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EFFICACY OF SOME BIOPESTICIDES AND THEIR MODE OF ACTION AGAINST INSECT PESTS (A LITERATURE REVIEW)

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Abstract

Biopesticides are naturally occurring substances from living organisms (natural enemies) or their products (microbial products, Phytochemicals) or their by-products (Semiochemicals) that can control pest by non- toxic mechanism. There are various types of bio-pesticides such as microbial pesticide, insect pheromones; plants-based extracts and essentials oils, insect growth regulators and Genetically Modified Organisms (G.M.O). This review seeks to show the effectiveness of bio-pesticides in the control of insect's pests. Several foreign and local papers were reviewed and evaluated to compile the result of this review. The result of the review clearly shows that all those bio-pesticides are effective in the control of insect pest. But their efficacy is less than the conventional chemical pesticide. Their mode of action against insect pest include altering certain activities of genes and proteins, it is effective against many biological processes, it may cause a reduction in feeding habit, suspend the molting process, larvae and pupae death and also cause sterility in the emerging adult. The mode of action is slow compared to conventional chemical pesticide. It inflicts damage to the insect pest through the following mechanisms: Antibodies, competition, hyper-parasitism and synergism. Therefore, the reviewer recommended that; Nigerian researchers should publish their research articles online for easy access by reviewers and other researchers, as most of the articles assessed by the reviewer are foreign due to inadequacy of indigenous research articles online. There is need for the researchers to identify safer means of improving bio-pesticides efficacy, such as using molecular based technologies and other biological techniques. Government need to contribute its own quota by providing necessary resources to the bio-pesticide researchers, bio-pesticide producers, e.t.c. More emphasis should be put on investigating not only the interaction between bio-pesticide and insect but also the interaction between bio-pesticide and other components of agro-ecosystem, for example plants, soil flora and fauna, e.t.c.

KEYWORDS: Insect pest, biopesticides, antibodies, competition, hyper-parasitism.

1.0 Introduction

1.1 Biopesticides

Bio-pesticides are naturally occurring substances from living organisms (natural enemies) or their products (microbial products, photochemicals) or their by-products (semiochemicals) that can control pest by nontoxic mechanisms (Salma and Jogen, 2011). Organization for Economic Co-operation and Development (2009), viewed bio-pesticides as manufactured mass produced agents derived from natural sources living micro-organisms and sold for use to control pests. According to Suman and Dikshit (2010), bio-pesticides encompass a broad array of microbial pesticides, biochemicals obtained from micro-organisms and natural sources.

The chemical pesticides used in crop protection, to reduce the damage caused by pathogens and pests in agricultural fields, pose many long-term threats and risks to living beings due to their harmful side effects. They are known to cause cancers (Nicolopoulou et al. 2016) and foetal impairments and they persist in the environment for many years (Van Oeston et al. 2017).

Bio-pesticides are naturally occurring compounds or agents that are obtained from animals, plants, and microorganisms such as bacteria, cyanobacteria, and microalgae and are used to control agricultural pests and pathogens. According to the US Environmental Protection Agency, bio-pesticides are 'derived from natural materials such as animals, plants, bacteria and certain minerals Products such as genes or metabolites from these bio-control agents can be used to prevent crop damage. The use of bio-pesticides is, by far, more advantageous than the use of their counterparts, traditional chemical pesticides, as they are eco-friendly and host specific. The use and application of agro-based chemicals in the agricultural sector to protect crop plants from invading and infecting pests can be greatly improved by employing bio-pesticides (Oesten, 2017).

1.2 Types of Bio-pesticides

There are many types of bio-pesticides, and they are classified according to their extraction sources and the type of molecule/compound used for their preparation (Riui, 2016). The categories are listed below.

a. **Microbial Pesticides**

These are derived from microorganisms including bacteria, fungi, and viruses. The active molecules/compounds isolated from these organisms attack specific pest species or entomopathogenic nematodes. Those known as bio-insecticides, target insects that harm crops, while those that control weeds via microorganisms, such as fungi are referred to as bio-herbicides. Over the last decade, extensive research activities on microbial bio-pesticides have led to the discovery and development of a good number of bio-pesticides and have paved the way for their marketability (Riui, 2018). The successful use of Bacillus thuringiensis (Bt) and some other microbial species led to the discovery of many new microbial species and strains, and their valuable toxins and virulence factors that could be a boon for the bio-pesticide industry, and some of these have been translated into commercial products as well (Ujváry, 2001). Major groups of bacterial entomopathogens include species of Pseudomonas, Yersinia, Chromo-bacterium, etc., while fungi comprise species of Beauveria, Metarhizium, Verticillium, Lecanicillium, Hirsutella, Paecilomyces, etc.(Sporleder et al. 2021). Other important microbial pesticide producers are baculoviruses that are species specific and their infectivity is associated with the crystalline occlusion bodies that are active against chewing insects (Lepidopteran caterpillars). The baculoviral occlusion body is basically a virion that is combined with the Bt toxin to produce recombinant baculovirus (Colorbtrus), producing occlusion bodies that incorporate the Bt insecticidal Cry1Ac toxin protein for enhancing the speed of action and pathogenicity with respect to its wild-type counterpart. Entomopathogenic nematodes (EPNs) used as bio-control agents belong primarily to species in the genera Heterorhabditis and Steinernema, associated with mutualistic symbiotic bacteria of the genera Photorhabdus and Xenorhabdus and are safe to mammals, environment, and non target organisms. Their commercial development as bio-control agents has been convenient because of their ease in mass production, using in vivo or in vitro techniques, and exemption from registration (Chang et al. 2003).

b. Biochemical Pesticides

Biochemical pesticides are naturally occurring products that are used to control pests through nontoxic mechanisms, whereas chemical pesticides use synthetic molecules that directly kill pests. Biochemical pesticides are further classified into different types depending upon whether they function in controlling infestations of insect pests by exploiting pheromones (semiochemicals), plant extracts/oils, or natural insect growth regulators (Jitendra Kumar et al. 2021).

c. Insect Pheromones

These are chemicals produced by insects which are mimicked for use in controlling insects in the integrated pest management programs. These chemicals are effective in disrupting insect mating to prevent the success of mating, thus reducing the number of insect progeny. The insects exploited in this process act as dispensers of pheromones that become confused due to the presence of pheromone flumes diffused in the surroundings. Insect pheromones are not true ‘insecticides’ since they do not kill insects but influence their olfactory system to affect behaviour (Gonzalez-Coloma et al. 2013). A detailed account of the mode of action of pheromones is given by Ujváry (2001). In summary, the antennae of the perceiving insect adsorb pheromones, which then diffuse into the interior of the sensilla through microscopic pores in the cuticle. Once inside, these are transferred through the hydrophilic sensillum to the chemosensory membranes by pheromone-binding proteins (PBPs). Subsequently, the pheromone or pheromone–PBP complex interacts with a specific receptor protein, which transducers the chemical signal into an amplified electric signal by a second messenger system connected with neuronal machinery (Gurr et al. 1999).

d. Plant-Based Extracts and Essential Oils

Over the last several years, plant-based extracts and essential oils have emerged as attractive alternatives to synthetic insecticides for insect pest management. These insecticides are naturally occurring insecticides as they are derived from plants and contain a range of bioactive chemicals (Magierowicz, 2020). Depending on physiological characteristics of insect species as well as the type of plant, plant extracts and essential oils (EOs) exhibit a wide range of action against insects: they can act as repellents, attractants, or anti feedants; they also may inhibit respiration, hamper the identification of host plants by insects, inhibit ovipositor and decrease adult emergence by ovicidal and larvicidal effects (Ali, 2017). Their composition varies greatly. Well-known examples in this regard are neem and lemongrass oil, which are very common in global herbal markets. A comprehensive study by Halder et al. (2013) showed that a combination of neem oil with entomopathogenic microorganisms, including Beauveria bassiana, was very successful against vegetable sucking pests. However, it is very important to determine the dose of azadirachtin content in neem oil so as not to kill the non target organisms (Mordue, 2005). A similar strategy has to be established for the entomopathogenic fungi that need to be supported by complementary laboratory bioassays, station, and/or field experiments for effective management of the target pests without affecting non target insects (Dannon etal, 2020). As regards the marketability of essential oils, they in fact, represent a market estimated at USD 700.00 million and a total world production of 45,000 tons, and industries in the US are able to bring essential oil-based pesticides to market in a shortened time period, as compared to the time taken in conventional pesticide launch (Parween, 2019).

e. Insect Growth Regulators

Insect growth regulators (IGRs) inhibit certain fundamental processes required for the survival of insects, thereby killing them. Furthermore, these compounds are highly selective and less toxic to non target organisms (Gurr, 1999). Depending on the mode of action, IGRs had been recently grouped in chitin synthesis inhibitors (CSIs) and substances that interfere with the action of insect hormones (i.e., juvenile hormone analogues and ecdysteroids). IGRs can control many types of insects including fleas, cockroaches, and mosquitoes even though they are not so fatal for adult insects. Although low in toxicity to humans, they prevent reproduction, egg-hatch, and molting from one stage to the next in the young insects, while mixing them with other insecticides is able to kill even the adult insects (Gwinn et al. 2018).

f. Genetically Modified Organisms (GMO) Products

These substances are produced through genetically modified organisms (GMOs). The genetic material is incorporated into the plant, which is then used as a source to produce pesticidal compounds, also referred to as plant-incorporated protestants (PIPs). Cry proteins are, by far the first-generation insecticidal PIPs that were introduced into the GM crops containing transgenes from the soil bacterium Bt. PIPs also demand the state of the research necessary for the ongoing environmental fate assessment of these molecules, primarily the RNAi-based PIPs (Parker, 2019) that would be discussed in a separate section.

2.0 LITERATURE REVIEW

Historically, bio-pesticides have been associated with the biological control and by implication, the manipulation of living organisms.

2.1 MECHANISMS OF ACTION OF BIO-PESTICIDES FOR PEST CONTROL:

They include the following:
a. Antibiosis
b. Competition
c. Hyper-parasitism
d. Synergism

a. Antibiosis:

This occurs as a result of an interaction with other microbes (microorganisms) mediated by specific metabolite of microbial origin, by volatile compounds, lytic enzymes or other toxic substances (Rikita and Utpal, 2014). The microorganisms produce antibiotics, bacteriocin, volatile compound and metabolite production.

b. Competition:

Another mechanism of control by bio-pesticides is their ability to compete aggressively, that they grow rapidly and colonize substrate to exclude pathogens. For example Trichorderma spp. are aggressive competitors of Fusarium spp.

c. Hyper-parasitism:

Hyperparasitism is the lysis of the death by other microorganisms or direct parasitism. For e.g *T. lignorum* is found to be parasitizing the hyphae of R. solani and therefore soil inoculation with Trichoderma spores help to control damping off disease in citrus seedlings (Rikita and Utpal, 2014).

d. Synergism:

The ability of some bioagent to combine actions of hydrolytic enzymes and antibiotic secondary metabolites. For example the effectiveness T. spp. as a bio-control agent and its fitness in the environment is as a result of synergistic effects of antimicrobial compounds. Example includes pyrones, coumarins etc.

2.2 Overview of the effectiveness and mode of Actions of bio-pesticides

Zhen Shen et al (1997) Studied the Mode of Action of Cholesterol Oxidase on Insect Midgut Membranes, they compared cholesterol concentrations and rates of cholesterol oxidation in the midgut membranes from larvae of boll weevil (*Anthonomus grandis*), southern corn rootworm (*Diabrotica undecimpunctata*), tobacco budworm (*Heliothis virescens Fabricius*), and yellow mealworm (*Tenebrio molitor Linnaeus*). Results showed that cholesterol concentration alone could not account for the differences in insecticidal activity and that midgut brush-border membranes of all species tested were generally susceptible to oxidation by cholesterol oxidase in vitro. They also demonstrated that cholesterol oxidase stability in the midgut environment was similar for the species tested and thus could not account for the differential activity. However, comparison of the pH of the insect midgut fluids with the pH optimum of cholesterol oxidase indicated that the lower sensitivity of lepidopteran larvae to the enzyme may be partially due to the alkaline nature of their midgut environments. In some species, oxidation caused significant changes in the activities of brush-border membrane alkaline phosphatase, and these changes did correlate with the susceptibility of the insect to cholesterol oxidase.

Similarly, Kashinath Chiluwal et al. (2017) reported the use of "Essential oils from selected wooden species and their major components as repellents and oviposition deterrents of *Callosobruchus chinensis*." Essential oils (EOs) from different parts of some selected wooden plants as well as the major component of Gaultheria fragrantissima, methylsalicylate were tested for adult repellence and oviposition deterrent effects on adzuki bean beetle (ABB), *Callosobruchus chinensis* L. in a Y-tube olfactometer assay and no choice assay, respectively. EOs of I. *Verumand C. Anisatum* as well as their common major component, trans-anethole and the major component of G. fragrantissima, methyl salicylate were effective repellents and had high degree of oviposition deterrent activity without affecting the seed viability. Linalool, the major component of A. rosaeodora and B. delpechiana EOs exhibited male repellency in higher concentrations but was not effective oviposition deterrent. From this study, two EOs: I. verumand C. anisatum and two major components; trans-anethole and methyl salicylate could be selected for use against C. chinensis for safe storage of adzuki bean.

Emeka D et al. (2013) found out the Potentials of Tropical African Spices with Entomocidal Properties as Sources for Safer Alternative Pesticides, according to the study *A. melegueta, Z. officinale, X. Aethiopica are identified* as antifeedants and insecticides. Prospects and challenges for vulgarizing these potential alternative plant protectants in the face of anticipated climate change and hence large-scale ecological and agricultural changes are also highlighted. The study revealed that several empirically validated studies have confirmed that these very odorous, locally available plants in Africa are potent insect feeding deterrents, repellents and often possess fumigant and/or insecticidal activities. Also, these indigenous tropical African species are often widely used as low-cost, eco-friendly, low-riskpesticidalalternatives to the obviously environmental harming conventional synthetic pesticides.

Furthermore, Ntonifor et al. (2010) conducted a study titled "Extracts of tropical African spices are active against Plutella xylostella". The study investigated extracts from *Piper guineense*, *Aframomum melegueta*, *Aframomum citratum* and *Afrostyrax kamerunensis* for their antifeedant, lethal and developmental effects against *Plutella xylostella* larvae through laboratory dual-choice tests and topical application. Water and ethanol extracts of *P. guineense* were dose-dependent antifeedants at concentrations ≥300 and 500 ppm, respectively, whilst methanol extracts required ≥1,000 ppm. Methanol and hexane extracts of *A. melegueta* acted at ≥100 ppm and water extracts at ≥300 ppm, but ethanol extracts were deterring feeding only slightly at ≥1,000 ppm. Hexane and methanol extracts of *A. citratum* inhibited feeding at ≥300 ppm and water extracts did so at ≥500 ppm. None of the *Afrostyrax kamerunensis* extracts deterred feeding at any of the concentrations tested. No mortality was observed at any of the concentrations after topical application of the extracts on the larvae. However, the effects on larval development varied with extract concentration and larval age. Ingestion of the water and ethanol extracts of P. guineense caused 100% mortality of second instars at ≥100 ppm two to three days after infestation (DAI). Methanol and water extracts of *A. melegueta* and *A. citratum*, respectively, achieved ≥80% mortality of larvae at concentrations of ≥500 ppm and ≥1,000 ppm, respectively. With third instars, the mortalities were significantly lower; however, the *P. guineense* water or ethanol extracts caused 100% mortality two to four DAI. Larvae that survived till pupation had significantly longer larval periods compared with the control after application of *A. melegueta* extracts.

Bajwa and Ahmad (2012) researched on the potential applications of neem based products as bio-pesticides in Lahore, Pakistan. The research argued that, Bio-pesticides are a good alternative to the synthetic pesticide. Both leaves and fruit of neem plant are known to have bitter taste having fungicidal, insecticidal and nematicidal properties. Azadirachtin, chemically a tetranorterpenoid component of neem acts on the mitotic cells and blocks the microtubule polymerization. Certain activities of genes and proteins are also altered by azadirachtin. As a botanical insecticide azadirachtin is effective against many biological processes. It may cause a reduction in feeding habit, suspend the molting process, larvae and pupae death and also cause sterility in the emerging adults, this all depend on the given dose. Apart from azadirachtin, many other components of neem also have insecticidal properties. Among them are saponins that are found to have antimicrobial activity that inhibits moulds and protecting plant from attack of insects. Likewise Nim and Neemas are also neem products that produce the insecticidal activity. In addition Parker oil TM is also effective insecticide which is a commercial product. There was maximum weight loss of treated insects when azadirachtin and NPV are used in combination. Commercial neem formulation has been assayed for the control of pine weevil in forestry, against rice leaf folder, root-knot nematodes and *P. xylostella*. Azadirachtin-A is extremely sensitive to the presence of sunlight so different mechanisms have been used to increase its photo stability.

In addition, Nathaletal (2005) researched the toxicity and physiological effect of neem limonoids on *Cnaphalocrocis medinalis* (Guenée) the rice leaf folder, The effect of neem (*Azadirachtaindica*) limonoids azadirachtin, salannin, deacetylgedunin, gedunin, hydroxyazadiradione, and deaceytlnimbin on gut enzyme activity of the rice leaf folder larvae was investigated. When fed a diet of rice leaves treated with limonoids in bioassays, gut tissue enzymes—acid phosphatases (ACP), alkaline phosphatases (ALP), and adenosine triphosphatases (ATPase) activities of rice leaf folder (*Cnaphalocrocis medinalis*) larvae are affected. Azadirachtin was most potent in all experiments. Larvae that were chronically exposed to limonoids showed a reduction in weight (59–89%) and exhibited a significant reduction in ACP, ALP, and ATPase activities. These results indicate neem limonoids affects gut enzyme activities. These effects are most pronounced in early instars.

Nathan et al. (2009) conducted another research on the toxicity and physiological effects of neem pesticides applied to rice on the Nilaparvatalugens Stål, the brown planthopper. The effects of two different neem products (Parker Oil and Neema) on mortality, food consumption and survival of the brown planthopper, Nilaparvatalugens Stål (BPH) (Homoptera: Delphacidae) were investigated. The LC (50) (3.45 ml/L for nymph and 4.42 ml/L for adult in Parker Oil treatment; 4.18 ml/L for nymph and 5.63 ml/L for adult in Neema treatment) and LC (90) (8.72 ml/L for nymph and 11.1 ml/L for adult in Parker Oil treatment; 9.84 ml/L for nymph and 13.07 ml/L for adult in Neema treatment) were identified by probity analysis. The LC (90) (equal to recommended dose) was applied in the rice field. The effective concentration of both Parker Oil and Neema took more than 48 h to kill 80% of the *N. lugens*. Fourth instar nymph and adult female N. lugens were caged on rice plants and exposed to a series (both LC (50) and LC (90)) of neem concentrations. Nymph and adult female N. lugens that were chronically exposed to neem pesticides showed immediate mortality after application in laboratory experiment. The quantity of food ingested and assimilated by *N. lugens* on neem-treated rice plants was significantly less than on control rice plants. The results clearly indicate the neem-based pesticide (Parker Oil and Neema), containing low lethal concentration; can be used effectively to inhibit the growth and survival of *N. lugens*.

Similarly, Huang et al. (2004) researched on protein metabolism in *Spodoptera litura* (F.) is influenced by the botanical insecticide azadirachtin. The research analyzed changes in protein metabolism of *Spodoptera litura* (F.) induced by azadirachtin. Following feeding 4th instar larvae of *Spodoptera litura* (F.) with an artificial diet containing 1 ppm azadirachtin until pupation, 48 h old pupae were collected and protein samples prepared. Total soluble protein content was measured and the results showed that azadirachtin significantly influenced protein level. Moreover, the proteins were separated by 2-DE (two-dimensional polyacrylamide gel electrophoresis) and 10 proteins were significantly affected by azadirachtin treatment when compared to an untreated control. Six of these proteins were identified with peptide mass fingerprinting using MALDI-TOF-MS after in-gel trypsin digestion. These proteins are involved in various cellular functions. One identified protein may function as an ecdysone receptor, which regulates insect development, and reproduction. It is suggested that the botanical insecticide azadirachtin affects protein expression and the azadirachtin-related proteins would be essential for a better understanding of the mechanisms by which neem toxins exert their effects on insects.

Furthermore, Ge-Mei Liang et al. (2003) analyses the Effects of three neem-based insecticides on diamondback moth (Lepidoptera: Plutellidae). Three commercial neem-based insecticides, Agroneem, Ecozin, and Neemix, were evaluated for oviposition deterrence, antifeedant effect to larvae, and toxicity to eggs of the diamondback moth, *Plutella xylostella L.*, in the laboratory. All three neem-based insecticides did not exhibit significant oviposition deterrence on *P. xylostella*. When cabbage leaves were used as an egg-laying substrate, numbers of eggs oviposited by *P. xylostella* adults on the cabbage leaves treated with the three neem-based insecticides were not significantly different from those treated with water.

However, when aluminum foil sheets coated with cabbage juice residue were treated with the three insecticides and were used as egg-laying substrates, significantly fewer eggs were found on the aluminum foil sheets compared with those treated with water. When eggs were treated with Agroneem, Ecozin and Neemix, 61.6%, 66.2%, and 75.2% of *P. xylostella* eggs developed to neonates, respectively, although the larval hatching rates in the treatment of Neemix were not significantly different from that in water control (81.2%). All larvae of *P. xylostella* fed on the leaves treated with the three neem insecticides died on or before day 7 compared with 70-74% larvae surviving to adults in the water control. All three neem insecticides exhibited significant antifeedant effect, and *P. xylostella* larvae on treated leaves quickly stopped feeding and dropped off treated leaves, resulting in no or minimal damage on the treated cabbage leaves. *P. xylostella* larvae that fed on neem insecticide treated leaves were significantly smaller (0.012-0.016 mg/larva, 13.5-14.8 mm in length, and 2.0-2.5 mm in diameter) compared with those fed on water-treated leaves (0.058 mg/larva, 30.2 mm in length, and 4.8 mm in diameter).

In another studies by Oparaeke A.M. (2007) on the Toxicity and spraying schedules of a bio-pesticide prepared from *Piper guineense* against two cowpea pests. The findings have reported toxicity of three concentrations (5%, 10% and 20% w/v) and spraying schedules (2, 4 and 6 weekly applications) of an extract from West African black pepper, *Piper guineense*, for managing two major post-flowering pests of cowpea, *Vigna unguiculata*, in two cropping seasons at the Research Farm of the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. The insect pests were the larvae of *Marucavitrata* (Lepidoptera: Pyralidae) and the cowpea coreid bug, *Clavigralla tomentosicollis* (Hemiptera: Coreidae). The higher concentrations (10% and 20% w/v) and more frequent applications (4 and 6/week) significantly ($P < 0.05$) reduced the numbers of the two insect pests compared to the untreated control in both years. Pod damage was significantly reduced and grain yields consequently increased in treated plots compared with the other extract treatments and the untreated control. West African black pepper extract applied at higher concentrations and more frequently could play an important role in integrated management of pests' infestations on field cowpea managed by limited resource farmers in third world countries.

Moreover, Dattaijo et al. (2019) researched the Phytochemical Screening and Preliminary Investigation on Comparative Efficacy of Sabruka and Garlic Formulations as Bio-Pesticides against Field Insect Pests of Groundnut. Field study was conducted at the research farm of Audu Bako College of Agriculture during the 2015 cropping season to investigate the efficacy of SABRUKA and garlic formulations as protectants of groundnut (*Arachis hypogaea L.*) against field insect pests. The experiment was laid out in a randomized complete block design consisting of four treatments, each replicated four times. The treatments were SABRUKA, garlic, Karate and Dimethoate (as a standard check) as well as control (untreated check). Compared to the control, the results showed a significant reduction in a number of insect pests and increased percent kill in all of the treatments, which were similar to the check, a day after spraying in the course of the four (4) spray regimes. Moreso, twenty-four hours before third and fourth applications, the results showed reduced number of insects in previously garlic-treated plots. Pod and seed yields (398 and 322 kg/ha) obtained in garlic- treated plots was significantly ($P< 0.05$) similar to those recorded in SABRUKA treated plots and both were comparable to yields from the check plots In conclusion, resource-poor farmers could use two (2) to three (3) fortnightly applications of garlic formulation or four (4) applications of SABRUKA formulation at a weekly interval, starting from flower bud formation, for the protection of groundnut against damage by field insect pests.

Another research was conducted by Frank et al. (2013) have also reported the potential of *Moringa oleifera Lam*, extracts in the control of some Field – Store Insect Pests of Cowpea. Actellic 2.5 EC at 0.20, 0.40 and 0.60 ml and *Moringa oleifera* extracts (seed and root) at 1.0, 2.0 and 3.0 ml/300 ml of water were compared for control of some field insect pests of cowpea. This was done using RCBD for field insect pests and CRD for postharvest laboratory cowpea seed screening. Results showed that only Moringa seed extracts and Actellic 2.5 EC reduced the number of field insect pests (*Megalurothrips sjostedti Trybom*, *Aphis crassivora Koch*. and *Marucavitrata Fab*.) and consequently increased pod and grain yields. Harvested seeds were screened for *Callosobruchus maculatus L*. infestation in the store. The seeds from plots sprayed with Actellic had least weevil perforation index (WPI) average of 17.76 %. This was followed by those sprayed with Moringa seed extract (42.10 %). Seeds from plots sprayed with Moringa root extract recorded 58.87 % WPI. The efficacy of the treatments was dose related. 100 % of the untreated seeds were perforated. The treatment materials had no significant effect on cowpea seed viability.

Udo and Ibanga (2019) compared the Efficacy of Aqueous Extract of three Botanicals on Corn Earworm (*Heliothis armigera*). A field research was conducted at Ikpe Annang, Essien Udim Local Government Area of Akwa Ibom State, Nigeria between March and June, 2015 to evaluate the efficacy of aqueous extract of *Azadirachta indica*, *Moringa oleifera* and *Ocimum grattissimum* on corn earworm (*Heliothis armigera*). The experiment was laid out in split plot fitted into randomized complete block design with three replicates. Aqueous extracts of the three botanicals were applied at the rates of 0, 100, 200 and 300 l/ha weekly to study the number of punch holes on leaves and the number of cobs attacked by corn earworm at 4, 6 and 8 weeks after planting (WAP), as well as grain yield. Data collected were subjected to analysis of variance (ANOVA) and significant means compared using least significant difference (LSD) at 5% probability ($p<0.05$). The results from the study showed that application of *A. Indica* and *M. oleifera* leaf extracts applied at 300 l/ha recorded fewer punch holes than *O. grattissimum* leaf extract, at different times after planting. At harvest, the application of neem leaf at 300l/ha recorded lesser number (1.49) of insect pest per cob than scent leaf (2.51) and moringa leaf (1.80) while fewer number of cobs were attacked by the insect pest. At harvest, the highest grain yield of 2.31 t/ha was recorded from maize treated with moringa leaf extract while neem leaf recorded 2.25 t/ha, as against scent leaf with the lowest yield of 1.85t/ha. The incorporation of bio-pesticides particularly neem and moringa for the management of field pests of maize is hereby advocated.

Also, Javaid Iqbal, et al. have evaluated the use of Indigenous Plant Extracts against sucking Insect pests of Okra crop. The study investigated the botanicals as an alternative approach to control sucking insect pests of okra crop. The plant extracts of eight indigenous plants viz., tumha (*Citrullus colosynthis L*.), datura (*Datura innoxia M*.), neem (*Azadirachta indica A*.), castor (*Ricinus communis L*.), hing (*Ferula asafetida L*.), eucalyptus (*Eucalyptus spp.*) bitter gourd (*Memordica charantia L*.) and garlic (*Allium sativum L*.) were tested for their potential insecticidal efficacy against sucking insect pests, jassid (*Amrasca bigutulla bigutulla I*.), whitefly (*Bemisiatabaci G*.) and thrips (*Thripstabaci L*.). The mean sucking insect population and fruit damage caused by the chewing borers was monitored to evaluate the efficacy of targeted plant extracts. It was revealed that, neem followed by garlic significantly reduce the mean population of jassid (6.31, 6.86), whitefly (7.41, 8.21) and thrips (11.99, 12.43), respectively. Neem also showed minimum fruit damage percentage (3.38%) followed by garlic (6.67%). The maximum pod yield (3178.7 kg/ha) was observed in neem treated plots. It was concluded that the plants could be the possible alternate option in insect pest management program.

Furthermore, Ndubuaku et al. (2015) reported the effects of *Moringa oleifera* leaf extract on morphological and physiological growth of cassava and its efficacy in controlling *Zonocerus variegatus*. The study was conducted in the Department of Crop Science experimental site, Faculty of Agriculture, University of Nigeria, Nsukka to investigate the effects of *M. oleifera* leaf extract (MLE) on the morphological and physiological growth characteristics of cassava (Manihot utilissima Pohl.); and its efficacy as organic insecticide for controlling *Z. variegatus* infestation. *M. oleifera* leaf extract diluted in water at the volume to volume (v/v) ratios of 1:10, 1:20, 1:30 and 1:40 were applied weekly while “Uppercut (R)” (30g dimethoate plus 250 g cypermethrin), used as water emulsifiable concentrate, was applied at the rate of 0.2 a.i./ha at three-weekly interval for two months. Result shows that *M. oleifera* leaf extract (MLE) dilution at the ratio of 1:30 MLE in water gave the highest percentage stem height difference (%SHD) at 32 weeks after planting with a value of 20.5% followed by 1:20 (17.8%), 1:10 (10.56%), dimethoate plus cypermethrin (8.98%) and 1:40 (8.05%). The control had the least %SHD and %LND. Dimethoate plus cypermethrin treatment was more efficacious as it eradicated the insects and caused significant ($p < 0.05$) increase in the number of leaves and reduction in the percentage leaf abscission especially from the thirtieth week after planting. However a combined use of Dimethoate plus cypermethrin and *M. oleifera* leaf extract may give a better result and as such recommended than a single treatment application.

Garba et al. (2018) studied the effects of some plants powders in the control of *Sotophilus zea mismostch* (Colleoptera: Curculeonidae) on stored maize (zea mays) grains at Dambatta, Kano. The experiment was conducted in the entomology laboratory of the department of Pest Management, Audu Bako College of Agriculture, Danbatta Kano, in 2018 dry season. The study was designed to assess the effectiveness of some plant materials as protectant against maize weevil (*Sitophilus zeamais Mostch*) in stored maize grains. Two plant powders of Moringa leaf and Citrus *sinensi peels* were tested under laboratory conditions at 30+-25o and 65% relative humidity. Three different dosages at 0.5g, 1.0g and 2.0g and 0.12g of the check (Primiphos methyl 2%) were applied for assessment of adult mortality, emergency and percentage grain damage. The treatments were replicated three times in a completely Randomized Design. The result indicated that citrus peels powder recorded 83.3 3-93% while that of Moringa leaf powder recorded 60.1-79.9% adult mortality. Similarly, Citrus peels recorded lowest emergence with least grain damage. Citrus peel should be used for the control of *Sytophius zea mais* on maize grains.

3.0 CONCLUSION AND RECOMMENDATIONS

3.1 Conclusion

Bio-pesticides are naturally occurring substances from living organisms (natural enemies) or their products (microbial products, phytochemicals) or their by-products (semiochemicals) that can control pest by non toxic mechanism. There are various types of bio-pesticide such as microbial pesticide, biochemicals pesticide such as microbial pesticide, biochemicals pesticide, insect pheromones, plants based extracts and essentials oils, insect growth regulators, genetically modified organisms (G.M.O). This review clearly shows that all those bio-pesticides are effective in the control of insect pest. But their efficacy is less than the conventional chemical pesticide. Their mode of action against insect pest include altering certain activities of genes and proteins, it is effective against many biological processes, it may cause a reduction in feeding habit, suspend the molting process, larvae and pupae death and also cause sterility in the emerging adult. The mode of action is slow compared to conventional chemical pesticide. It inflicts damage to the insect pest through the following mechanisms; Antibodies, competition, hyper-parasitism and synergism.

3.2 Recommendations

- Nigerian researchers should publish their research articles online for easy access by reviewers and other researchers. As most of the articles assessed by the reviewer are foreign due to inadequacy of indigenous research articles online.
- There is need for the researchers to identify safer means of improving bio-pesticides efficacy, such as using molecular based technologies and other biological techniques.
- Government need to contribute its own quota by providing necessary resources to the bio-pesticide researchers, bio-pesticides producers, e.t.c.
- More emphasis should be put on investigating not only the interaction between bio-pesticide and insect but also the interaction between bio-pesticide and other components of agro eco-system, for example plants, soil flora and fauna. e.t.c.
- Government should impose strict safety criteria on conventional chemical pesticide and this will result in fewer products on the market. This will create a real opportunity for bio-pesticide companies to help fill the gap.
- Researchers should investigate variety of our local indigenous plants for their potential use as bio-pesticide and also to compare their efficacy in order to identify the most effective against insect pest.

References

Ali, M.A.; Doaa, S.M.; El-Sayed, H.S.; Asmaa, M.E. (2017) Antifeedant activity and some biochemical effects of garlic and lemon essential oils on *Spodopteralittoralis* (Boisduval) (Lepidoptera: Noctuidae). *J. Entomol. Zool*. 5, 1476–1482.

Bajwa, Amna & Ahmad, Aftab. (2012). Potential applications of Neem based products as bio-pesticides. 3. 116-120.

Chang, J.H.; Choi, J.Y.; Jin, B.R.; Roh, J.Y.; Olszewski, J.A.; Seo, S.J.; O'Reilly, D.R.; Je, Y.H. (2003) An improved baculovirus insecticide producing occlusion bodies that contain *Bacillus thuringiensis* insect toxin. *J. Invertebr. Pathol*. 84, 30–37. [CrossRef]

Daizy R. Batish, Harminder Pal Singh b, Ravinder Kumar Kohli, Shalinder Kaur (2008) Eucalyptus essential oil as a natural pesticide. *Forest Ecology and Management* 256, 2166–2174.

Dannon, H.F.; Dannon, A.E.; Douro-kpindou, O.K.; Zinsou, A.V.; Houndete, A.T.; Toffa-Mehinto, J.; Elegbede, I.A.T.M.; Olou, B.D.; Tamo, M. (2020) Toward the efficient use of Beauveria bassiana in integrated cotton insect pest management. *J. Cotton Res*. 3, 24.

Dattijo, S. A., 1Dawakiji, A. Y., Garba, M., Musa, R. A. & Umar, A. M. (2019), Phytochemical screening and preliminary investigation on comparative efficacy of sabruka and garlic formulations as bio-pesticides against field insect pests of groundnut (*arachis hypogaea*). Proceedings of the 5th ASUP ABCOAD ANC. Pg. 239.

Feng, R., &Isman, M.B. (2005). Selection for resistance to azadirachtin in the green peach aphid, *Myzuspersicae Experientia*, *51*, 831-833.

Gonzalez-Coloma, A.; Reina, M.; Diaz, C.E.; Fraga, B.M.; Santana-Meridas, O. (2013) Natural Product-Based Biopesticides for Insect Control. In Reference Module in Chemistry, Molecular Sciences and Chemical Engineering; Elsevier Inc.: Amsterdam, The Netherlands.

Gurr, G.M.; Thwaite, W.G.; Nicol, H.I. (1999). Field evaluation of the effects of the insect growth regulator (tebufenozide) on entomophagous arthropods and pests of apples. Austr. J. Entomol. 38, 135–140.

Gwinn, K.D. (2018), Bioactive Natural Products in Plant Disease Control. In Studies in Natural Products Chemistry; Attaur, R., Ed.; Elsevier Inc.: Amsterdam, The Netherlands, Volume 56, pp. 229–246. [CrossRef]

Halder, J.; Rai, A.B.; Kodandaram, M.H. (2013) Compatibility of Neem Oil and Different Entomopathogens for the Management of Major Vegetable Sucking Pests. Natl. Acad. Sci. Lett. 36, 19–25. [CrossRef]

Huang, Zhiwei& Shi, Ping & Dai, Jianqing& Xu, Fei. (2004). Protein metabolism in Spodopteralitura (F.) is influenced by the botanical insecticide azadirachtin. Pesticide Biochemistry and Physiology. 80. 85-93. 10.1016/j.pestbp.2004.07.001.

ImeOkon Udo and Paulinus Titus Ibanga (2019). Comparative Efficacy of Aqueous Extract of three Botanicals on Corn Earworm (Heliothisarmigera). Asian Journal of Agriculture and Food Sciences (ISSN: 2321 – 1571) Volume 07 – Issue 01.

Jitendra Kumar, AyyagariRamlal, Dharmendra Mallick and Vachaspati Mishra (2021). An Overview of Some Biopesticides and Their Importance in Plant Protection for Commercial Acceptance. file:///C:/Users/Oumar/Downloads/plants-10-01185%20(3).pdf

Liang GM, Chen W, Liu TX. (2003) Effects of three neem-based insecticides on diamondback moth (Lepidoptera: Plutellidae). Crop protection. 22(2):333-340. DOI: 10.1016/s0261-2194(02)00175-8.

Magierowicz, K.; Górska-Drabik, E.; Golan, K. (2020) Effects of plant extracts and essential oils on the Inc.behavior of Acrobasisadvenella (Zinck.) caterpillars and females. J. Plant Dis. Prot. 127, 63–71. [CrossRef]

Mordue, A.J.; Morgan, E.D.; Nisbet, A.J. (2005). Azadirachtin, a Natural Product in Insect Control. In Comprehensive Molecular Insect Science; Gilbert, L.I., Ed.; Elsevier: Amsterdam, The Netherlands, pp. 117–135.

Ojiako Frank O1 ,Agu, Clifford M1 , Ahuchaogu, Christopher E (2013), Potentiality of Moringa oleifera Lam. Extracts in the Control of some Field – Store Insect Pests of Cowpea. International Journal of Agronomy and Plant Production. Vol., 4 (S), 3537-3542, Available online at http:// www.ijappjournal.com ISSN 2051-1914 ©2013 VictorQuest Publications.

Oparaeke A.M. (2007): Toxicity and spraying schedules of a bio-pesticide prepared from Piper guineense against two cowpea pests. Plant Protect. Sci., 43: 103–108.

Parker, K.M.; Barragán, B.V.; van Leeuwen, D.M.; Lever, M.A.; Mateescu, B.; Sander, M. (2019) Environmental Fate of RNA Interference Pesticides: Adsorption and Degradation of Double-Stranded RNA Molecules in Agricultural Soils. Environ. Sci. Technol. 53, 3027–3036. [CrossRef]

Parween, T.; Jan, S. Pesticides and environmental ecology. In Ecophysiology of Pesticides; Parween, T., Jan, S., Eds.; Academic Press: Cambridge, MA, USA, 2019; pp. 1–38.

Potential applications of Neem based products as bio-pesticides. Available from: https://www.researchgate.net/publication/263973149_Potential_applications_of_Neem_based_products_as_bio-pesticides [accessed Aug 01 2021].

Rikita, B and Utpal, D. (2014). An overview of fungal and bacterial biopesticides to control plant pathogens/diseases. African Journal of Microbiology Research, 8, 1749-1762.
(16) (PDF) BIOPESTICIDES FOR PESTS CONTROL: A REVIEW. Available from: https://www.researchgate.net/publication/321075197_BIOPESTICIDES_FOR_PESTS_CONTROL_A_REVIEW [accessed Aug 04 2021].

Ruiu, L. Microbial Biopesticides in Agroecosystems. Agronomy 2018, 8, 235. [CrossRef] 20. Ujváry, I. Chapter 3—Pest Control Agents from Natural Products. In Handbook of Pesticide Toxicology, 2nd ed.; Krieger, R.I., Krieger, W.C., Eds.; Academic Press: San Diego, CA, USA, 2001; pp. 109–179.

Salehzadeh, A., Jabbar, A., Jennens, L., Ley, S., Annadurai, R., Adams, R., & Strang, R. (2002). The effects of phytochemical pesticides on the growth of cultured invertebrate and vertebrate cells. *Pest management science, 58 3*, 268-76.

Salma, M. and Jogen, C. K. (2011). A review on the use of biopesticides in insect pest management. International Journal of Science and Advanced Technology, 1, 169-178.
(16) (PDF) BIOPESTICIDES FOR PESTS CONTROL: A REVIEW. Available from: https://www.researchgate.net/publication/321075197_BIOPESTICIDES_FOR_PESTS_CONTROL_A_REVIEW [accessed Aug 04 2021].

Sengottayan, Senthil-Nathan,. (2015). A Review of Bio-pesticides and Their Mode of Action Against Insect Pests. 10.1007/978-81-322-2056-5_3.

Senthil-Nathan, S., Choi, M. Y., Paik, C. H., Seo, H. Y., &Kalaivani, K. (2009). Toxicity and physiological effects of neem pesticides applied to rice on the Nilaparvatalugens Stål, the brown planthopper. Ecotoxicology and environmental safety, 72(6), 1707–1713. https://doi.org/10.1016/j.ecoenv.2009.04.024

Sporleder, M.; Lacey, L.A. Biopesticides. (2021) In Insect Pests of Potato; Alyokhin, A., Vincent, C., Giordanengo, P., Eds.; Elsevier: Oxford, UK, 2021; pp. 463–497

Suman, G. and Dikshit, A. K. (2010). Biopesticides: An eco-friendly approach for pest control. Journal of Biopesticides,3, 186-188. *(16) (PDF) BIOPESTICIDES FOR PESTS CONTROL: A REVIEW*. Available from: https://www.researchgate.net/publication/321075197_BIOPESTICIDES_FOR_PESTS_CONTROL_A_REVIEW [accessed Aug 04 2021].

Ujváry, I. (2001). Chapter 3—Pest Control Agents from Natural Products. In Handbook of Pesticide Toxicology, 2nd ed.; Krieger, R.I., Krieger, W.C., Eds.; Academic Press: San Diego, CA, USA,pp. 109–179

United Nations Department of Economic and Social Affairs, 2015, retrieved from: https://www.un.org/en/development/desa/news/2015.html

United Nations Department of Economic and Social Affairs. World Population Prospects: The 2015 Revision, Key Findings and Advance Tables; Working Paper No ESA/P/WP; United Nations Department of Economic and Social Affairs: New York, NY, USA, 2015.