letter and counting around each spot ten plant, with these, each of ten plants is checked to see whether the plants are affected and how many are affected.

3.5.2 Signs and symptoms before application

The data recorded after ten days of the emergence of the maize of the presence of signs and symptoms was only the window panes of an average of six and it was above the average standard of the PPRSD. In Ratings on damage caused by FAW on maize plant, leaf attack can be physically examined on 20 randomly selected plants from 4 or 5 different parts using the 'W, X, Z method (PPRSD, 2017) in the field on the following scale in Table below.

Table 2 : Indicating leaf damage rating scale

Explanation/definition of damage Rating	Rating
No visible leaf damage; 0	0
Only pin-hole damage 1	1
Pin-hole and small circular hole damage to leaves 2	2
Pinholes, small circular lesions and a few small elongated (rectangular shaped) lesions of up to 1.3 cm in length present on whorl and furl leaves.	3
Several small to mid-sized 1.3 to 2.5 cm in length elongated lesions present on a few whorl and furl leaves	4
Several large elongated lesions greater than 2.5 cm in length present on a few whorl and furl leaves and/or a few small- to midsized unit-form to irregular shaped holes (basement mem-brane consumed) eaten from the whorl and/or furl leaves.	5
Several large elongated lesions present on sever-al whorl and furl leaves and/or several large uniforms to irregular shaped holes eaten from furl and whorl leaves.	6
Many elongated lesions of all sizes present on several whorl and furl leaves plus several large uniform to irregular shaped holes eaten from the whorl and furl leaves.	7
Many elongated lesions of all sizes present on most whorl and furl leaves plus many mid- to large-sized uniform to irregular shaped holes eaten from the whorl and furl leaves.	8
Whorl and furl leaves almost totally destroyed	9

3.5.3 Signs and symptoms every other day

The signs and symptoms were taken every other day for 80 days period representing 40 daily records within the period. The signs and symptoms count records were not specific to each as narrated as Presence of the worm, Fras of the worm, chewed parts, perforations. The records were picked as composite of the mentioned parameters

3.6 Data analysis

For the social survey, statistical analysis was carried out using Statistical Package for Social Sciences (SPSS) version 23.0 (statistical software) and Microsoft Excel. Results were presented in tables and graphs (pie and bar charts).

Percentage and count data were transformed using log10 (x + 1) (Gomez and Gomez, 1984) and subjected to analysis of variance (ANOVA) using GenStat discovery edition 12.1 for the field experiment. All treatment means were compared using Least Significant Difference (LSD) at 5% level of significance.

3.7 Experimental site

Studies have shown that methods and procedures applications that emanate from the concerned group get better adoption compared with those that are arranged for them. Given this, in trying to look at pest control issues in northern Ghana, the study sought the concern of farmers on the issue for a comprehensive and more acceptable solution through a questionnaire in Tamale Metropolis and Talon Districts.

3.8 Sample size

A total of one hundred (100) farmers were randomly selected from the communities as follows; Kpalsogu; 10 responders, Lingbunga; 12 responders, Kpeindua; 8 responders. Tibogu; 6

responders and kpalgun; 8 responders representing Tolon District. Gukpegu-Tua; 13 responders, Nanton-Changnaayili; 10 responders, Pagazaa; 10 responders, Dakpemyili; 13 responders and Northern Farmers Association; 10 responders, in the Tamale Metropolis

The sample of 100 farmers in the communities above, were questioned on the parameters as main staple crop grown, common pest, control method, source of agricultural information and protocol observation in these areas, and their responses have been summarized as follows

1. The main staples grown in these areas were ranked according to the most cultivated
   - I. Maize
   - II. Groundnut
   - III. Rice
   - IV. Soya bean
   - V. Pepper
2. The main pest was ranked according to their economic importance as follows
   - i. Fall armyworm
   - ii. Maize streak
   - iii. Nematodes
   - iv. Larger grain borer
   - v. Termites/Aphids
3. On the damages caused by the pest, specifics were on the commodity bases
   - i. FAW destroys maize mainly
   - ii. Nematodes attack groundnut and vegetables
   - iii. Maize streak virus on maize
   - iv. Larger grain borer attacks maize and cowpea grain mainly

- v. Aphids are mainly on vegetables
- vi. Termite attacks maize both vegetative stage and at home and rice mainly at harvest in the field

4. The most common pest control methods in the areas were ranked as follows
   - i. Chemical
   - ii. Traditional – use of plant materials (neem extract, pepper, ash)
   - iii. Physical –scare scrolls, handpicking
5. Source of information on the use of chemicals were ranked as follows
   - i. MOFA AEA'S
   - ii. Radio
   - iii. Research institutions-SARI
   - iv. Other farmers
6. The method of chemical applications in the areas includes
   - i. Spray by the use of knapsack
   - ii. Broadcast – in the case of termite control
   - iii. Pour on/insert/sprinkle in the case grains.
7. Farmers' ways of handling and application chemicals in terms of rates and precautionary measures had a larger proportion of farmers use the irregular rates and do not use any form of personal protective.
8. Reasons for the choice of chemical control over the local/ traditional ways were stated as;
   - i. Faster in action on pest
   - ii. Cost-effective
   - iii. Easy to apply

9. On the adverse effects of chemical, the following observations were made
   i. Fear of future consequences of the chemical residue due to continuous use
   ii. Reduce shelve life of some commodities; notably Yam
   iii. Complaints of skin, eyes itching and headaches were common among users.
   iv. Instances of vomiting and collapsing after application were also mention
   v. Food poisoning due to the inappropriate use of chemicals.
10. When asked as to any other way to take care of the pest rather than the use of chemicals, there were no direct alternatives suggested as all attempts were either tilted toward chemical or an emphatic statement 'we cannot abandon the use of chemicals.

COMMUNITIES: Kpalsogu 14 responders, Gukpegu-Tua 19 responders, Nanton-Changnaayili 15responders, Pagazaa 12responders, Northern Farmers Association 10 responders in Tamale Metropolis and Lingbunga, Kpalsogu and Kpiendua in Tolon District.

The sample farmers in these two areas in northern Ghana were questioned on the crops and pest situation in these areas and their responses has been summarized by ranking using pairwise ranking base on the activity/item and using a scale of 1 to 5 where 1= first, 2-second, 3=third, 4= fourth, 5=fifth when applicable.

CHAPTER FOUR

4.0 RESULTS

4.1 Survey Results

4.1.1 Cropping systems in northern Ghana.

The results from the survey conducted indicated that majority of the farmers in the study area practiced continuous cropping system, whiles few still practice fallow system as shown in Figure 4 below.

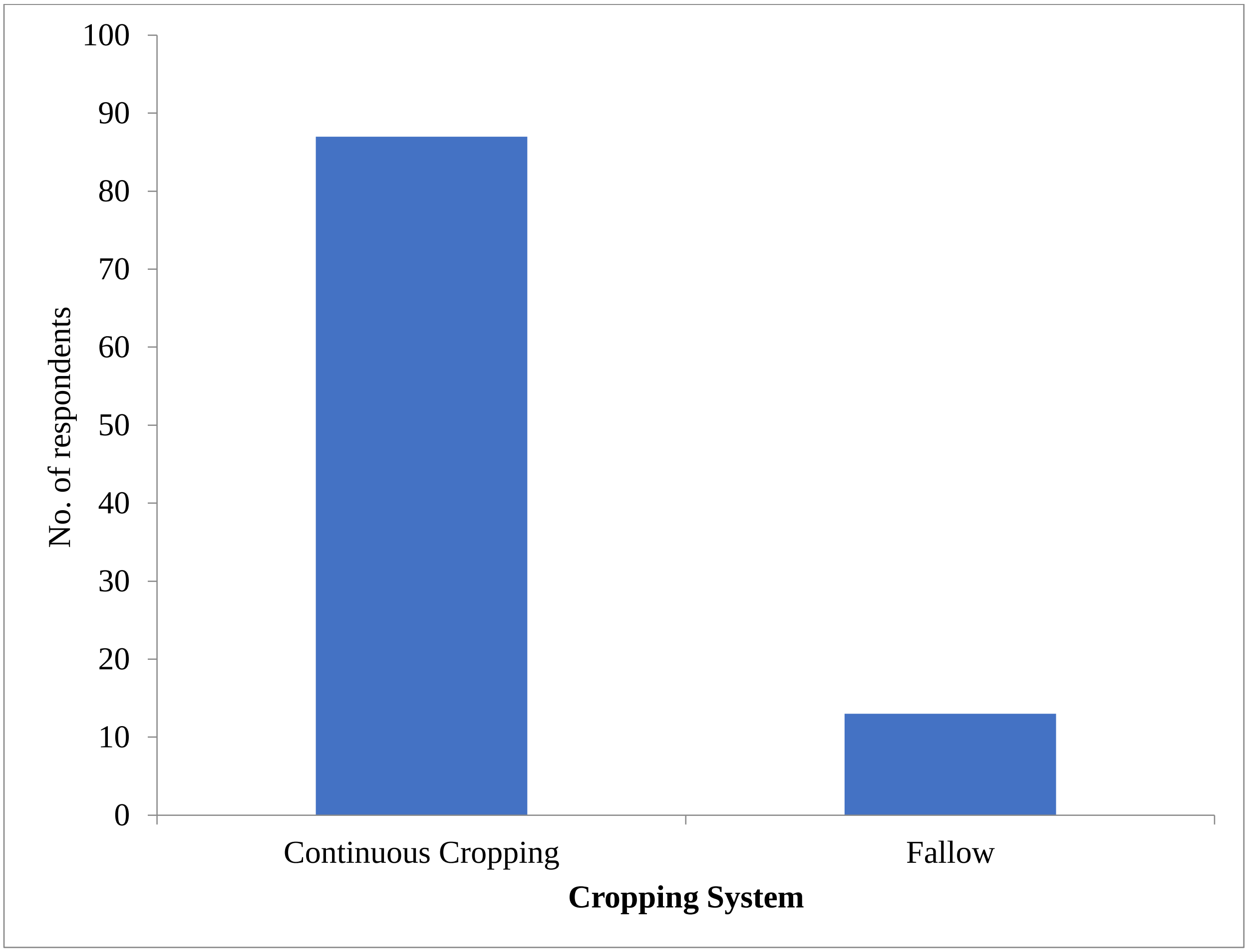


Figure 4: Cropping systems in Northern Ghana

4.1.2 Crop type cultivated

The response from the survey gave the crop type cultivated and the number of farmers engaged in the cultivation of each crop. The major crop –Maize, as indicated in Figure 5 below have a larger number of farmers engaged in its cultivation.

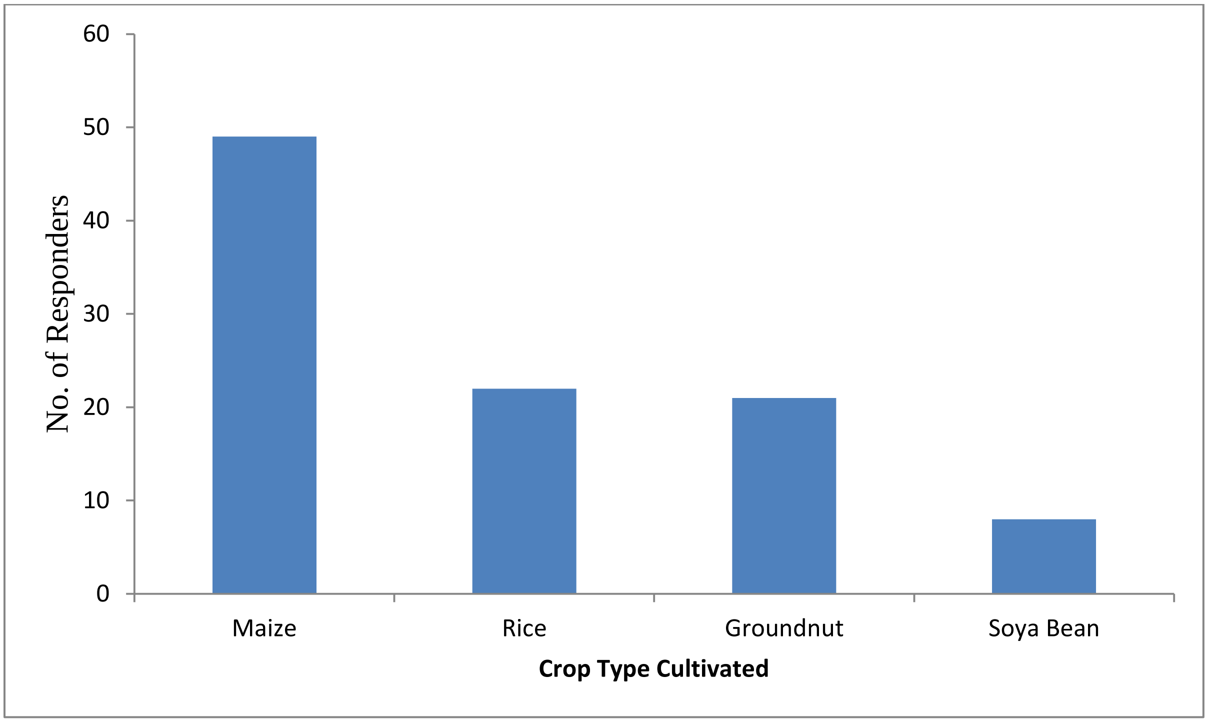


Figure 5: Crop type cultivated

4.1.3 Common pest identified

Common pest in the survey area put Fall Armyworms as the most common and damaging pest in the areas. It also indicated that maize which is a staple crop in the area is the preferred crop in the areas. The results also gave an indication that the pests followed the ranked crops. Fall Armyworm and Larger Grain Borer both damage maize, Nematodes on the other hand damage

Groundnut whiles soya bean is usually damaged by termites. Table 3 below indicates the ranked common insect pest in the area.

Table 3: Pest infestation pattern

PEST	RESPONDERS	RANK
FALL ARMYWORM	43	1st
LARGER GRAIN BORER	27	2nd
NEMATODES	19	3rd
TERMITES	11	4th

4.1.4 Pest control methods

Synthetic chemicals recorded the highest patronage among chemical methods practiced among farmers in the two areas with very few farmers using the other chemicals as shown in Figure 8 below.

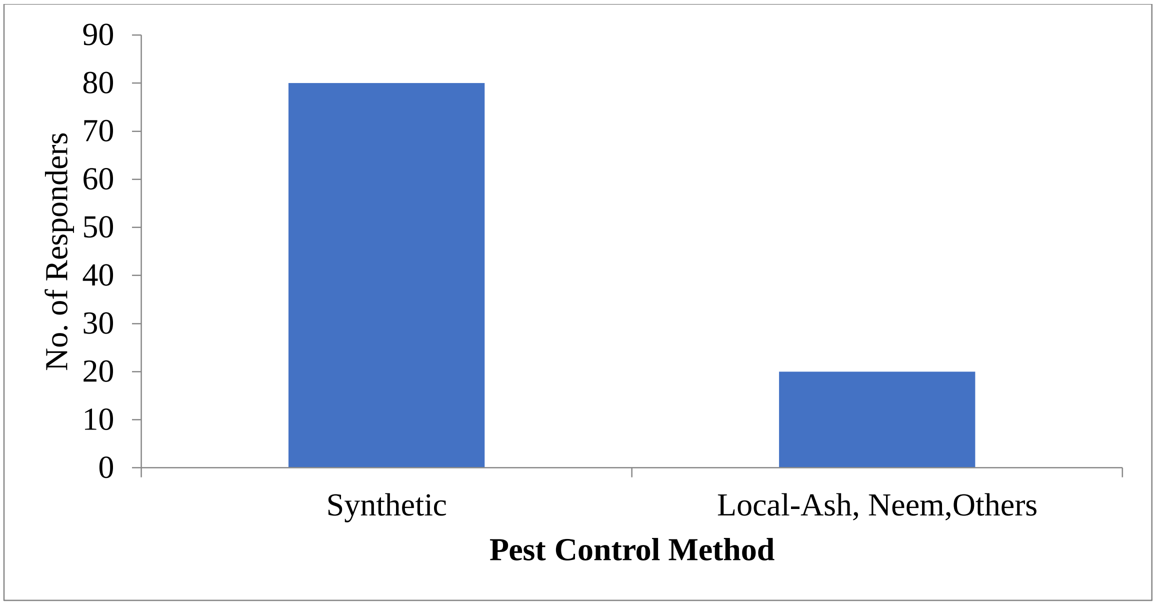


Figure 6: Pest control methods

4.1.5 Source of pest control information

Ministry of Food and Agriculture (MOFA) is the main source of information on chemicals and general agricultural matters in the areas. Radio stations followed closely to the MOFA. Source of information on insect pest for farmers in the two ranking is shown in figure 7 below.

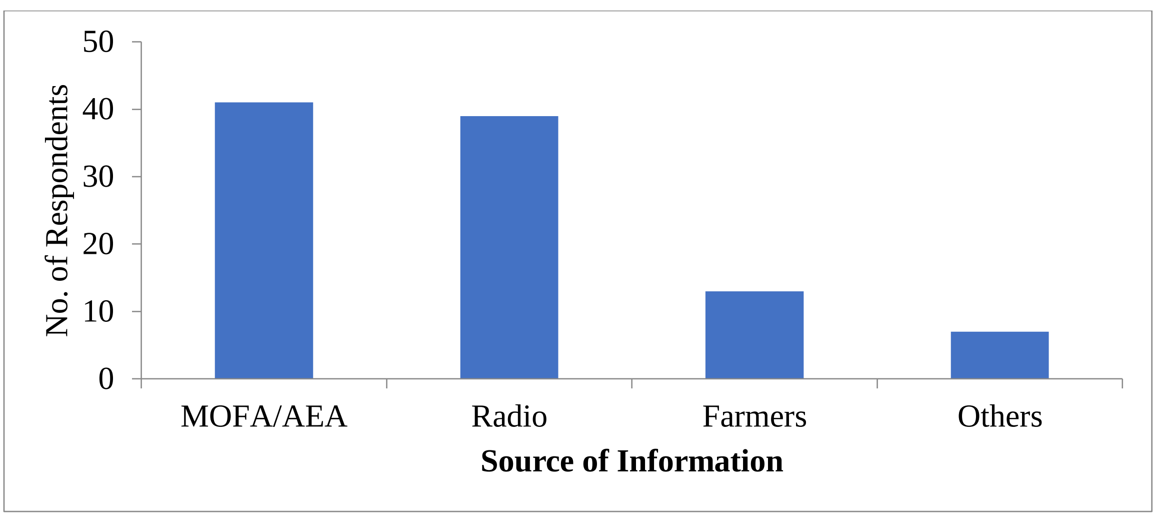


Figure 7: Source of pest control information

4.1.6 Ranked of Safety Protocol Observation

Majority of the farmers in these two areas do not adhere to any safety precautions in the use and handling of chemicals. Table 4 shows the ranked in safety protocols observation by farmers in the surveyed areas.

Table 4:. **Ranked of safety protocol observation**

SAFETY PROTOCOL	Responders	Rank
No protocols	69	1ST
Minimum protocols	21	2ND
Protocols Observed	10	3RD

4.2 Field Experiment Results

4.2.1 Effects of lemon basil on damage caused by FAW in maize

Lemon basil extracts significantly affected (P < 0-001) damage caused by FAW in maize (Figure 10). Shade dried soaked treated plots recorded the least significant damage which was significantly different from the damage recorded in control plots. Among insecticide treatments, SUDP recorded the highest FAW damage which was significantly different from damage recorded from the control plots. Among the insecticide formulations, the soaked extracts recorded lower damage which was significantly different form damage recorded in the powder formulation plot (Figure 8).

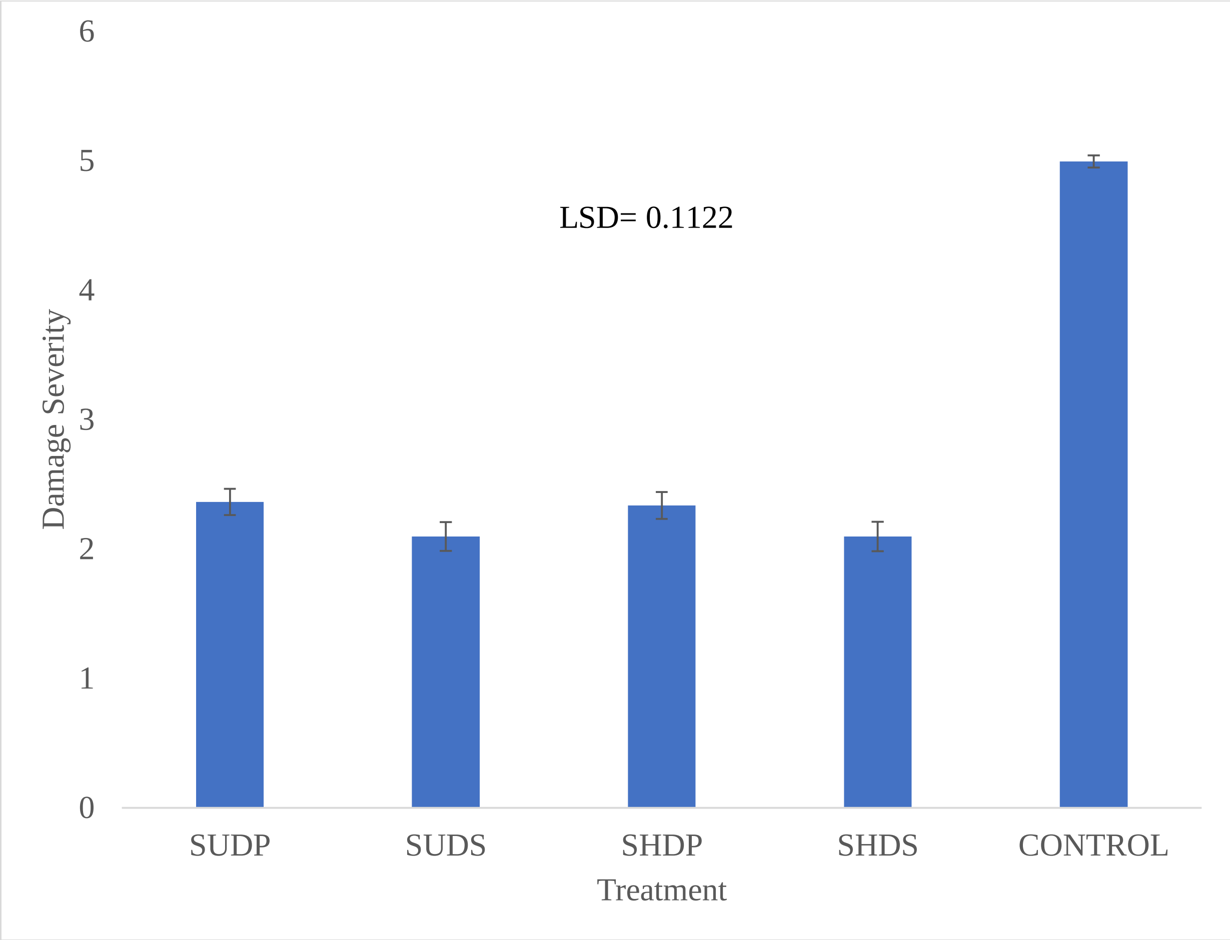


Figure 8: Damage severity in maize caused by FAW after insecticide application

During the first round of treatment application, damage caused by FAW in maize was significantly (P < 0.001) affected by the treatment applied. Among treatments applied, SUDP treated plots recorded the lowest FAW damage while control plots recorded the highest significant damage. Just as was observed in the first round of treatment application, damage in maize due to FAW infestation was significantly (P < 0.001) affected by treatments applied. However, SHDP treated plots recorded the lowest damage while control recorded the highest damage. Among the treatments, SUDP recorded the highest significant damage compared to rest of the treatments. Generally, across the various rounds of treatment application, damage in maize due to FAW infestation was significantly ($P < 0.001$) affected by treatments applied. The soaked extracts recorded the lowest mean damage while control recorded the highest significant damage throughout the experiment as shown in Figure 9 below.

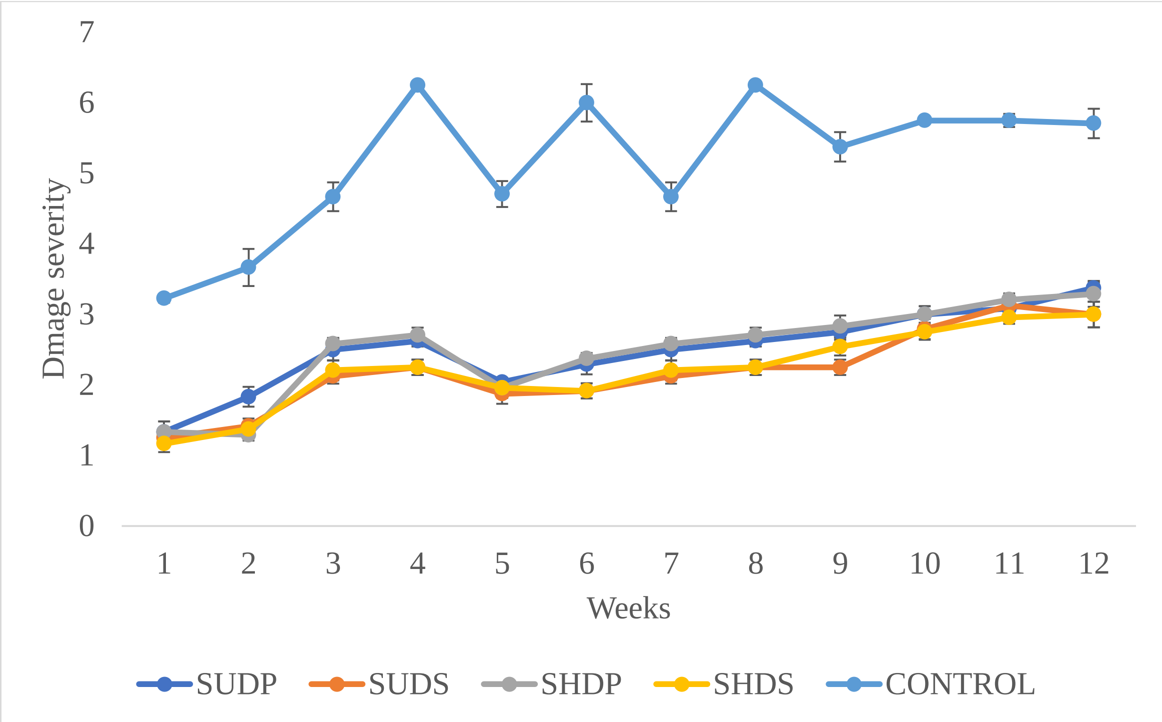


Figure 9: Damage severity in maize subjected to the various insecticide treatments across the various application dates

4.2.2 Effects of lemon basil on FAW abundance in maize

Lemon basil significantly affected (*P* < 0-001) abundance of FAW in maize under the various treatments (Figure 10). SHDS treated plots recorded the lowest significant number of FAW which was significantly different from the abundance recorded in control plots. Among insecticide treatments, SHDP recorded the highest number of FAW which was significantly different from number recorded from the control plots.

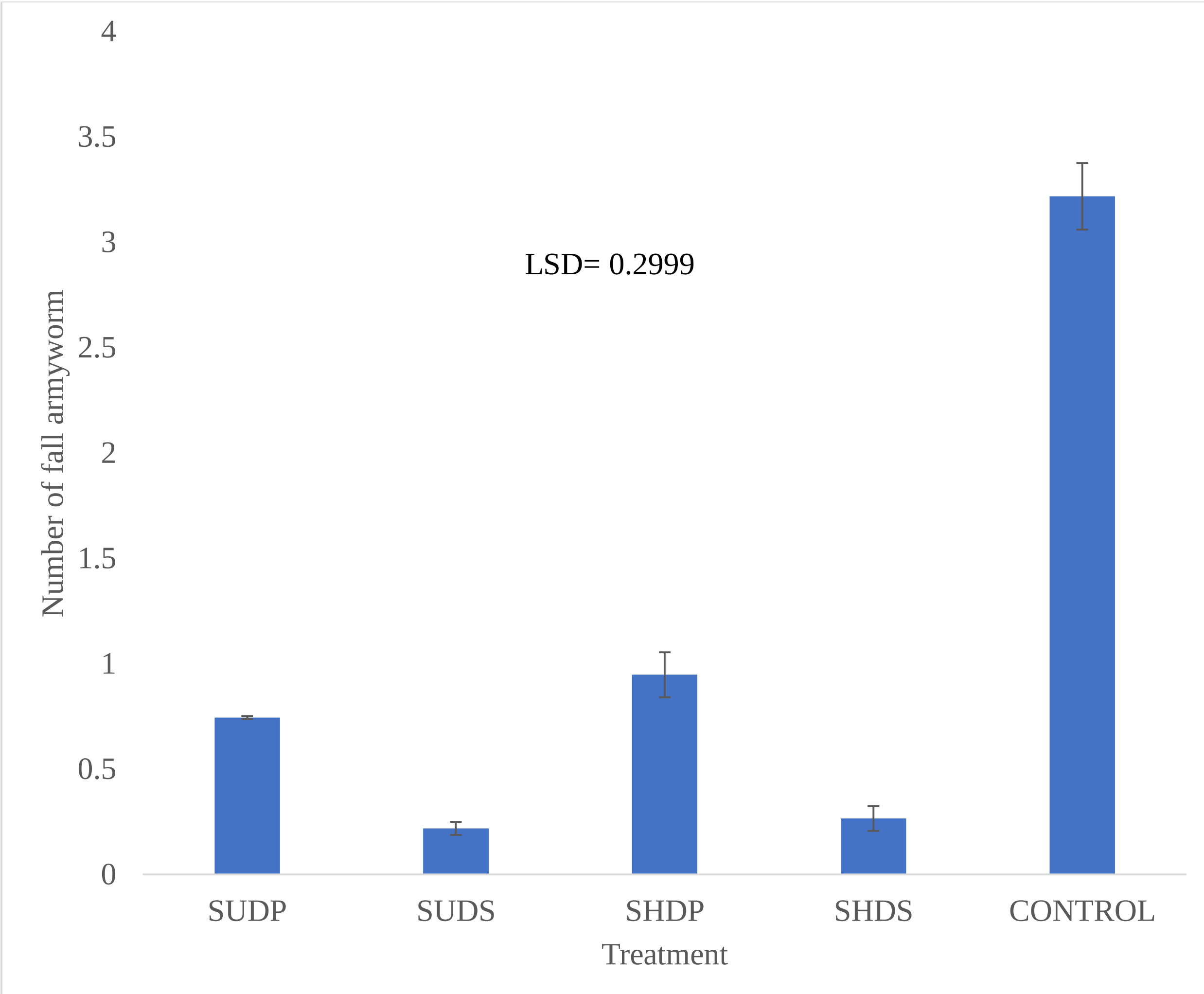


Figure 10: FAW abundance in insecticide treated plots

4.2.3 Lemon basil efficacy

The results indicates significant differences among the treatments for the number dead fall armyworm larvae collected on 4, 6 and 8 days after insecticide spraying (DAT) (Table 5). On the fourth day treatment application, the highest mean dead larvae was recorded in the SUDS treated plots which was not statistically different from mean number of dead larvae recorded in SHDS while 0.35% was recorded in the control plot. Similarly, percent mortality in the control plot was significant different from SHDP and SUDP treated plots. However, there was deference between SHDP and SUDP.

Similar observations were made in the sixth and eighth day, however, no dead larvae was recorded in the control plots in these days as shown in Table 5.

Table 5: Effects of lemon basil treatment on fall armyworm mortality

Insecticide treatment	Mean larval mortality (%) after expose		
	4 DAT	6 DAT	8 DAT
SHDS	6.913 (2.695)	4.85 (2.275)	2.425 (1.648)
SUDS	6.990 (2.643)	4.77 (2.248)	2.575 (1.675)
SHDP	2.368 (1.575)	1.55 (1.188)	0.322 (0.883)
SUDP	2.398 (1.558)	1.45 (1.250)	0.337 (0.903)
Control	0.350 (0.812)	0.00 (0.710)	0.00 (0.725)
LSD (0.05)	0.5188 (0.1659)	0.910 (0.2755)	0.2011 (0.0792)
CV (%)	8.9 (5.8)	23.4 (11.7)	11.5 (4.4)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Crop cultivating pattern in northern Ghana

From the survey conducted through a questionnaire on the cultivated crops, common pest's incidence, pest's management methods among others, revealed some pertinent issues and inherent ripples that called for comprehensive measures if we are to ensure food security among the small holder farmers. According to Akinola *et al*., 2007 and FAO, 2005, the crops cultivated and the farming systems practiced are generally influenced by the economic, physical and biological factors by either increasing or lowering productivity. In Modern agricultural development techniques, the trend has been more on intensive monoculture (Kentie *et al*, 2015)

Cereals, especially maize came out as the most cultivated crop is faced with serious challenges of land scarcity and tenure issues, soil fertility, poor crops husbandry practices. Many farmers still rely on the indigenous germplasm of seed notwithstanding the numerous improved seed in the seed industry. Maize is the most cultivated crop in Ghana and is the commonest source of daily household food consumed (Akinola *et al*.. 2007). Farmers are interested in culverted large acreages with little resources to meet the input demand in terms of fertilizer and even weed control. Whereas the recommended fertilizers rate for an acre from MOFA is two compound and one sulphate of ammonia, farmers use this quantity for on an average two and half (2.5) acres. This means that farmers generally used the one acre rate for one hectare.

Another disturbing phenomenon is the indiscriminate use and handling of chemicals for both pests and weed control among farmers in these areas. Majority of the farmers use these chemicals with total disregard or ignorant of the health and environment effects of these chemicals. Literature available corroborated most of the findings from the survey and with some perspectives. 'The agro-ecological system; Physical and biological characteristics, as well as socioeconomic issues, largely determine which crops and farming systems will yield the highest output or pose the least risk to the farmer and household (Gyasi, *et al.*, 1995, FAO 2005).

Smallholder farmers in Ghana commonly practice the following farming systems: continuous cropping and bush fallow (Gyasi, *et al.*, 1995). The two types of cropping systems used in these farming systems are polyculture and monoculture. The bush fallow system begins in the dry season, when the bush in the northern savannah is cleared, excluding the nitrogen fixing trees and some local economic important trees like shea nut trees which nuts are processed into shea-butter and Dawadawa tress (Gyasi, *et al.*, 1995). For about two to three years, staple crops are intercropped among commercial trees; after that, the land is temporarily abandoned to allow for the restoration of natural vegetation and soil fertility. Continuous cropping refers to a densely cultivated system with no fallow period, which can include polyculture or monoculture systems. In the northern savannah, a "compound system" is also known as a "continuous cropping system," owing to the system's location, which is frequently attached to a compound (group of homes) (Gyasi, *et al.*, 1995).

Intercropping and mixed crop planting are indigenous agricultural practices that have been used for a long time to control various pest and disease situations across board (Litsinger and Moody 1976 and Altieri, 2004). Crop arrangement patterns in controlling of pest and diseases includes; relay intercropping, mixed planting crops, strip intercropping and row intercropping. However, these methods are being limited due to the use of mechanization and herbicides by many farmers, including subsistence farmers, in the northern region of Ghana. The survey found mono-cropping to be the most used farming method in the survey area, owing to the use of chemicals for weed control by the majority of farmers in the area. Mono-cropping is another farming type most practiced in which farmers cultivate cash crops such as cotton, tobacco, cashews, or staple foods for market sale (Oppong-Anane 2006).

5.2. Effect of lemon basil on FAW abundance and damage in maize

Numerous plants with insecticidal properties have been identified, but only a few have been used in the world. Botanical insecticides are known to degrade quickly and have little or no effect on the farmer or consumer of farm produce. Plant-based insecticides have long been used to control FAW, but only a few have been commercialized. Despite the fact that only a few of these products are registered and used in Africa, azadirachtin (from neem) and pyrethrins (from pyrethrum) are the most commonly used. Basil oil; from *ocimum bacilicum*, *ocimum gratissimun* and *ocimum americamum* have been found to contain repellent properties against many insects (Odalo *et al.*, 2005). According to Rana and Blazquez 2015, camphor, methyl eugenol, methyl chavicol and linalool are oils from *ocimum bacilicum.* These oils are said to be insecticidal (Bowers and Nishida, 1980), anti bacterial (Moghaddam, *et al.*, 2011), antimicrobial (Elgayyar *et al*., 2001), are used in the preservation of food and form constituents of some pesticides of organic origin (Bowes, 2004)

The severity of lemon basil extracts' damage on the treated plots were not significantly different from one another; however, soaked extracts from both sundried and shade dried treated plots had significantly lower damages than the powder solution plots. The availability of many plant host, migratory ability, and the occurrence of multiple generations make control difficult. Pesticides are regarded as the first line of defence against pests and diseases.

Despite the fact that FAW consume both vegetative and reproductive maize (Abrahams *et al*., 2017), feeding on leaf tissue alone may not result in yield loss because the plants can tolerate such damage. The subsequent yield loss is determined by the stage of maize growth and the level of infestation (Abrahams *et al*., 2017). Because of the severity of the FAW attack and the resulting low profitability, many farmers have resorted to spraying insecticides (Harrison *et al* 2019). Methyl parathion, methamidophors, phoxim, chlorpyrifos, among other synthetic insecticides have been used to achieve good results in the control FAW in maize production in Mexico. According to van den Berg *et al (*2021), the number and timing of insecticide applications were critical in the control of FAW in many areas of Central and South America that had economic infestations of FAW. Keeping plants larvae-free during the vegetative stage can help to reduce the number of sprayings required during the silking stage (Smith, 2006), so spraying should be spaced evenly throughout the growing period.

Lemon basil (*Ocimum basilicum*), a local herb, is used by farmers as an indigenous pest control, particularly during storage. According to Tawatsin *et al*. 2001, the herb contains insecticidal materials that act as both a contact and repellent. Basil oil, extracted from the leaves and other parts of the plants through steam distillation, is used to flavour foods, dental and oral products, and as a fragrance in traditional rituals and medicines (Simon *et al*. 1990). Basil oil contains insecticidal (Keita *et al*. 2001), repellent (Tawatsin *et al.* 2018 and Paula *et al.* 2019), nematicidal, fungistatic (Reuveni *et al.* 1984), or antimicrobial constituents (Ling-Chang *et al.* 2009). These characteristics are frequently attributed to essential oil constituents such as methyl chavicol (estragole), methyl eugenol, linalool, camphor, and methyl cinnamate (Baritaux *et al*. 1992).

Cabbage is grown in all parts of the country in Benin (Assogba Komlan *et al*., 2012), but production is hampered by a variety of pests, the most common of which are Lepidopterans can reduce yields by 38 to 90 percent in the absence of pest management. Farmers improperly use synthetic insecticides to control insect damage, which negatively impacts human health and the environment (Ahouangninou *et al.*, 2012). Pest resistance (Agboyi *et al.*, 2016), elimination of natural enemies (Ahmad *et al.*, 2011), and pesticide residues in vegetables are just a few of the issues caused by synthetic pesticides. Crop associations- intercropping with some herb plants, such as lemon basil, are some of the potential alternatives that need to be considered. This has helped to reduce pest populations in many cases by driving pest away from the host and, in some cases, making it difficult to locate the actual host plants (Schader *et al*., 2005). Intercropping cabbage with other crops (Coriandrum sativum Linn., Calendula officinalis Promyk, Tagetes patula nana Kolombina Cleomae gynandra Linn., Lycopersicum esculentum Linn.) was previously thought to be the best way to reduce P. xylostella populations on cabbage (Ogol and Makatiani, 2007).

5.3 Species of Plant Extract for Pest Management

If FAW is not present in the importing country, the arrival of FAW in Africa poses a new threat to countries that import crops from affected African countries, including Asian and European countries (Abrahams *et al* 2017). FAW is one of the most difficult pests in Africa to deal with due to a number of factors including; its ability to migrate, a wide range of plant host and multiple generations. The continent main threat to food security now is FAW. To address the FAW threat to food security and protect the socioeconomic conditions of the smallholders, immediate and coordinated action is required, as well as massive information sharing and collaborations among stakeholders from the local to global levels is important.

The benefits and results products from plant base is always unpredictable even though the search for plant base products is on the move (Isman and Grieneisen, 2013). There are many known potential species of plants with pesticidal ingredients and their chemistry and efficacy known under laboratory conditions and can therefore be developed into usable product (Isman, 2017).

The results of the experiment on the use of locally extracted lemon basil (Ocimum basilicum) gave a clear positive indication of how the botanicals available could have helped for the management of pests situations among small holder farmers at the local level using local materials that were less expensive, had no or little health risk, and were environmentally friendly.

According to Isman (2017), it is important to conduct research to find out the practical issues within agro-ecological conditions given the increasing number of farmer using natural pesticides, specifically the knowledge on the performance of different plant base product when applied under different environmental conditions. Also, their impact on the target and the non-target, as well as their safeness and overall socioeconomic and agro-ecological benefits must be studied. Only field testing can provide proof of efficacy for many farmers to adopt the use of natural control products, especially given that natural compounds are frequently less effective when compared with the synthetic products (Casida, 1980). There are many advantages in using plant extracts in the control of pest such as lower cost, low persistence on the environment and prevention of insecticides resistance because it contain many bio active properties. Which is especially beneficial for low income farmers whose budgets is always limited (Angioni *et al*., 2005; Caboni *et al*., 2006; Isman, 2008). There are however challenges such as efficacy variability, low levels of toxicity and persistence on target insect pest which is due in the quick degradation of the active ingredients because of its photosensitive nature, and the ease with which such extracts wash away by rain water. However, drawbacks include variable efficacy, low toxicity, and low persistence against target pests, Stakeholders in the sector, mainly policy makers and consumers are calling for a reduction in application of synthetics in agricultural production, and rather promote other techniques such as agriculture performance and improvement strategies through ecological principles integration into management of farming systems and use of plant base product could be suitable for the vision (Grzywacz *et al.*, 2014; Pavela and Benelli, 2016)

The impact of crop protection strategies on ecosystem services is one crucial area to consider in controlling arthropods when secondary metabolites are to be used. The use of synthetic pesticides has a negative impact on arthropods regulation and pollination (Rundlöf *et al*., 2015; Potts *et al.,* 2016). A cost of 239 million US dollars within four states in America was the estimates for natural suppression of aphis in soybean (Fledier *et al.*, 2008), indicating that the benefits of natural pest regulation can be measured in both environmental and economic terms. A sustained and improved natural and or controlled ecosystem and land uses are required to preserve legume pollinators within the agro-ecosystem, (Le Cocq *et al*., 2017). (Lautenbach *et al.*, 2012). Pollinator decline is as a results of different factors; however, the increased in the synthetic pesticides use the main cause (Potts *et al.*, 2016), sustainable agriculture therefore need policies and program which ensure environmentally friendly approaches (Dicks *et al.*, 2016). Despite the fact that some studies have been done the potential effects of plant base pesticides on non-targets Although some research has been conducted on the impact of pesticidal plant use on non-target family Arthropoda (Mkenda *et al*., 2015), it is still an overlooked research area that requires more exploration as well as the short falls associated with the use of botanical products for pest control FAW's invasion has alarmed governments in a number of African countries, prompting individual countries to organize both human and material resources to take care of the affected farms first and foremost to prevent further spread and protect crop. Farmers are using various types of unregistered synthetic insecticides, according to recent studies conducted in Ethiopia and Kenya (Kumela *et al* 2018), possibly due to the pest destructive tendencies that requires a quick attention and strategy in tackling the situation. Locally available insecticidal plants were found to have varying degrees of efficacy against FAW larvae in the current study. High FAW larvae mortality is always assured when extracts of S. molle , P. dodecandra, and A. indica are applied (Silva *et al*. 2015), an A. indica seed cake extract caused high larval mortality in FAW. According to a recent study, extracts of ethanol from A. ochroleuca Sweet (Papaveraceae) is responsible for larvae mortality and restrict larvae growth of FAW as a result of starvation (Martinez *et al* 2017). Research on P. boldus Molina and Boldo shows that its toxicity contains high concentration of repellent properties and acts as inhibitory factor to pest feeding (Silva *et al*. 2015).

The research conducted affirms the possibility of using botanicals available within our environment by the smallholder farmer as part of their pest managements locally. There are many plants available in Africa with the potential for FAW control which the smallholders can use an alternative to synthetics The use of botanical products smallholder is common in many developing countries. Many different insecticidal plants and their potentials for plant based pesticides production in Africa was reviewed by Stevenson (Stevenson *et al* 2017)

The use of botanicals in FAW control can be embraced under the concept of Integrated Pest Management (IPM), so that the relatively low efficacy levels of these botanicals, when combined with other control measures, can result in more effective FAW management results, resulting in higher maize yields (Siazemo, 2020) that can be implemented under smallholder farmer conditions. Furthermore, this alternative can help to avoid overuse or misuse, which can lead to environmental backlash such as resistance (Barzman, *et al.* 2015).

CHAPTER SIX

6.0 CONCLUSION AND REMMENDATIONS

6.1 Conclusions

- The results of the survey indicates that mono-cropping has become the major cropping method among the farmers in the two districts
- Cereals especially maize is the leading crop among the major staples and cash crops cultivated mostly in the areas
- FAW was the major destructive pest and is threatening food security in the area
- Majority of the farmers in the area rely on synthetic chemicals for the control of most pest and disease situations
- Among local material use for pest management included neem, ash, pepper and lemon basil
- The results from the field experiment on the use of lemon basil extract for the control of FAW proved positive
- The result shows no significant difference between the sun dried material and the shade dried material
- In both experiments, damage severity in maize due to FAW infestation were significantly affected by both insecticide treatments of the lemon basil
- It however indicates that the soaked solution had more effect on the FAW than the Powder solution

6.2 Recommendations

Based on the scope of the present study (the survey and the field experiment) and the key findings obtained, the following recommendations were made:

- In designing agricultural extension service delivery, emphasis should be placed on good agronomic practice in relation to cropping calendar, improved seeds, optimum inputs rates and timely applications of cultural practices.
- That further studies on the efficacy of the lemon basil conducted with the emphasis on the rates in order to ascertains the rate that can more effective manage the issue of FAW among farmers at the local level. This will help reduce the cost of pest management and risk associated with the use of synthetic chemicals.
- Multinationals in the chemical industry should consider the extraction of lemon oil from the basil in commercial quantities for the purpose of insecticides production. This will help to eliminate the issue of environmental pollution and the health implications associated with use synthetic chemical.

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APPENDICES

Appendix 1: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 1.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.60556	0.20185	9.48	
Treatment	4	13.68889	3.42222	160.70	<0.001
Residual	12	0.25556	0.02130		
Total	19	14.55000			

Appendix 2: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 2.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.31667	0.10556	3.48	
Treatment	4	16.01389	4.00347	132.02	<0.001
Residual	12	0.36389	0.03032		
Total	19	16.69444			

Appendix 3: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 3.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.5500	0.1833	1.75	
Treatment	4	31.9667	7.9917	76.38	<0.001
Residual	12	1.2556	0.1046		
Total	19	33.7722			

Appendix 4: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 4.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.393056	0.131019	13.80	
Treatment	4	17.186111	4.296528	452.71	<0.001
Residual	12	0.113889	0.009491		
Total	19	17.693056			

Appendix 5: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 5.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.18194	0.06065	0.79	
Treatment	4	24.25556	6.06389	78.90	<0.001
Residual	12	0.92222	0.07685		
Total	19	25.35972			

Appendix 6: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 6.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.61111	0.20370	2.98	
Treatment	4	48.75833	12.18958	178.51	<0.001
Residual	12	0.81944	0.06829		
Total	19	50.18889			

Appendix 7: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 7.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.80556	0.26852	7.48	
Treatment	4	17.70278	4.42569	123.35	<0.001
Residual	12	0.43056	0.03588		
Total	19	19.93889			

Appendix 8: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 8.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.32778	0.10926	7.04	
Treatment	4	46.71389	11.67847	753.00	<0.001
Residual	12	0.18611	0.01551		
Total	19	47.22778			

Appendix 9: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 9.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.96111	0.32037	12.70	
Treatment	4	25.56389	6.39097	253.29	<0.001
Residual	12	0.30278	0.02523		
Total	19	26.82778			

Appendix 10: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 10.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.55972	0.18657	12.21	
Treatment	4	26.47222	6.61806	433.18	<0.001
Residual	12	0.18333	0.01528		
Total	19	27.21528			

Appendix 11: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 11.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.637500	0.212500	70.62	
Treatment	4	22.708333	5.677083	1886.54	<0.001
Residual	12	0.036111	0.003009		
Total	19	23.381944			

Appendix 12: ANOVA for damage severity in maize subjected to the various insecticide treatments at week 12.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	1.43750	0.47917	16.56	
Treatment	4	21.13056	5.28264	182.57	<0.001
Residual	12	0.34722	0.02894		
Total	19	22.91528			

Appendix 13: ANOVA for mean damage severity in maize subjected to the various insecticide treatments across the various weeks.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.519010	0.173003	32.64	
Treatment	4	24.857388	6.214347	1172.53	<0.001
Residual	12	0.063600	0.005300		
Total	19	25.439998			

Appendix 14: ANOVA for mean number of FAW recorded in maize subjected to the various insecticide treatments across the sampling weeks.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.03652	0.01217	0.32	
Treatment	4	24.42222	6.10556	161.14	<0.001
Residual	12	0.45469	0.03789		
Total	19	24.91343			

Appendix 15: ANOVA for percent FAW larva mortality recorded in maize subjected to the various insecticide treatments at four days after treatment application.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.1249	0.0416	0.37	
Treatment	4	143.1410	35.7853	315.57	<0.001
Residual	12	1.3608	0.1134		
Total	19	144.6267			

Appendix 16: ANOVA for percent FAW larva mortality recorded in maize subjected to the various insecticide treatments at six days after treatment application.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.3125	0.1042	0.30	
Treatment	4	75.8000	18.9500	54.27	<0.001
Residual	12	4.1900	0.3492		
Total	19	80.3025			

Appendix 17: ANOVA for percent FAW larva mortality recorded in maize subjected to the various insecticide treatments at eight days after treatment application.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.03556	0.01185	0.70	
Treatment	4	25.28817	6.32204	371.18	<0.001
Residual	12	0.20439	0.01703		
Total	19	25.52812			