EFFECT OF NEEM AND GARLIC EXTRACT ON FALL ARMYWORM (*Spodoptera frugiperda*) INFESTATION ON MAIZE (*Zea mays*)

BY

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BENIN CITY

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF CROP SCIENCE, FACULTY OF AGRICULTURE, UNIVERSITY OF BENIN, BENIN CITY. IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF AGRICULTURE (B. Agric) DEGREE (CROP SCIENCE).

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CERTIFICATION

This is to certify that this project titled " **EFFECT OF NEEM AND GARLIC EXTRACT ON FALL ARMYWORM (*Spodoptera frugiperda*) INFESTATION ON MAIZE (*Zea mays*)**" was carried out by **ERIBO NOSA RICHARD** with matriculation number **AGR2004339** of the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City.

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DR. (MRS.) M.E OMOREGIE **DATE**
Project Supervisor

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PROF. S.U. EWANSIHA **DATE**
Head of Department

DEDICATION

This report is dedicated to God almighty who through his unending love, grace and mercy for me made completion of this project a reality.

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To God almighty I give all the Glory and Acknowledgement for seeing me through with all the resources I need and want.

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ABSTRACT

This study evaluated the effect of aqueous neem (*Azadirachta indica*) and garlic (*Allium sativum*) extracts on Fall Armyworm (*Spodoptera frugiperda*) infestation in maize (*Zea mays*) at the Teaching and Research Farm, Department of Crop Science, University of Benin. The experiment was conducted using a Randomized Complete Block Design (RCBD) comprising four treatments: neem extract, garlic extract, neem + garlic extract, and a control, each replicated three times. Data were collected weekly on infestation incidence, larval abundance, and damage severity using the Davis and Williams (1992) visual rating scale. Results showed no significant differences ($p > 0.05$) among treatments across all sampling periods. However, slight numerical reductions in infestation and damage were observed in the neem and garlic treatments compared to the control. The limited effectiveness recorded may be attributed to environmental factors such as rainfall, temperature, and sunlight, which reduced the persistence of the extracts, as well as the use of aqueous formulations that typically degrade quickly under field conditions. The combination of neem and garlic did not produce any synergistic effect. The study concludes that although neem and garlic extracts offer mild suppressive activity against Fall Armyworm, they are insufficient as stand-alone control options under field conditions. Their use is therefore recommended as part of an integrated pest management (IPM) strategy alongside cultural and biological control methods for more effective and sustainable Fall Armyworm management in maize production.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Maize (*Zea mays* L.) belongs to the family Poaceae (*Gramineae*), which is commonly referred to as the grass family. It is one of the world's most important cereal crops and a major staple food for millions of people, especially in sub-Saharan Africa. It is a versatile crop that serves multiple purposes: it is consumed directly by humans, used as animal feed, and employed as a raw material in various industries such as biofuel, paper, starch, and brewing (Ranum *et al.,* 2014). Originating from southern Mexico over 9,000 years ago, maize has evolved into a globally cultivated crop due to its high yield potential, adaptability to diverse environmental conditions, and short maturation cycle. In Nigeria, maize is a dominant cereal crop grown in all agro-ecological zones. It plays a significant role in household food security and rural livelihoods. According to the Food and Agriculture Organization (FAO, 2021), Nigeria is the largest maize producer in Africa, yet the country still faces deficits in meeting domestic demand due to several constraints. Among the leading challenges to maize production are pest and disease outbreaks, particularly the infestation by the Fall Armyworm.

The production of maize is highly susceptible to numerous pests, including stem borers, cutworms, aphids, and, most recently, the Fall Armyworm (*Spodoptera frugiperda*). These pests pose a serious threat to maize productivity. Infestations can begin as early as the seedling stage and persist through to maturity, resulting in significant yield losses. The Fall Armyworm (FAW), *Spodoptera frugiperda*, is an insect pest of global concern that belongs to the family Noctuidae, Order Lepidoptera. Members of this family are typically nocturnal, medium-sized moths with robust bodies and dull forewings that provide camouflage, while the hindwings are usually lighter in color. They are pest native to the Americas. It was first detected in West Africa in 2016 and has since spread rapidly across the continent, causing widespread damage to maize fields. The pest is highly polyphagous, meaning it feeds on a wide variety of crops, although maize remains its preferred host. The larvae are the most destructive stage, feeding on leaves, stems, and reproductive parts of the plant. Their feeding results in ragged leaves, windowpane damage, and eventual stunting or death of the maize plant (Bolu *et al.,* 2020). One of the characteristics that makes FAW particularly challenging to manage is its high fecundity, short life cycle, and resistance to many conventional pesticides. Furthermore, its ability to migrate long distances and infest new areas has compounded the difficulties of regional control efforts (Harrison *et al., 2019*). As a result, its impact on food security and economic stability in maize-producing regions cannot be overemphasized.

Managing the Fall Armyworm has proven to be difficult due to its rapid spread, adaptability, and resistance to chemical insecticides. Chemical insecticides are widely used due to their immediate effect. Products containing lambda-cyhalothrin, chlorpyrifos, and emamectin benzoate are commonly applied. However, misuse and overreliance on these chemicals have led to resistance development in FAW populations, as well as environmental and health concerns (Sisay *et al., 2019*). Despite their effectiveness, chemical insecticides pose numerous challenges. Continuous application often leads to pesticide resistance, killing of non-target organisms, residue accumulation in food, and water pollution (Isman*, 2006*). These issues have generated interest in more sustainable and eco-friendly pest control methods. Botanical insecticides, derived from plants with pesticidal properties, have gained attention as viable alternatives. These biopesticides are generally biodegradable, pose minimal risks to human and environmental health, and are often accessible to smallholder farmers. Examples of such botanicals include neem (*Azadirachta indica*), garlic (*Allium sativum*), pyrethrum (*Chrysanthemum cinerariifolium*), rotenone (derived from *Derris* spp.), and essential oils such as eucalyptus (*Eucalyptus globulus*) and lemongrass (*Cymbopogon citratus*) extracts, all of which have been reported to possess insecticidal, repellent, or antifeedant properties against various crop pests.

1.2 Justification of the Study

There is urgent need for effective, affordable, and sustainable alternatives to chemical insecticides in managing Fall Armyworm infestations. The growing resistance of FAW to synthetic chemicals, along with their adverse environmental and health effects, necessitates the exploration of bio-based solutions. While neem and garlic extracts have shown promise, most studies are limited to laboratory conditions or small-scale trials. Few studies have tested different extraction methods under field conditions specifically against Fall Armyworm. Moreover, the combined application of neem and garlic remains underexplored. These gaps justify further research into their efficacy under local agro-ecological conditions.

1.3 Main Objective

The main objective of the study was to evaluate the bio-insecticidal potential of neem and garlic aqueous extract on Fall Armyworm infestation on maize.

Specific Objectives

The specific objectives were to:

i. determine the effect of aqeous extract of neem and garlicon incidence on Fall army worm on maize

ii. evaluate the effect of aqeous extract of neem and garlic on damage and severity by Fall armyworm on maize

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Botanical insecticides are plant-derived compounds that possess insecticidal, repellent, or growth-disrupting properties. They are biodegradable, environmentally safe, and often locally available (Isman, 2006). Extracts from plants such as neem, garlic, pyrethrum, derris, and chili have been tested with varying success against Lepidopteran pests. Their mode of action includes deterrence of feeding, growth inhibition, sterilization, and mortality induction (Mordue and Nisbet, 2000).

2.2 Neem and Garlic as Botanical Insecticides

Neem (*Azadirachta indica*) is widely recognized for its insecticidal and antimicrobial properties. Its active ingredient, azadirachtin, functions as an insect growth regulator, antifeedant, and repellent. Neem extract interferes with the hormonal system of insects, preventing molting and reproduction. Studies have shown that neem-based formulations are effective against several agricultural pests including aphids, beetles, and caterpillars (*Isman, 2006*). Garlic (*Allium sativum*) contains organosulfur compounds such as allicin, which have insecticidal and repellent properties. Garlic extract affects the nervous system of pests and disrupts their feeding behavior. It is also known to have synergistic effects when combined with other botanicals, enhancing overall pest control efficacy (*Singh and Sharma, 2017*). When neem and garlic are combined, they may provide a broader spectrum of action against pests like the Fall Armyworm. The combination could potentially deliver both repellent and growth-inhibiting effects, leading to reduced larval abundance and damage severity on maize.

2.3 Neem Extracts and Their Efficacy

Neem (*Azadirachta indica*) is a tropical tree widely recognized for its pesticidal, medicinal, and ecological importance. It has been traditionally used in agriculture as a natural alternative to synthetic chemicals due to its broad-spectrum activity and environmental safety. The insecticidal properties of neem are mainly attributed to its bioactive compounds such as azadirachtin, nimbin, salannin, and nimbidin. These compounds act as antifeedants, repellents, growth regulators, and oviposition deterrents, disrupting the life cycle of many insect pests. Neem extracts are commonly prepared in various forms including neem seed kernel extract (NSKE), neem oil, neem leaf extract, and neem cake, while commercial formulations such as Neem Azal and Nimbecidine are also widely applied. Several studies have demonstrated neem's efficacy against agricultural pests, particularly chewing insects like caterpillars and sucking pests such as aphids and whiteflies. Its use against the fall armyworm (*Spodoptera frugiperda*) in maize has shown significant effects including reduced larval feeding, higher mortality rates, and lower crop damage. Neem products are also eco-friendly, biodegradable, and relatively safe for non-target organisms, making them highly suitable for integrated pest management (IPM). Despite these advantages, neem extracts face challenges such as short persistence under field conditions, variable effectiveness across formulations, and slower action compared to synthetic pesticides. Nevertheless, neem remains a valuable and sustainable pest management option that reduces reliance on chemical insecticides while promoting safer agricultural practices.

Research into neem (*Azadirachta indica*) as a botanical pesticide has consistently highlighted its potential for managing fall armyworm (FAW) in maize. Maredia *et al.,* (2010) reported that neem seed extracts significantly reduced larval survival and feeding activity. Their findings showed that neem not only caused direct mortality but also acted as a growth regulator, delaying larval development and reducing maize leaf damage.

Similarly, Silva (2010) examined aqueous neem extracts and found that both leaf and seed-based preparations produced measurable toxic effects on FAW larvae. Silva emphasized that efficacy was dose-dependent and that seed-kernel extracts were generally more effective than leaf preparations. Importantly, the study pointed out that crude aqueous extracts prepared by farmers could be practical but often varied in consistency compared to standardized commercial formulations. In agreement with maredia (2010), Silva findings underscore neem's dual action as an insect growth regulator and anti-feeding agent. While laboratory results were promising, both authors cautioned that field effectiveness may be lower due to environmental factors and variability in extract quality. Nonetheless, their work established neem as a viable, eco-friendly alternative for integrated management of fall armyworm in maize.

Between 2016 and 2020, Hellpap's research (1986) contributed to research highlighting the behavioral effects of neem on fall armyworm (FAW). His studies showed that neem-based formulations not only act as toxicants but also influence pest behavior, particularly oviposition. Neem extracts applied to maize plants significantly reduced the number of eggs laid by FAW females, suggesting that oviposition deterrence is an important mechanism of control. This work emphasized that neem could interfere with the pest's reproductive cycle, lowering population build-up in addition to direct larval mortality.

Mercado (2020) made similar contributions through studies and reviews documenting neem's effects on fall armyworm. His work reinforced evidence that neem seed and leaf extracts suppress larval feeding, inhibit growth, and reduce maize damage under both laboratory and semi-field conditions. The author highlighted neem's role as a natural growth regulator, stressing its ability to delay larval development and disrupt pupation. The author also noted that neem is best suited as part of an integrated management strategy rather than as a stand-alone solution, due to variability in field performance. The author's contributions have therefore been important in contextualizing neem as a practical but complementary tool for sustainable maize protection.

In 2018, Samuel., et al conducted field studies assessing the effectiveness of neem formulations against fall armyworm (FAW) on maize which was published in 2025. Their trials showed that neem seed and leaf extracts reduced larval populations and visible foliar damage compared to untreated controls. While neem treatments did not completely eradicate FAW, they consistently lowered infestation levels and delayed crop injury. Importantly, the studies emphasized neem's eco-friendly profile and suggested its integration with other management options, rather than sole reliance. These findings provided practical field-based evidence that neem can play a valuable role in smallholder maize systems, particularly where synthetic insecticides are costly or unavailable.

In a related effort, Shaiba (2018) carried out a field application study using neem oil formulations against fall armyworm in maize plots and was published in 2019. The author's results demonstrated that neem oil sprays reduced larval feeding and leaf damage, though efficacy varied with application frequency and concentration. The research confirmed that neem oil could serve as a low-cost, accessible option for farmers but also highlighted challenges such as rapid degradation under sunlight and the need for repeated applications. By providing real-world field data, the author's work reinforced the practical potential of neem while pointing out its limitations under natural farming conditions.

Percy M. Matova *et al.,* (2020) published a comprehensive review that compiled available evidence on fall armyworm (FAW) control practices, including the use of neem seed, leaf, and oil extracts. Their synthesis highlighted that neem remains one of the most widely studied botanical options due to its multiple bioactive effects: larval mortality, feeding inhibition, growth disruption, and reduced oviposition. The study emphasized that neem's value lies not only in direct control but also in its compatibility with other pest management methods, such as cultural practices and biological control. The review also pointed out that while laboratory results are consistently positive, field performance can vary depending on formulation, dosage, and environmental conditions. By bringing together results from different regions and methodologies, the study reinforced neem's place as a key component of integrated pest management strategies for sustainable maize production.

In 2021, Samuel *et al.,* conducted experimental research titled *"Potential of neem extracts as natural insecticide against fall armyworm."* Their work tested different neem extracts under controlled and semi-field conditions to evaluate their effect on fall armyworm (FAW) infestation in maize. The study demonstrated that neem seed and leaf extracts significantly reduced larval abundance, delayed development, and lowered foliar damage compared to untreated controls. Tulashie and colleagues emphasized that neem is not only effective in reducing pest pressure but is also a safer, environmentally friendly alternative to synthetic insecticides. Importantly, their findings supported the integration of neem into pest management programs as a natural, affordable possibility for smallholder farmers confronting FAW outbreaks.

Saleem *et al.,* published a laboratory toxicology study in *Heliyon* that combined bioassays with chemical profiling of neem leaf extracts against fall armyworm (FAW) in 2025. The research began in 2022, Their work showed that neem leaf extracts significantly reduced larval survival and feeding activity in controlled assays, with toxicity levels increasing at higher concentrations. Using gas chromatography–mass spectrometry (GC–MS), the authors identified multiple bioactive compounds in the extracts, including azadirachtin derivatives and limonoids, which are known to disrupt insect feeding and development. The study concluded that neem leaf extracts possess strong insecticidal potential while also providing a chemical fingerprint that could guide the development of standardized formulations. This research advanced the understanding of both the biological efficacy and chemical basis of neem activity against FAW.

Also, in 2022, Wacal, *et al.,* conducted field experiments in Uganda to evaluate different concentrations of neem leaf extract for managing fall armyworm (FAW) in maize which was published in 2024. Their study showed that neem applications significantly reduced larval abundance and crop damage, with higher extract concentrations providing stronger suppression. Importantly, neem-treated plots also recorded notable improvements in maize yield compared to untreated controls, demonstrating both protective and agronomic benefits. The authors emphasized that while neem was less immediately potent than synthetic insecticides, it offered a low-cost, environmentally sustainable alternative that could be adopted by smallholder farmers. Their findings reinforced neem's role as a practical component of integrated pest management (IPM) strategies for FAW in East African maize systems.

In 2025, I. Oyege reported on the development of neem-extract-based nanopesticides designed to enhance the efficacy of botanical insecticides against fall armyworm (FAW). Laboratory assays demonstrated that these nano-formulations achieved higher larval mortality rates than conventional neem extracts, owing to improved stability, controlled release of active compounds, and better penetration into insect tissues. The study highlighted nanopesticides as a promising innovation that could overcome limitations commonly associated with crude neem preparations, such as rapid degradation under sunlight and inconsistent potency. Oyege's work positioned neem-based nanopesticides as a frontier in sustainable pest management research, offering both higher effectiveness and reduced environmental impact.

2.4 Garlic Extracts and Their Efficacy

Garlic (*Allium sativum*) is one of the oldest cultivated plants, believed to have originated in Central Asia, particularly around regions of present-day Iran and Turkmenistan. It has been widely used for centuries both as food and as a natural remedy due to its strong antimicrobial and pesticidal properties. To obtain garlic extracts for pest management, cloves are usually crushed or blended and then mixed with water, sometimes with additives like soap or ethanol to improve adhesion and penetration. The solution is filtered to remove solids, leaving a liquid extract that contains bioactive compounds such as allicin, which is mainly responsible for its insecticidal effect. In managing Fall Armyworm (*Spodoptera frugiperda*), garlic extract is applied as a foliar spray on maize plants. Its strong odor and chemical compounds act as both a repellent and a toxicant. The extract disrupts feeding, reduces larval survival, and minimizes plant damage. Farmers prefer it as an eco-friendly option since it is biodegradable, less harmful to beneficial insects, and safer compared to synthetic pesticides.

In 2019, Figueroa *et al.,* produced one of the earlier reports on the bioactivity of garlic (*Allium sativum*) extracts against fall armyworm (FAW). Their laboratory and field evaluations demonstrated that garlic formulations reduced larval survival and feeding, leading to lower foliar damage in maize compared to untreated controls. Although mortality levels were generally lower than those achieved with synthetic insecticides, the study highlighted garlic's potential as a natural repellent and growth-disrupting agent. Since publication, Figueroa *et al.,* (2019) has been widely cited in subsequent regional studies as foundational evidence supporting the use of garlic extracts in integrated pest management (IPM) programs for FAW. The frequent citation of this work underscores its influence in validating garlic as a complementary botanical option alongside neem and other plant-derived insecticides.

In 2020, Munyore *et al.,* conducted a greenhouse trial evaluating garlic (*Allium sativum*) and onion (*Allium cepa*) extracts for the management of fall armyworm (FAW) on baby corn. Their experiments showed that both extracts significantly reduced larval feeding and plant injury compared to untreated controls, with garlic extract proving more effective than onion. The study provided direct experimental evidence that locally available Allium-based botanicals could serve as practical biopesticides for smallholder farmers.

Abdul Abbas published a synthesis on biological control strategies for fall armyworm (FAW) in 2022, with a focus on botanical and ecological options. The review highlighted garlic (*Allium sativum*) and neem (*Azadirachta indica*) extract as among the most effective plant-derived treatments tested across field and laboratory settings. Abbas ranked these botanicals alongside other promising approaches, noting their ability to reduce larval feeding, suppress population growth, and lower maize damage. The review emphasized that while botanicals are generally slower acting than synthetic insecticides, their environmental safety and accessibility make them highly suitable for integrated pest management (IPM). Abbas's work therefore positioned garlic and neem as reliable, low-cost tools within broader sustainable FAW control frameworks.

Luis F. Ceja-Torres conducted field trials on native maize varieties to evaluate the effectiveness of organic plant extracts, including garlic (*Allium sativum*), against fall armyworm (FAW) which was published in 2023. The study reported that garlic extract treatments reduced larval presence and feeding damage compared to untreated controls, with noticeable improvements in crop protection. Although garlic was not as fast-acting as synthetic insecticides, its consistent suppression of FAW and compatibility with organic maize production systems were highlighted as major strengths. The author's work demonstrated that garlic extract can be effectively integrated into ecological farming practices, providing sustainable pest control options for traditional maize systems while reducing chemical input reliance.

M. C. Keerthi published a study on bio-intensive tactics for managing fall armyworm (FAW) in 2023, compiling evidence on ecological, cultural, and botanical approaches. The review explicitly listed garlic (*Allium sativum*) among the botanicals that have shown measurable activity against FAW in both laboratory and field studies. The author summarized results demonstrating that garlic extracts reduce larval feeding, suppress infestation levels, and contribute to lower crop damage when applied regularly. The review emphasized garlic's value as part of integrated pest management (IPM), particularly in smallholder systems where affordable and eco-friendly alternatives to synthetic insecticides are needed. By situating garlic within a broader suite of bio-intensive options, the author reinforced its role as a sustainable and practical botanical tool for FAW control.

Kizito S. Eboh (also cited as Kizito Sone) conducted field research evaluating a locally prepared garlic (*Allium sativum*) emulsion in combination with intercropping practices for the management of fall armyworm (FAW) on maize which was published in 2023. The study demonstrated that garlic emulsion treatments significantly reduced larval damage when applied regularly, and their effectiveness was enhanced when combined with intercropping systems that naturally disrupted pest colonization. The research highlighted that garlic-based emulsions can be prepared on-farm at low cost, offering farmers an accessible and eco-friendly control option. Eboh's findings reinforced the importance of integrating botanical extracts like garlic with cultural practices to achieve sustainable and practical FAW management under smallholder farming conditions.

Oliveira *et al.,* published a study in 2024 on the activity of essential oils (EOs) against fall armyworm (*Spodoptera frugiperda*), showing that several EOs negatively affected larval survival, feeding, and development. Within the broader EO literature, garlic

(*Allium sativum*) essential oil was discussed as a promising candidate due to its sulfur-rich compounds, which act as strong feeding deterrents and disrupt insect physiology. Oliveira *et al.,* highlighted that garlic EO, alongside other plant-derived oils, has the potential to serve as an eco-friendly biopesticide. In the same year, an article in an entomology journal evaluated garlic essential oil specifically**,** testing its effects with and without mineral oil additives. The study found that garlic EO significantly reduced FAW feeding and survival, with additive formulations enhancing persistence and activity in field conditions. These results positioned garlic EO as a potent botanical option, particularly when optimized with carriers like mineral oils that improve stability and field efficacy.Together, these 2024 studies extended the garlic literature from crude extracts and emulsions into the essential oil domain, demonstrating stronger and more targeted insecticidal properties that can complement integrated pest management (IPM) approaches for maize farmers.

2.5 Combined Use of Neem and Garlic Extracts

Studies indicate that combining neem and garlic extracts can produce additive or synergistic effects. Neem acts as a growth regulator and antifeedant, while garlic functions primarily as a repellent and contact toxicant. This dual mechanism can enhance control efficiency and reduce the likelihood of resistance development. Although research on their combination against Fall Armyworm is still limited, preliminary studies suggest potential complementary action.

Luis Miguel Álvarez Cedeño conducted and completed a final-year thesis in Ecuador, which investigated the use of garlic (*Allium sativum*) and neem (*Azadirachta indica*) extracts both individually and in combination for the management of the fall armyworm (*Spodoptera frugiperda*) in maize. The research, which began in 2014 and concluded with its publication in 2015, was based on farmer-participatory field trials and drew comparisons with earlier local studies on botanical pest control. The study revealed that both garlic and neem extracts effectively reduced larval infestation and visible leaf damage, while the combined application of the two showed slightly stronger effects than either extract alone. The author emphasized that botanical extracts provided a cost-effective and environmentally safer alternative for smallholder farmers who often lacked access to synthetic insecticides. His work stood out as one of the early regional contributions validating farmer-driven approaches to botanical pest management and demonstrated the practical feasibility of garlic–neem combinations for the suppression of fall armyworm in Ecuadorian maize systems.

Gualteros *et al.,* from Colombia reported research in *Acta Biológica Colombiana* and related conference proceedings that investigated the use of multiple plant extracts and their mixtures against fall armyworm (*Spodoptera frugiperda*) which was published in 2019. Their experimental programme included neem (*Azadirachta indica*) and garlic (*Allium sativum*), tested both individually and in combination with other botanicals. The study showed that several of the extracts reduced larval feeding and survival, while mixtures often produced stronger suppression than single extracts. Neem and garlic were highlighted for their notable bioactivity, and when used together or with other botanicals, they enhanced overall insecticidal effects. This Colombian contribution was significant because it not only provided evidence of the individual efficacy of neem and garlic but also stressed the value of botanical mixtures as a more robust strategy for FAW management. Such an approach aligned with sustainable pest control practices and offered practical alternatives for small-scale farmers in the region.

Jonathan Mora Arechua completed an agronomy thesis in Ecuador focused on the agroecological management of fall armyworm (*Spodoptera frugiperda*) which was published in 2020. His research explored practical, farmer-friendly pest control methods using plant-based preparations. Among them, a garlic (*Allium sativum*) and neem (*Azadirachta indica*) mixture proved especially effective, reducing larval populations and visible crop damage under field conditions. The author highlighted the mixture's affordability, environmental safety, and suitability for small-scale farmers bridging experimental research with real-world agricultural practice.

Miguel Tomás Riquelme Ríos published a field-trial report in 2024 in the journal Columbia ProInv from Paraguay, in which he evaluated several botanical extracts for pest management. Among the tested treatments was a farmer-oriented extract combining garlic (ajo) and neem (*Azadirachta indica*), applied weekly as a foliar spray. Although the primary target crop was passion fruit (*maracuyá*), the formulation and weekly application protocol mirror those recommended for managing the fall armyworm (*Spodoptera frugiperda*) in maize systems. The study emphasised the extract's practicality, low cost and adaptability making the garlic–neem mixture a viable eco-friendly option for small-scale growers.

2.6 Other Botanicals in Fall Armyworm Management

Other botanicals such as chili (*Capsicum spp.*), lemon grass (*Cymbopogon citratus*), and Tephrosia (*Tephrosia vogelii*) have been evaluated against Lepidopteran pests. For example, extracts of *T. vogelii* showed contact toxicity against caterpillars (Belmain *et al.,* 2012). Pyrethrum (*Chrysanthemum cinerariifolium*) is another botanical with strong insecticidal properties, often used in smallholder systems. These studies collectively demonstrate the potential of botanicals as safer alternatives to chemical pesticides.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental site

The study was carried out on early planting season at teaching and research farm of Department of Crop Science, Faculty of Agriculture, University of Benin with the latitude of 6.3 degrees N and longitude of 5.6 degrees E.

3.2 Sources of experimental materials

The maize seeds were obtained from Premier seeds The variety used was Oba 98, The NPK 15:15:15 and Urea was obtained from Lagos Street, Benin City, Polytene nylon for barrier was obtained at Ring Road, Benin City.

3.3 Experimental layout

The experimental layout was a Randomized Complete Block Design (RCBD) with the plot area of 15m by 11m, have 4 treatment plots measuring 3m by 2m, 3 replications and the alley way was 1m, (fig 1).

3.3.1 Treatments

T1 = Neem extract application, T2 = Garlic extract application, T3 = Neem + Garlic extract combination application, 4 = Control (no treatment).

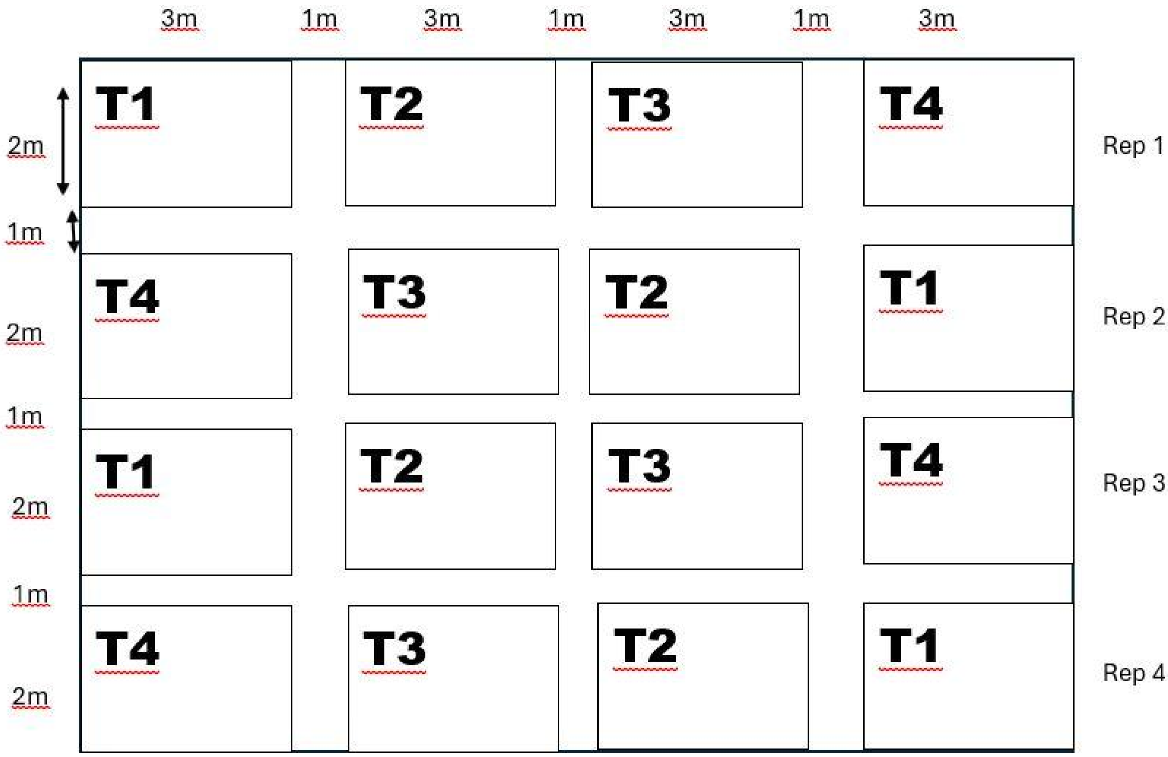

Fig. 1. Experimental Layout

3.2.2 Land Preparation

The vegetation was cleared manually using cutlass, it was stumped using hoe and cutlass to remove the stumps in the site. Mapping out the area to get the treatment plot size and the number of replications was carefully done.

3.3.3 Sowing

The seeds were sown in the treatment plot, spaced 75cm between rows and 25cm within rows, 3 seeds per hole and as later thinned to 1 per stand.

3.3.4 Weeding

Weeding was carried out manually 2 weeks after sowing. Second weeding was carried out 6 weeks after sowing.

3.3.5 Fertilization application

NPK 15:15:15 fertilizer was applied at the rate of 60 kg/ha on each treatment plot at two weeks after sowing. Urea was applied at the rate of 20 kg/ha per treatment plot at six weeks after sowing.

3.4 Preparation of Experimental Materials

All botanical extracts used in this study were prepared using freshly collected plant materials to ensure maximum potency. The extracts were prepared in the laboratory prior to field application, and each preparation followed a standardized boiling and filtration process.

3.4.1 Preparation of Neem Extract

Fresh neem leaves were collected and rinsed under clean water to remove dust and debris. A total of 200 g of neem leaves were weighed and placed into a pot containing 1000 ml of distilled water. The mixture was brought to a gentle boil for approximately 20–30 minutes to allow the active compounds to be released into the solution. After boiling, the extract was allowed to cool at room temperature and then filtered through a muslin cloth to obtain a clear neem solution used for field application.

3.4.2 Preparation of Garlic Extract

Garlic cloves were peeled, washed, and ground into a fine paste. Fifty grams (50 g) of the crushed garlic were measured and added to 1000 ml of distilled water. The mixture was boiled for 15–20 minutes to enhance the extraction of its bioactive components. Once removed from heat, it was allowed to cool and then filtered using a muslin cloth. The filtrate served as the garlic extract for the experiment.

3.4.3 Preparation of Neem + Garlic Combination Extract

For the combined botanical treatment, 250 g of neem leaves and 75 g of crushed garlic were weighed and added together into 1500 ml of distilled water. The mixture was boiled for about 20–30 minutes to ensure proper extraction from both plant materials. After boiling, it was cooled and filtered with a muslin cloth to produce a homogeneous neem–garlic extract used for the combined treatment plots.

3.4.4 Method of Application of Neem and Garlic Extracts.

The neem, garlic, and neem–garlic extracts were applied using the foliar application method. 5 mL of each treatment was measured with a syringe and carefully applied into the maize whorls.

3.5 Data collection

Weekly observations from one week after the first treatment application until flowering. Data collection started 2 weeks after sowing, 5 randomly selected plant were sampled per treatment plot. Collection of data usually was at the early hours of the morning. The data was collected on number of FAW larvae, number of damaged plants and severity was scored using visual rating scale for leaf damage assessment by Davis and Williams (1992).

Table 1: Visual rating scale for leaf damage assessment

Scale	**Description**
0	No visible leaf damage
1	Only pin hole damage on leaves
2	Pin hole and short hole damage
3	Small elongated lesions (5-10mm) on 1-3 leaves
4	Mid-size lesions (10-30mm) on 4-7 leaves
5	Large elongated lesions (>30mm) or small portion eaten on three leaves
6	Elongated lesions (>30mm) or large portion eaten on three leaves
7	Elongated lesions (>30mm) and 50% of leaf eaten
8	Elongated lesions (>30mm) and large portion eaten or 70% of leaf eaten
9	Most leaves with long lesions and complete defoliation observed

Source: Davis and Williams (1992)

3.6 Data analysis

Data in the treatment were square-root transformed and analyzed using one-way Analysis of Variance (ANOVA). Significant means at $p<0.05$ was separated using Least Significant Difference (LSD). All analysis was done using GenStat Version 12.1.

CHAPTER FOUR

RESULTS

4.1 Effect of Neem and Garlic on Fall Armyworm Infestation

The effect of neem, garlic, and their combination on Fall Armyworm infestation is presented in Table 2. The analysis of variance (ANOVA) showed no significant difference ($p > 0.05$) among treatments across all sampling periods.

At 3 weeks after sowing (3 WAS), no infestation was observed in all treatments, indicating that Fall Armyworm activity had not yet begun. At 4 WAS, slight infestations were recorded, with neem and the control having the same mean value (1.25), while garlic and neem + garlic recorded slightly lower means (1.00).

At 5 WAS, neem recorded the highest infestation (1.50), while garlic recorded the lowest (0.25), suggesting that garlic may have exerted a mild suppressive effect on the pest. By 6 WAS, infestation reduced in most treatments, though neem + garlic recorded a slightly higher mean (2.25). These differences were not statistically significant ($p > 0.05$).

Table 2: Effect of Neem and Garlic on Fall Armyworm Infestation.

Treatments	3 weeks	4 weeks	5weeks	6 weeks
Neem	0.00	1.25	1.50	1.25
Garlic	0.00	1.00	0.25	0.75
Neem + Garlic	0.00	1.00	1.00	2.25
Control	0.00	1.25	0.00	0.75
Significant difference		N.S	N.S	N.S

NS = Not Significant ($p > 0.05$)

4.2 Effect of Neem and Garlic on Fall Armyworm Larval Abundance

The effect of neem and garlic on the abundance of Fall Armyworm larvae is shown in Table 3. The ANOVA results revealed no significant difference ($p > 0.05$) among treatments at all sampling periods.

At 3 WAS, no larvae were recorded across all treatments. At 4 WAS, the control and garlic treatments had the highest larval counts (1.00), while neem and neem + garlic recorded lower values (0.75).

At 5 WAS, neem recorded the highest larval abundance (1.00), while both garlic and neem + garlic had the lowest (0.25). By 6 WAS, larvae were completely absent in most treated plots, suggesting possible suppression or repellency of the extracts. Despite these variations, the observed differences were not statistically significant ($p > 0.05$).

Table 3: Effect of Neem and Garlic on Fall Armyworm Larvae Abundance.

Treatments	3 weeks	4 weeks	5weeks	6 weeks
Neem	0.00	0.75(1.06)	1.00(1.18)	0.00(0.71)
Garlic	0.00	1.00(1.14)	0.25(0.84	0.25(0.84)
Neem + Garlic	0.00	0.75(1.06)	0.25(0.84)	0.00(0.71)
Control	0.00	1.00(1.18)	0.00(0.71)	0.00(0.71)
Significant difference		N.S	N.S	N.S

Values in parentheses are square root–transformed means. NS = Not Significant ($p > 0.05$).

4.3 Effect of Neem and Garlic on Fall Armyworm Damage Severity

The effect of neem and garlic on the severity of Fall Armyworm damage is shown in Table 4. The ANOVA indicated that there were no significant differences ($p > 0.05$) among treatments throughout the sampling periods.

At 3 WAS, all treatments recorded low severity levels, with values ranging from 0.00 to 0.25. At 4 WAS, garlic recorded the highest severity score (2.38), followed by the control (1.58), while neem and neem + garlic recorded lower scores (0.88 and 1.00, respectively).

By 5 and 6 WAS, the severity levels decreased across all treatments, showing a general decline in damage intensity as the crop matured. Neem consistently maintained lower severity values throughout the period, suggesting a moderate suppressive effect on the pest. However, the observed differences were statistically insignificant ($p > 0.05$).

Table 4: Effect of Neem and Garlic on Fall Armyworm Severity.

Treatments	3 weeks	4 weeks	5weeks	6 weeks
Neem	0.00	0.88	0.75	0.00
Garlic	0.25	2.38	0.25	0.25
Neem + Garlic	0.00	1.00	1.00	0.00
Control	0.00	1.58	0.00	0.00
Significant difference	N.S	N.S	N.S	N.S

NS = Not Significant ($p > 0.05$)

4.4 Summary of Findings

The overall ANOVA results revealed that neem, garlic, and their combination did not significantly affect Fall Armyworm infestation, larval abundance, or damage severity at any sampling period ($p > 0.05$).

However, numerical trends showed that neem and garlic treatments slightly reduced infestation and severity compared to the untreated control. The combined neem + garlic treatment did not demonstrate any synergistic effect, and replication effects were minimal, indicating that the observed variations were primarily due to natural differences rather than treatment impact.

CHAPTER FIVE

5.1 DISCUSSION

5.1.1 Effect of Neem and Garlic on Fall Armyworm Infestation

The results of this study showed that the application of neem, garlic, and their combination produced no statistically significant effect ($p > 0.05$) on Fall Armyworm (FAW) infestation across all sampling weeks. Although numerical variations existed, such as slightly lower infestation in garlic-treated plots at 5 WAS and slightly higher values in the neem + garlic treatment at 6 WAS, these differences were not large enough to indicate a real treatment effect.

The lack of significant impact may be attributed to rapid degradation of botanical compounds under field conditions. Neem extracts, for example, are known to break down quickly when exposed to sunlight and rainfall (Isman, 2006). Similarly, the active compound in garlic allicin is unstable and loses potency rapidly after extraction. These abiotic factors likely reduced the residual effectiveness of the sprays shortly after application.

Despite the nonsignificant results, the numerical trends still agree with previous research showing that both neem and garlic possess mild suppressive effects. Studies such as Maredia *et al.,* (2010) and Figueroa *et al.,* (2019) have documented slight reductions in infestation after the application of botanical extracts, particularly when applied frequently or at higher concentrations. The trends observed in this study though weak suggest that the extracts had some repellent effect, even if not strong enough to be statistically validated.

5.1.2 Effect of Neem and Garlic on Fall Armyworm Larval Abundance

Similar to infestation, the treatments did not produce statistically significant differences in larval counts. Larval abundance fluctuated across treatments and weeks, but the variations followed no consistent pattern. At 4 WAS, garlic and the control had the highest larval counts, while neem and neem + garlic recorded slightly lower numbers. By 6 WAS, larvae were absent in most treatments, which may not necessarily indicate treatment effect but rather natural population decline as maize matured.

One important factor that may explain the absence of significant reductions in larval abundance is the developmental stage of larvae during treatment periods. Botanical extracts are most effective against younger instars. If larvae present during the application were in later developmental stages, the extracts may have had limited impact. Additionally, the aqueous extraction method used in this study yields relatively low concentrations of active compounds, which may not be potent enough to inhibit larval development under field conditions.

Other studies, such as Samuel *et al.,* (2021) and Wacal *et al.,* (2024), have reported reductions in larval populations when using neem extracts, but many of these studies were conducted under controlled or semi-controlled conditions where environmental stress on the extracts was minimal. The field environment of this study likely diluted or degraded the active components, resulting in the observed weak effects.

5.1.3 Effect of Neem and Garlic on Fall Armyworm Damage Severity

The severity of FAW damage also followed a similar pattern to infestation and larval counts, with no significant differences among treatments ($p > 0.05$). Although garlic plots recorded higher severity at 4 WAS and neem maintained consistently lower damage scores, these variations were still within nonsignificant ranges.

Damage severity typically reflects accumulated feeding activity, and the absence of significant differences aligns with the nonsignificant larval population results. If the extracts were not strong enough to suppress larval feeding, then substantial differences in damage would not be expected.

However, the general decline in damage severity over time suggests that as maize plants grew older, they became more tolerant to FAW feeding. This natural tolerance has been reported in several studies and is a typical pattern in maize–armyworm interactions.

Neem showed slightly better performance in reducing damage numerically, which supports findings by Silva (2010) and Mercado (2020) that neem possesses antifeedant properties, even when not producing outright larval mortality. But again, the environmental conditions of the field sunlight, rainfall, humidity, and high temperatures may have weakened the protective effects of both neem and garlic extracts.

5.2 Conclusion

This study evaluated the effects of neem, garlic, and their combination on FAW infestation, larval abundance, and damage severity under field conditions. The results showed that none of the treatments produced statistically significant reductions in any of the measured parameters. Although numerical differences were observed such as reduced infestation and lower damage scores in some treated plots the effects were mild and inconsistent.

The limited efficacy observed in this study was likely influenced by abiotic factors such as:

Sunlight, which accelerates the degradation of neem's azadirachtin;

Rainfall, which can wash off botanical sprays shortly after application;

Temperature and humidity, which affect the stability of garlic's active compounds; and

Field variability, which is common in open-field experiments involving mobile pests like FAW.

Other limitations of the study include the use of aqueous extracts, which are less stable and less potent than oil-based or ethanol-based formulations, and the possibility that applications did not always coincide with the most susceptible larval stages.

Despite these limitations, the study supports the idea that neem and garlic extracts may serve as complementary components of an integrated pest management (IPM) system rather than as standalone control methods.

5.3 Recommendations

Based on the findings, the following recommendations are made:

1. Use higher concentrations or more stable formulations of neem and garlic extracts (e.g., oil-based, soap-enhanced, or nano-formulated botanicals) to improve persistence under field conditions.

2. Time applications to target early larval stages, as botanical extracts are more effective on young larvae.

3. Integrate neem and garlic extracts with other IPM strategies, such as early planting, resistant maize varieties, and biological control agents.

4. Conduct further studies that measure how abiotic factors (rainfall, temperature, sunlight intensity) affect the persistence and performance of botanical insecticides applied in the field.

5. Engage farmers in training on correct extract preparation, concentration, and application intervals to enhance field effectiveness.

6. Explore multiple application schedules or shorter intervals between sprays, as botanical insecticides have short residual periods.

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