KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST),

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SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

FIELD EVALUATION OF LEVO 2.4 SL (BOTANICAL) FOR THE MANAGEMENT OF INSECT PESTS OF EGGPLANT (*Solanum melongena* L.) AND OKRA *(Abelmoschus esculentus* L. Moench)

BY

JOHN PETER NYAABA AETIBA (B.Sc. Agric. Technology)

JUNE, 2015

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JOHN PETER NYAABA AETIBA (B.Sc. Agric. Technology)

A Thesis Submitted to the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana In Partial Fulfillment of the Requirement for the Degree

Of

Masters of Philosophy in Crop Protection (Entomology)

JUNE, 2015

DECLARATION

I, **John Peter Nyaaba Aetiba** hereby declare that the results of this study, except for references to other people's work, which have been duly cited, are the account of my own investigations and have not been submitted either in part or in whole for any degree elsewhere other than my master of philosophy (MPhil) degree in crop protection (entomology) at the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi-Ghana.

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ABSTRACT

Renewed interest in the use of botanical insecticides for the management of insect pests necessitated field experiments to be carried out during the major and minor cropping season at the plantation crops section of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology, (KNUST) in 2013 to evaluate insecticidal potency of Levo (botanical insecticide) for the management of insect pests of eggplant (*Solanum melongena* L.) and okra (*Abelmoschus esculentus* L. Moench). The trial comprised the following treatments: (i) Levo (a.i. Oxymatrine) at 1.68 ml /0.5 litre water, (ii) Lambda-super (a.i. Lambda-cyhalothrin) at 1.5 ml /0.5 litre water and (iii) A control (water only). *Leuninodes orbonalis* (Guen), *Bemisia tabaci* (Gennadius), *Aphis gossypii* (Glover), and *Eublemma olivacea* (Walker) were collected on eggplant and *Podagrica* spp. (Jac.), *Bemisia tabaci* (Gennadius), and *Aphis gossypii* (Glover) on okra in the study area. Significant differences ($P < 0.05$) were observed among the treatments with respect to the abundance of *A. gosspyii*, *L. orbonalis, B. tabaci* and *E. olivacea* on eggplant during the major season. Similar results were obtained in the minor season. There were significant differences ($P < 0.05$) in *Podagrica* spp., *B. tabaci* and *A. gosspyii* densities between insecticide-treated and the control plots of okra in both seasons. The damage caused by *Podagrica* species to okra leaves was significantly different ($P < 0.05$) among treatments plots in both seasons. Significantly higher yields were obtained from the insecticide-treated eggplant plots but no significant differences were obtained between insecticide-treated and control okra plots. The study showed that Levo was as effective as Lambda super and can be recommended as a substitute in the management of insect pests of eggplant and okra.

DEDICATION

This work is dedicated to the Almighty God and also to my beloved mom Awine Aetiba and late dad Aduko Aetiba and my siblings.

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This research wouldn’t have been possible without the invaluable contributions from several individuals who made this work a success. First and foremost, I am very grateful to the Almighty God for his guidance and protection which enable me to accomplish this work. For this, I offer glory to God.

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CHAPTER ONE

1.0. INTRODUCTION

Vegetables are important components of human food. Regular intake of vegetable food is indispensable for good health, fitness and the feeling of well-being (Ahmed, 2000). Vegetables are important sources of vitamin, minerals and plant proteins in human diets throughout the world (Srinivasan, 2009), and are rapidly becoming an important source of income for rural population (Alam *et al.*, 2003).

Eggplant (*Solanum melongena* L.) is a popular vegetable crop grown in the subtropics and tropics (Owusu, 1980). According to the FAO (2007), more than two million hectares are devoted to the cultivation of eggplant in the world. In Ghana it is one of the most important vegetable crops extensively cultivated especially in the forest zone, during both the major and minor seasons (Akpabi, 1989). Eggplant is a potential export crop for Ghana, but only a very small amount of the total production in Ghana is exported. However, its exports are on the ascendency. The marketable surplus of eggplant is about 20 percent of the annual production. (Asante, 2004).

Despite its importance in terms of nutrition and export potential for foreign exchange, increasing damage by arthropod pest is affecting eggplant cultivation (Alam *et al.*, 2003). A survey of vegetable pests conducted by the world vegetable center (AVRDC) indicated that *Leuninodes orbonalis* (Guen) is the most destructive pest in most major eggplant producing countries (Alam *et al.*, 2003). Other insect pests that severely constrain eggplant production in the tropics are; leaf lopper, whiteflies, thrips, aphid, spotted beetles, leaf rollers, stem borers, blister beetles, spider mites (Alam *et al.*, 2003).

Okra (*Abelmoschus esculentus* L. Moench) is a vegetable widely grown in West Africa. In Ghana, it is grown for its immature edible pods which are consumed as a vegetable. In

Northern Ghana, the leaves are cooked with other vegetables and consumed. Okra is rich in mineral salts, carbohydrates, fibre and roughage. Okra is available almost throughout the year and cultivated even in poor soils and dry areas (Anonymous, 1994). Insect pests infestation is one major factor affecting okra cultivation in Ghana.

In West Africa, the plant is attacked by two flea beetle species, *Podagrica uniformis* (Jac.) and *Podagrica sjostedti* (Coleoptera; Chrysomelidae) which are responsible for heavy defoliation (Odebiyi, 1980). Important yield losses are reported in Nigerian and Ghana (Obeng- Ofori and Sackey, 2003, Ahmed *et al.*, 2007). According to Fasunwon and Bonjo (2010), *Podagrica* species attack the lamina of the foliage and matured leaves of the Okra plant which results in the reduction of photosynthetic ability of the leaves. The insects are also responsible for transmission of mosaic virus; this infection can result in 20-50% yield reduction. Whiteflies also feed on plant sap causing okra leaf curl disease and yellow mosaic virus.

West-Africa produces more than 75% of okra produced in Africa, but the average productivity in the region is very low (2.5 t/ha) compared to East (6.2 t/ha) and North Africa (8.8 t/ha) (FAOSTAT, 2006). Nigeria is the largest producer (1,039,000 t) followed by Cote d'Ivoire and Ghana (FAOSTAT, 2008). Generally, synthetic insecticides are the most effective means of controlling insect pests due to their quick action and lasting effect (Alao *et al.*, 2009).

Although synthetic pesticides application remains the primary agricultural pest control strategy, it is evident that society cannot continue to tolerate their harmful effects on the environment and non-target organisms. One way to manage this menace is to develop pest management systems that are based on judicious application of synthetic insecticides. Thus there is the urgent need for the development of alternative control strategies (Osei Owusu, 2010).

According to Muhammed (2009), botanicals are one of the groups of safe insecticides which have a broad spectrum of anti-pest activity, relatively to specific mode of action, low mammalian toxicity and more tendency to disintegrate, in nature or metabolic in a biological system. Moreover, their preparation and application at farm level are more convenient for the farmers and are quite incorporable into integrated pest management programmes. It is based on this that Levo botanical was evaluated for its insecticidal activity for the management of insect pests of okra and eggplant.

1.1 The specific objectives were to;

i. identify the major insect pest species affecting okra and eggplant in the study area
ii. determine the effect of Levo botanical insecticide on the incidence of insect pests of okra and eggplant
iii. determine the effect of the insecticide on damage caused by the insect to okra and eggplant
iv. determine the effect of the insecticide on fruit yield of okra and eggplant

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Botany of eggplant

Eggplant (*Solanum melongena* L.) is a member of the family *Solanaceae* and is botanically related to tomato, pepper and potato. Eggplants are native to India and China but were introduced to southern Europe and the Mediterranean region by Arabic traders (Lewish, 2005). The Indians call it Brinjal and the Europeans call it Aubergine (Doijode, 2001).

Eggplants produce a bushy, vigorous plant with large leaves, woody stems and attractive flowers. Some eggplant cultivars can reach a height of 4.5 metres. Eggplants have a deep taproot, which helps them tolerate dry weather. Flowers are open for two to three days and are self-pollinated. However, insects may improve both pollination and yield of eggplant. Fruits vary in size and shape, from round to bell-shaped, oval or elongated. The fruit surface of eggplant is smooth and glossy. Fruit colour can be yellow, green, white, purple, black, violet or various combinations of these colours. Eggplant is well adapted to high rainfall and high temperatures, and is among the few vegetables capable of high yields in hot-wet environments (Hanson *et al.*, 2006).

2.2. Varieties of eggplant

The name eggplant is derived from the shape of the fruit of some varieties, which are white and shaped, very similar to chicken eggs. There are three main varieties under the species *melongena*. The round or egg-shaped cultivars are grouped under var. *esculentum* (common eggplant). The long, slender types are included under var. *serpentinum* (snake eggplant) while the small and straggling plants are put under var. *depressum* (dwarf eggplant) (Choudhury, 1976).

2.3. Eggplant production in Ghana and the world

Eggplant is one of the top ten vegetables in the world. It is grown on more than two million hectares with a production of nearly 33 million tons per annum (FAO, 2007). According to FAO (2010), production of eggplant is highly concentrated, with 90% of output coming from five countries.

China is the top producer (58 % of world output) and India is second (25%), followed by Egypt, Iran and Turkey. Asia accounts for about 94% of the world eggplant area, with about 92% of world output (FAO, 2007). India and Indochina are considered the centres of origin for eggplant (Vavilov, 1951).

In 2008, a total land area of 1,600 ha was used for the cultivation of eggplant in Ghana. This yielded 37,500 metric tons per ha with a total export of 19,500 metric tons to USA and this earned the country 3,671,000 US dollars (FAO, 2009). The Ashanti Region is the leading producer in Ghana followed by the Volta Region (FAO, 2009).

2.4 Economic importance of eggplants

Rural and urban families in Ghana consume eggplant on a daily basis and it also represents a main source of income for many rural households in the forest zone of the country as about 60% of house-hold income comes from eggplant production (Danquah-Jones, 2000; Owusu-Ansah *et al.,* 2001). The unripe fruit of eggplant is primarily used as a cooking vegetable for various dishes in different regions of the world (Grubben and Denton, 2004). It may contain certain medicinal properties; white eggplant for example is good for diabetic patients. The fried fruit has been reported to cure toothache. It has also been recommended as an excellent remedy for those suffering from liver complaints (Chen and Li, 1996).

According to Hajiya (2013) eggplant has an anti-ulcer remedy, which can be used as treatment for ulcer. High consumption of eggplant is also recommended for glaucoma patients because it serves as an antioxidant, which prevents cells in the body from damage. Eggplant leaves can also be used in treating snake bites, which indicates that every part of the plant is useful.

2.5 Nutrient composition of eggplant fruit

According to Horna *et al.* (2006) eggplant is one of the important vegetable crops in West Africa and probably the third most consumed vegetable in Ghana. It is an excellent source of digestion-supportive dietary fiber and bone-building manganese. It is very good source of enzyme-catalyzing molybdenum and heart-healthy potassium. Eggplant is also a good source of bone-building vitamin K and magnesium as well as heart-healthy copper, vitamin C, vitamin B6, folate, and niacin. Eggplant also contains phytonutrients such as nasunin and chlorogenic acid. The crop also contains phytonutrients such as nasunin and chlorogenic acid (Horna *et al.*, 2006)

2.6. Constraints to eggplant production in Ghana

2.6.1. Major pests of eggplant

In the tropics, eggplant production is severely constrained by several insect and mite pests. The major pests include eggplant fruit and shoot borers, leafhoppers, whiteflies, thrips, aphids, spotted beetles, leaf rollers, stem borers, blister beetle and red spider mites.

Growers rely heavily on chemical pesticides to protect their eggplant. For instance, farmers in certain areas of Philippines spray chemical insecticides up to 56 times during a cropping season; the total quantity of pesticide used per ha of eggplant was about 41 litres of different brands belonging to the four major pesticide groups (Gapud and Canapi 1994; Orden *et al.,* 1994). In Bangladesh, some farmers spray about 180 times during a cropping season (SUSVEG-Asia, 2007).

2.6.2 Major diseases of eggplant

Diseases that are found in eggplant are mostly caused by bacteria, viruses, fungi and nematodes. The leaf spot disease in eggplant is either caused by *Alternaria* spp. or *Cercospora* spp. This disease causes the leaves to drop off prematurely resulting in the reduction of yield. Bacterial wilt disease (*Pseudomonas solanacearum)* causes a severe problem in eggplant cultivation in the subtropics and tropics. Once it becomes well established, it can be one of the most destructive pathogens known (Chen and Li, 1996).

The fungi *Pythium* spp., *Phytophthora* spp. and *Rhizoctonia* spp. cause damping-off disease in young seedlings, where the affected tissues rot and the seedlings die. The fungus *Phomopsis vexans* causes Phomopsis blight disease in eggplant. This disease occurs in the stems, leaves and fruits of the plant causing the plant to break off or to wilt and die (Chen and Li, 1996).

Eggplant is highly susceptible to the nematode *Meloidogyne*. Plants attacked become stunted, and their leaves show yellowing or chlorotic symptoms. The infestation is also easily recognized by the characteristic root galls (Chen and Li, 1996). There are several viruses that infect eggplant under natural conditions and produce mosaic symptoms. They are cucumber mosaic virus (CMV), potato virus Y (PVY), potato virus X (PVX) and tobacco ring spot virus (TRSV), etc. Plants infected with the virus are generally stunted in growth and show mosaic symptoms on leaves (Chen and Li, 1996).

2.7. Botany of Okra

Okra, *A. esculentus* is a vegetable widely grown in West-Africa. It is also termed as lady's finger and belongs to the Malvaeceae family (Anonymous, 1994). The plant is thought to be native to an area extending from Ethiopia to the Sudan. Its early history and distribution are not known, but it was apparently introduced into Egypt in the seventh century. Okra then was carried through North Africa and areas bordering the Mediterranean and eastward (Ahmed, 2000).

Okra is an annual, erect herb up to 5 m (but typically about 2 m) tall. Stems are succulent with scattered, stiff hairs. The whole plant has an aromatic smell resembling cloves. The leaves grow up to 50 cm wide and 35 cm long, deeply lobed, with toothed margins, hairy on both surfaces, especially on the nerves. Each leaf is borne on a petiole (leaf stalk) up to 50 cm long. Flowers are showy, up to 8 cm in diameter, usually yellow with a dark red, purple or mauve centre, borne on a stout flower stalk (peduncle) up to 4 cm long. Stamens (male parts) are united into a white, hairless column up to 2.5 cm long. Stigmas (female parts) are dark purple, Calyx (whorl of sepals) and epicalyx (whorl of bracts) are both present. Okra fruits are capsule, 10–20 cm long, roughly circular in cross-section with a pointed end, usually 5-ribbed, borne at the leaf axils. Immature fruit can be purple-red, reddish-green, dark green, pale green or yellow. At maturity, fruits turn brown and split into segments (Düzyaman, 2010).

Okra is warm season crop growing best during summer with irrigation or during rainy season, but can be grown all-year-round in tropical, subtropical and temperate zones. It thrives in a wide range of soils as long as they are well drained. Time to maturity is 45-

50 days after sowing. The harvest season continues for 3-4 months. Only the younger pods 2-3 days after flowering are desired in the market, as the older ones become tough and woody. More frequent harvest results in more yields, a longer picking period and better quality produce (Ahmed, 2000).

2.8. Varieties of okra

Okra is a cultigen (a plant that has been altered by humans through a process of selective breeding). Some of the popular okra cultivars in Ghana are Indiana, Saloni (F1), Asontem and Torkor.

2.9. Okra production in Ghana and the world

The total area and production under okra is reported to be 1.148 million hectares yielding 7896.3 thousand tons. It is mainly grown in India, Nigeria, Sudan, Pakistan, Ghana, Egypt, Benin, Saudi Arabia, Mexico and Cameroon. Largest area and production is in India followed by Nigeria. Highest productivity is reported from Egypt (12.5 tons/ha) followed by Saudi Arabia (13.3 tons/ha). Ghana recorded a yield of (3.90 tons/ha) (FAOSTAT, 2008).

2.10. Economic importance of okra

The roots and stems of okra are used for cleaning the cane juice from which gur or brown sugar is prepared (Chauhan, 1972). Its ripe seeds are roasted, ground and used as a substitute for coffee in some countries. Mature fruits and stems containing crude fibre are used in the paper industry.

Extracts from seeds of okra are viewed as alternative source of edible oil. The greenish yellow edible oil has a pleasant taste and odour, and is high in unsaturated fats such as oleic acid and linoleic acid. The oil content of the seed is quite high at about 40% (Chauhan, 1972).

2.11. Nutrient composition of okra fruit

Okra provides an important source of vitamins, calcium, potassium and other mineral which are often lacking in the diet of developing countries. The composition of edible portion of okra contains moisture 89.9g, protein 1.9g, calcium 66g, fibre 1.2g, sulpur 30mg etc (Gopalan *et al.*, 2007). Okra is reported to be very useful against genito-urinary disorders, spermatorrhoea and chronic dysentery (Nandkarni, 1927). Its medicinal value has also been reported in curing ulcers and relief from haemorrhoids (Adams, 1975).

2.12. Constraints to okra production in Ghana

2.12.1. Major pests of okra

In West-Africa, the plant is attacked by two flea beetle species, *P. uniformis* and *P. sjostedti* which are responsible for heavy defoliation (Odebiyi, 1980). Flea beetles infest the seedlings and can cause damage of economic importance by feeding on the leaves. If more than 2-3 individuals appear per seedling, then chemical control measures should be initiated.

Whiteflies (*B. tabaci*), Jassids (*E. lubica*) and Aphids (*A. gossypii*) also attack okra. These pests infest leaves, stems, branches and pods during the dry season. Pods and flowers are primary targets of spiny bollworm (*Earias insulanaa*), while the caterpillar of the American bollworm (*Heliothis armigera* Hubner) prefers the reproductive parts of the plant, including buds, flowers and fruits. Control measures against this pest are only recommended in intensive production areas (Ahmed, 2000).

2.13. Biology of major pests of eggplant and okra

2.13.1. Eggplant fruit and shoot borer (*Leuninodes orbonalis* Guenee)

Biology

The adult females lay eggs singly or in groups of two to five on the under surfaces of leaves, tender shoots, flower buds, or the base of developing fruits. Each female lays about 250 eggs, which are creamy white soon after laying, but turn red before hatching. The egg period is three to five days. The larva is creamy white to pink in colour in the early stages. The grown-up larva is pink with sparse hairs on the warts on the body and a dark brown or blackish head. The full-grown larva measures about 16-23 mm in length. The larva usually has five instars, sometimes six. The larval period is about two weeks in summer and three weeks in winter (Srinivasan, 2009).

The larva pupates on the plant parts or plant debris on the soil surface, or rarely, under the soil. The pupation occurs in tough silken cocoons, and the pupa is dark brown in colour. The pupa measures about 13 mm. The pupal period varies from one to two weeks. The moth is white or dirty white with pale brown or black spots on the dorsum of thorax and abdomen. Wings are white with a pink or blue tinge, and have pink or brown and red spots on the forewings. The female is bigger than male, with a bulged abdomen. The female moth tends to curl its abdomen upwards. The adult life span is about a week; the females live longer than males (Srinivasan, 2009).

Plate 2.1. Shoot (left) and fruit (right) damaged by larva of eggplant shoot and fruit borer

2.13.2. Whitefly (*B. tabaci)*

Biology

The females mostly lay eggs near the veins on the underside of leaves. They prefer hairy leaf surfaces to lay more eggs. Each female can lay about 300 eggs in its lifetime. Eggs are small (about 0.25 mm), pear-shaped, and vertically attached to the leaf surface through a pedicel. Newly laid eggs are white and later turn brown. The eggs are not visible to the naked eye, and must be observed under a magnifying lens or microscope. Egg period is about three to five days during summer and 5 to 33 days in winter (David, 2001).

Upon hatching, the first instar larva (nymph) moves on the leaf surface to locate a suitable feeding site. Hence, it is commonly known as a “crawler.” It then inserts its piercing and sucking mouthpart and begins sucking the plant sap from the phloem. The first instar nymph has antennae, eyes, and three pairs of well developed legs. The nymphs are flattened, oval-shaped, and greenish-yellow in colour (David, 2001).

The legs and antennae are atrophied during the next three instars and they are immobile during the remaining nymphal stages. The last nymphal stage has red eyes. This stage is sometimes referred to puparium, although insects of this order (Hemiptera) do not have a perfect pupal stage (incomplete metamorphosis). The adult whitefly is a soft-bodied, moth-like fly. The wings are covered with powdery wax and the body is light yellow in colour. The wings are held over the body like a tent. The adult males are slightly smaller in size than the females. Adults live from one to three weeks (David, 2001).

2.13.3. Aphid (*A. gossypii*)

Biology

Unlike many insects, most aphids do not lay eggs. They usually reproduce through parthenogenesis (development of embryo without mating with males) and are viviparous (give birth to nymphs directly rather than eggs). The adult colour is highly variable and it varies from light green to greenish brown. Both wingless and winged forms occur. Winged forms are produced predominantly under high population density conditions, inferior host plant quality, etc. The wingless forms are more common. They possess a pair of black-colored cornicles on the dorsal side of the abdomen. Aphids mostly are found in groups. Each female produces about 20 nymphs a day, which become adults in a week (Srinivasan, 2009)

2.13.4 Leaf rollers (*Eublemma olivacea* Walker)

Biology

The females lay eggs mostly on the younger leaves in groups and each group consists of 10-20 eggs. The egg period is three to five days. The larva is stout and purple brown in colour with long hairs on yellow or cream coloured tubercles in the dorsal and lateral sides of the body. The larval period is two to three weeks. The full-grown caterpillars pupate within the folded leaves. The pupal period is about 7-10 days. The medium-sized moth is olive green in colour. The forewing is green, with a large triangular spot on the outer area toward the apex (Srinivasan, 2009)

2.14 Management of insect pests of eggplant and okra

2.14.1 Cultural control

Farmers adopt various measures to manage insect pests on eggplant and okra and these include removal of weeds and alternative hosts during the dry season to reduce infestation, crop rotation, intercropping with other crops and the use of tolerant or resistant cultivars. The sprinkling of ash and the broth of goat faeces on the leaves of eggplant and okra is also used to prevent feeding by pests.

2.14.2 Mechanical or manual control

Mechanical or manual method of pest management involves the use of physical force with or without the aid of special tools. This technique is aimed at removing, injuring, killing, scaring or making growing condition of pests unfavorable. Some of the common practices including erecting mechanical barriers, cleaning of planted areas prior to, during or after the cropping season (also termed sanitation) and denying pests alternate sources of food. Mechanical control techniques give immediate and tangible results; it is however time consuming.

2.14.3. Host plant resistance

Insect-resistant cultivars are used by vegetable farmers to reduce pests infestation. This is because pest-resistant varieties are specific to a particular pest, cumulative (lower number of pest over time because of low fecundity), easy to adopt, relatively inexpensive, easy transferability to farmers' fields, no danger to humans and domestic animals, and compatibility with all other control practices. However, it is not available in all situations.

2.14.4 Biological control

This involves the use of natural enemies to keep pest populations within reasonable level under natural conditions. Most of these natural enemies can be other arthropods, or entomopathogens such as fungi, bacteria, viruses, or nematodes.

2.14.5 Chemical control

The use of insecticides is currently the main method of pests control by most farmers to prevent pests population from getting to economic injury level. Contact insecticides are the most commonly used and show varying degrees of efficacy against the pest (Yein, 1985; Paul and Ghosh, 1990). Deltamethrin, Endosulfan, Dimethoate, Cypermethrin and a host of other synthetic insecticides are some of the chemicals used across the world to manage pests of eggplant and okra (Thanki and Patel, 1991).

2.15. Plants with insecticidal properties

Over the past 50 years, more than 2,000 plant species belonging to different families and genera have been reported to contain toxic principles, which are effective against insects (Isman, 1997). Twenty-five of these plants species pose the characteristics required for an ideal botanical insecticide and are therefore more promising for use in organic pest control programmes (Radhakrishnan, 2005).

Secondary products from higher plants represent an enormous diversity of biologically active compounds that have been exploited as pesticides. However, these products received only the most rudimentary entomological study and few were subjected to detailed chemical examination, although, active principles were isolated. Recently, studies have been intensified on the use of naturally occurring pesticides for pest control. Many investigators isolated, identified and screened chemical compounds from leaves and seeds of many botanical families for insect deterrence and growth inhibition. Some of the anti-pest plants documented included Neem, Chrysanthemum, Annona, Mahogoni, Albizzia etc (Reed *et al.*, 1982).

Neem (*Azadirachta indica*): Neem has emerged as the single most important source of botanical insecticides having a wide control of numerous insects, mites, fungi, nematodes and viral diseases. Neem is a natural source of eco-friendly insecticides, pesticides and agrochemicals (Brahmachari, 2004). Neem products have no ill effects on humans and animals and have no residual effect on agricultural produced (Reed *et al.*, 1982).

Chrysanthemum *(Chrysanthemum cinerariafolium)*: It is extracted from the dried flowers of *Chrysanthemum.* Pyrethrum or natural pyrethroid is a mixture of six different substances. The main active principle is the alkaloid stachydrine. It has the ability to paralyse the pests on contact. Pyrethrum can be effectively used to control sucking pests like Tea mosquito bugs, thrips, aphids, scale insects etc (Reed *et al.*, 1982).

Annona (*Annona squamosa*): The leaves and seeds of this plant contain lanolin and anonaine having insecticidal properties. The seeds are to be dried, powdered and made into a solution by mixing with water or alcohol for application. It is useful against stem borer, sucking pests, scale insects etc. The aqueous leaf extract of annona has antifeedant activity (66-82%) against *Helopeltis* (Gurusubramanian *et al.*, 2008).

Mahogoni (*Swietenia mahagoni*): The seeds of the Mahogoni plant are very toxic to insect pests and pathogens. The extracts are very effective for the control of *Helopeltis* and Red spider mites in tea (Mamun and Ahmed, 2011).

Albizzia *(Albizzia procera)*: The crude extracts of the seeds of *A. procera* are very effective against coleopteran insects like beetles and weevils (Gurusubramanian *et al.*, 2008).

2.16. Botanicals used for the management of insect pests.

Many entomologists have explored naturally occurring insecticidal plants and have discovered some of them to be effective against some insect pests. Alao *et al.* (2009) evaluated the insecticidal potential of organic compost extracts against insect pests of okra (*A. esculentus)*. The extracts were applied to the foliage to control *Podagrica* species, *Zonocerus variegatus* and *Bemisia tabaci* on okra with efficacy ranging from 60% to 80%. Results of the study suggest that organic composts especially maize stover compost can be used as insecticide in organic farming system to raise okra plant.

Mohamed-Ahmed (2000) also studied the effectiveness of different neem formulations against the major insect pests complex and on yield of okra (*Hibiscus esculentus),* tomato (*Lycopersicon escculentum),* and onion (*Allium cepa)* and found that the product reduced the number of *A. gossypii*, *B. tabaci.* Similarly, the number of plants infested by the larvae of the spotted boll worm, *Earias vittella* and the number of leaves damaged by *P. puncticollis* adults also reduced significantly. Against the insect pest complex of tomato, neem formulations reduced the number of the leaves damaged by the larvae of the leaf miner *Liriomyza trifolii* significantly, while it reduced the number of aphids by 40% and the number of whiteflies by 33%. The product also increased the weight of onion by 15% over the control.

Daniel (2010) investigated the bioactivity of ethanolic leaf extract (*Annona muricata)* against *L. orbonalis* on eggplant in the field and reported that even though the extract could not completely prevent damage to shoots, flowers and the fruits of the eggplant, it significantly reduced the damage.

2.17. Botany of *Sophora flavescens* plant

Sophora flavescens Aiton (Leguminosae) is an ancient Chinese herb that grows wild in China. The dry root of the plant is commonly called Ku Shen. About two dozen alkaloids have been identified in Ku Shen, with matrine and oxymatrine being the major compounds. The plant is a dwarf-shrub, 50 to 120 cm high. Root is cylindrical and yellow in appearance. Stems are herbaceous, green, and with yellow hair when young and irregular longitudinal groove. Pinnately compound leaves are odd, alternate, and with linear stipules underneath; blade is from 20 to 25 cm long and with pubescent axis; leaflets are 5 to 21, with a short handle, ovate-elliptic to oblong-lanceolate, rounded or blunt-tipped apex, rounded or wedge-shaped base (Mao and Henderson, 2007).

Racemes are acrogenous, short-haired, 10 to 20 cm long; bracts are linear; flowers are yellowish white; calyx is bell-shaped and slightly oblique; corolla looks like butterfly. Pods are linear and the apex has a long beak. Seeds usually are three to seven, black, nearly spherical, and with constriction between seeds. It flowers from May to July and fruits from July to September.

Habitats are places exposed to the sun, including grassy hillside, plains, roadsides, sandy soil and red soil (Mao and Henderson, 2007).

Plate 2.2 *Sophora flavescens* plant and roots

2.18. Insecticidal properties *of Sophora flavescens plant*

A lot of chemical compounds have been extracted from the root and other parts of the sophora flavescens plant. Sophora root mainly contains alkaloids, flavonoids, quinones, and triterpenoid saponins. Alkaloids contain matrine, oxymatrine, sophoridine, sophoranol, sophoramine, etc.

Flavonoids and alkaloids have shown both insecticidal and antibacterial properties. They have been used for the treatment of medical conditions, such as skin disease, intestinal worms and inflammation of the eye (Pinto, 2002). Antifeedent activity, acute and residues toxicity of alkaloids from *Sophora flavescens* against *Formosa subterranean* termites were reported by Henderson (2007). In a screening study of Chinese medicinal herbs against two stored-grain insects, the methanol extract of *Sophora flavescens* has represented contact toxicity and feeding-deterrent activities (Liu *et al.*, 2007).

A formulation called Exodus containing extracts of a leguminous plant *Sophora flavescens* was found to be very effective against red spider mites in tea. Sophora root extracts (Levo) have been found to be a stomach poison with anti-feeding and repelling activity. It may act as a crop growth stimulant and control agent for downy mildew. Sophora root extract is essentially free of environmentally harmful chemicals and is effectively nontoxic to people and livestock. Residual effectiveness of *Sophora* root extract lasts for 15 days and target pests do not develop resistance easily (Muarleedharan, 2005)

2.19. Economic importance of *Sophora flavescens*

Sophora flavescens is economically important in many areas especially health. It has been used frequently for the treatment of diarrhoea, gastrointestinal haemorrhage and eczema (Zhang *et al.*, 2007). Prenylflavonoids are major components of *Sophora radix* which has a wide range of biological functions and has been reported to contain prenylated flavonoids (Yamazaki, 2000). In animal studies, the alkaloid matrine was found to be as effective as methylxanthine bronchodilator aminophylline without its stimulatory side effects. Oxymatrine was also found to inhibit histamine release in mice. Sophocarpine, another alkaloid in Ku Shen (Root of *Sophora flavescens*) was found be antitussive, inhibiting the urge to cough, while its flavone compounds demonstrated expectorant effects.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Experimental Site

The study was conducted in both major and minor crop growing seasons at the Faculty of Agriculture plantation site of the Kwame Nkrumah University of Science and Technology (KNUST). The major growing season lasted May to September, 2013 while the minor season spanned late September to December 2013. Average annual rainfall collected in the major season was 850.5 mm and the minor season recorded 640.5 mm. The soil texture was sandy loam; average temperature range and humidity range recorded during the study were 21.9 ^{o}C and 84% for the major season and 31.1^{o}C and 71 % during the minor season (KNUST- DAE, 2013).

3.2. Source of seeds

The variety of eggplant used was the local Aworoworo and that of the okra was Asontem which were obtained from the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI), Kwadaso, Kumasi. These varieties are improved but both are susceptible to insect pests and diseases.

3.3. Land preparation

The experimental field was first sprayed with Adom 480 SL weedicide at of 300 ml to control weeds. The land was then ploughed and disc-harrowed to fine soil. The field was lined and pegged prior to transplanting of the eggplant and sowing of okra.

3.4. Field layout and experimental design

The field was laid out in a randomized complete block design (RCBD) with three treatments. Each plot measured 5 m x 5 m with inter and intra-row spacing of 1 m x 0.5 m. A 1.5 m alley was allowed between the plots so as to minimize spray drifts to adjacent plots.

3.5. Transplanting and sowing of seed

Eggplant seedlings were transplanted when they were four weeks old (one seedling per stand). Replacement of dead seedlings was carried out a week after transplanting. Okra seeds were sown directly. Prior to the sowing, the seeds were soaked in water overnight to facilitate field germination. The seeds were sown two or three per hole at a depth of 3 cm with a cutlass and later thinned after full emergence to one or two plants per hill. Each plot contained five rows with 10 plants per row, giving a total of 50 plants per plot for both crops.

Three treatments, each with three replications were used.

(i) Levo (a.i. Oxymatrine) at 1.68 ml / 0.5 litre water

(ii) Lambda super (a.i. Lambda-cyhalothrin) at 1.5 ml / 0.5 litre water

(iii) Control (water only)

3.6. Cultural practices on eggplant and okra fields

The normal agronomic practices (e. g. weeding, irrigation, fertilization) were carried out. Manual weeding was done at three weeks interval for both crops. The fields were irrigated as and when necessary since rainfall was erratic. Fertilizer was applied in two splits. The first dose of N: P: K 15: 15: 15 was applied three weeks after transplanting of eggplant and sowing of okra at a rate of 10/g per plant while Urea (46 % N) at 2.2 g per plant was applied three weeks later.

3.7. Sampling for insect pest infestation on eggplant fields

Sampling for insect pests was done on weekly basis between 0800 – 1100 h when the insects' build-up was high. Sampling was done on five plants randomly selected from the three middle rows per plot. For *B. tabaci*, sampling involved visual examination of each plant and the number of insects on two leaves were recorded. This was done for the first two weeks of sampling but thereafter three leaves were examined with the aid of a magnifying lens. For the other insects, namely *A. gossypii*, *E. olivacea*, and *L. orbonalis*, three leaves from both the upper and lower canopies were collected into high density polyethylene bottles containing 70% ethanol. These were transported to the insectary for processing and identification using a stereo microscope. Insecticide application was done after sampling.

3.8. Sampling for insect pests infestation on okra fields

The procedure described previously in 3.6 for sampling of *B. tabaci* was also used for sampling *Podagrica* spp and *B. tabaci* on okra fields while *A. gossypii* followed the same sampling technique used for *A. gossypii*, *E. olivacea,* and *L. orbonalis*.

3.9. Estimation of fruit yield

Okra and eggplant fruits were harvested every three or four days when they reached maturity and then weighed using a Switzerland-made Metler Toledo PB302 electronic weighing scale in the laboratory. The results obtained for each treatment were then extrapolated to kilograms per hectare (kg/ha) using the formula:

Fruit yield/ha $= \frac{1000}{\text{area harvested}} \times$ fruit yield/plot (Asante *et al.*, 2001).

3.10. Yield and Yield Components Assessments

The following data were also taken; number of fruits per plant, weight of fruits per plant and yield. Damaged fruits included all okra and eggplant fruits that had injuries or blemishes apparently caused by insects.

3.11. Estimation of percentage defoliation on okra

Damage caused by the flea beetles (*Podagrica* spp.) on okra leaves was based on estimates of defoliation (Banful and Mochiah, 2012) A leaf each from the top, middle and low canopy levels of 5 randomly selected plants on each plot were compared to a chart of leaves graded 5%, 10%, 20%, 30%, 40% and 50% depending on the level of damage through a critical observation of the leaves and sections of the leaves that have lost virtually all the photosynthetic sites (scarified leaves or holes) through the feeding habits of the flea beetles and the mean level of defoliation recorded. The percentage defoliation was then estimated using the formula:

$$\%\text{Defoliation} = \frac{\text{Total number of leaves defoliated}}{\text{Total number of leaves in a sample}} \times 100$$

3.12. Data analysis

Insects data were transformed using square root transformation and percentages by arcsine transformation and then analysed using Analysis of Variance (ANOVA) with the statistix software, version (9.0). Defoliation data was also analysed using Analysis of Variance. The treatment means were separated using Tukey at 5% probability.

CHAPTER FOUR

4.0. RESULTS

This chapter reports the results obtained from the field experiment on insect pests of the two crops.

4.1. Insect Pests collected on eggplant in the major season in 2013

There were significant differences ($P < 0.05$) among treatments with respect to abundance of *B. tabaci* and *A. gossypii* (Table 4.1). There were also significant differences ($P < 0.05$) in the population of *L. orbonalis* and *E.olivacea* between insecticide-treated plots and control. However, there was no significant difference ($P > 0.05$) between the insecticide-treated plots with respect to *L. orbonalis* and *E. olivacea* densities. Significant difference was also recorded on plots treated with Levo and Lambda super with respect to *A. gosspyii* and *B. Tabaci* abundance (Table 4.1).

4.2. Insect Pests collected on okra in the major season in 2013

There were significant differences ($P < 0.05$) in *Podagrica* spp. *B. tabaci* and *A. gossypii* densities between insecticide-treated plots and the control (Table 4.2). Among the insecticide treated plots, there were significant differences ($P < 0.05$) in the aggregations of *Podagrica* spp. *B. tabaci* and *A. gossypii* in plots treated with Levo and Lambda super (4.2).

Table 4.1: Mean number of insect pests collected on eggplant (*Solanum melongena*) as affected by insecticides treatment in the major crop growing season in Kumasi in 2013

	Mean number (± SEM) of insect per plant.			
Treatment	*A. gosspyii*	*B. tabaci*	*L. orbonalis*	*E. olivacea*
Levo	1.17 ± 0.07 ^{c}	1.67 ± 0.05 ^{c}	0.88 ± 0.28 ^{b}	0.80 ± 0.02 ^{b}
Lambda Super	2.75 ± 0.21 ^{b}	2.29 ± 0.09 ^{b}	0.80 ± 0.21 ^{b}	0.85 ± 0.25 ^{b}
Control	5.32 ± 0.32 ^{a}	2.97 ± 0.12 ^{a}	1.39 ± 0.45 ^{a}	1.39 ± 0.04 ^{a}

Means with the same letter in a column are not significantly different from each other ($P < 0.05$, Tukey test)

Table 4.2: Mean number of insect pests collected on okra (*Abelmoschus esculentus*) as affected by insecticides treatment in the major crop growing season in Kumasi in 2013

	Mean number (± SEM) of insect per plant.		
Treatment	*Podagrica* spp	*B. tabaci*	*A. gossypii*
Levo	2.29 ± 0.62 ^{c}	1.62 ± 0.04 ^{c}	0.99 ± 0.67 ^{c}
Lambda Super	2.61 ± 0.07 ^{b}	1.99 ± 0.06 ^{b}	1.79 ± 0.19 ^{b}
Control	4.02 ± 0.10 ^{a}	3.44 ± 0.09 ^{a}	4.90 ± 0.27 ^{a}

Means with the same letter in a column are not significantly different from each other ($P < 0.05$, Tukey test)

4.3. Insect Pests collected in the minor season on eggplant in 2013

The effect of the different treatments on the abundance of insect pests on eggplant in the minor season is presented in (Table 4.3). It was observed that there were significant differences (P < 0.05) between insecticide-treated and the control plots with respect to densities of *A. gosspyii*, *B. tabaci*, *L. orbonalis*, and *E. olivacea* (Table 4.3). There was also significant difference (P < 0.05) in the number of *A. gosspyii*, *B. tabaci*, and *L. orbonalis* among insecticide-treated plots (Table 4.3).

4.4. Insect Pests collected in the minor season on okra in 2013

In the minor season, significant differences (P < 0.05) were recorded in *Podagrica* spp. *A. gossypii* and *B. tabaci* densities between treatments means (Table 4.4). There were also significant differences observed in the aggregations of *B. tabaci*, *Podagrica* spp and *A. gossypii* among insecticide-treated plots and the control.

Table 4.3: Mean number of insect pests collected on eggplant (*Solanum melongena*) as affected by insecticides treatment in the minor crop growing season in Kumasi in 2013

	Mean number (± SEM) of insect per plant.			
Treatment	*A. gosspyii*	*B. tabaci*	*L. orbonalis*	*E. olivacea*
Levo	1.14 ± 0.61 c	1.61 ± 0.04 c	0.05 ± 0.03 c	0.89 ± 0.03 c
Lambda Super	1.88 ± 0.11 b	2.22 ± 0.04 b	1.32 ± 0.05 b	1.06 ± 0.04 b
Control	3.45 ± 0.16 a	2.67 ± 0.05 a	1.50 ± 0.05 a	1.50 ± 0.05 a

Means with the same letter in a column are not significantly different from each other (P < 0.05, Tukey test)

Table 4.4: Mean number of insect pests collected on okra (*Abelmoschus esculentus*) as affected by insecticides treatment in the minor crop growing season in Kumasi in 2013

Treatment	Mean number (± SEM) of insect per plant.		
	Podagrica spp	*B. tabaci*	*A. gossypii*
Levo	1.77 ± 0.03^{c}	1.99 ± 0.03^{c}	1.56 ± 0.07^{c}
Lambda Super	2.33 ± 0.04^{b}	2.24 ± 0.03^{b}	2.44 ± 0.10^{b}
Control	3.30 ± 0.06^{a}	2.76 ± 0.05^{a}	5.86 ± 0.21^{a}

Means with the same letter in a column are not significantly different from each other ($P < 0.05$, Tukey test)

4.5. Effect of Insecticide Treatments on Insect Pests Population dynamics on eggplant.

Whiteflies (*B. tabaci*)

In the major season, the density of *B. tabaci* in Levo treated plots increased slightly after the first application on 25th July and remained steady till 29th August. However, there were weekly increases in *B. tabaci* numbers in plots treated with Lambda-super and the Control till 22nd August when its density declined before a slight increase on 29th August.

In the minor season, the mean number of *B. tabaci* on Levo-treated plots was about 1.7 per leaf and reduced to 1.5 per leaf after 5th November treatment till the last spray application on 22th November. However, plots sprayed with Lambda super and the Control had increases in *B. tabaci* numbers after the 1st, 2nd and 3rd spray application which reduced slightly after 5th November. Control plots had a mean number of three *B. tabaci* per leaf at the end of spray regime on 26th November (Figure 4.2). In general, the major season recorded a high density of *B. tabaci* with about four per leaf as compare to three per leaf in the minor season (Figure 4.2)

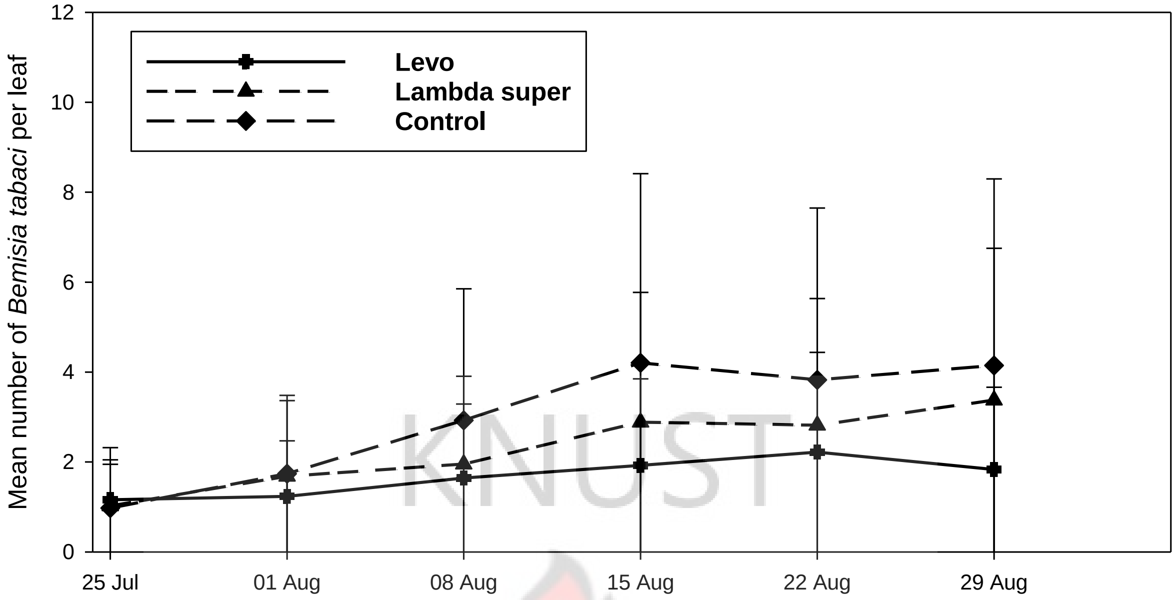

Figure 4.1: Effect of insecticides application on mean number of *B. tabaci* per eggplant (*Solanum melongena*) in the major season in Kumasi in 2013.

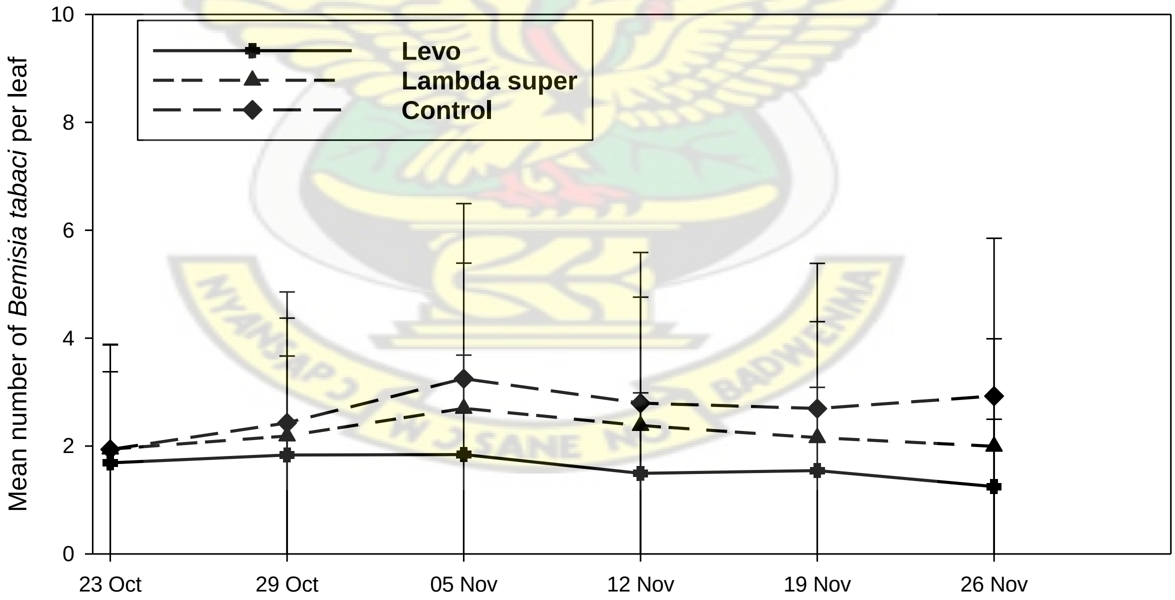

Figure 4.2: Effect of insecticides application on mean number of *B. tabaci* per eggplant (*Solanum melongena*) in the minor season in Kumasi in 2013.

Aphids (*A. gossypii*)

The number of *A. gossypii* started to increase after the second insecticide application in all the treatments with a density of about 10 per leaf recorded in the control. The aggregations of *A. gossypii* in the insecticide treated plots were less than six throughout the sampling period in the major (Figure 4.3).

In minor season, *A. gossypii* numbers in the insecticide treated plots were between 1.5 and 3.0 per leaf whilst that in the control plots, a density of about six per leaf were recorded by 26th November, 2013 (Figure 4.4)

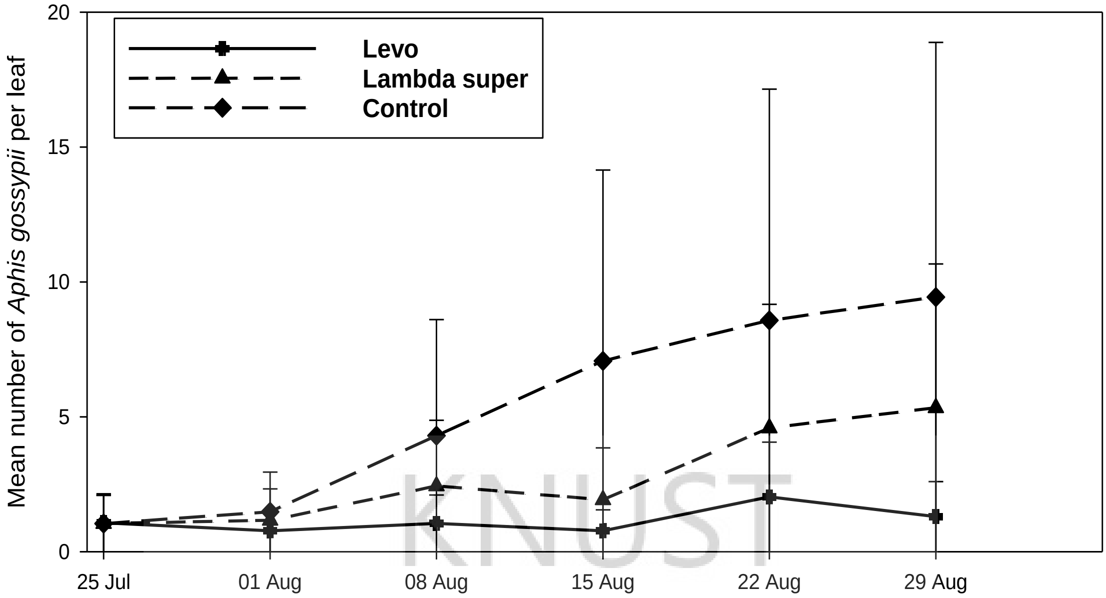

Figure 4.3: Effect of insecticides application on mean number of *A. gossypii* per eggplant (*Solanum melongena*) in the major season in Kumasi in 2013.

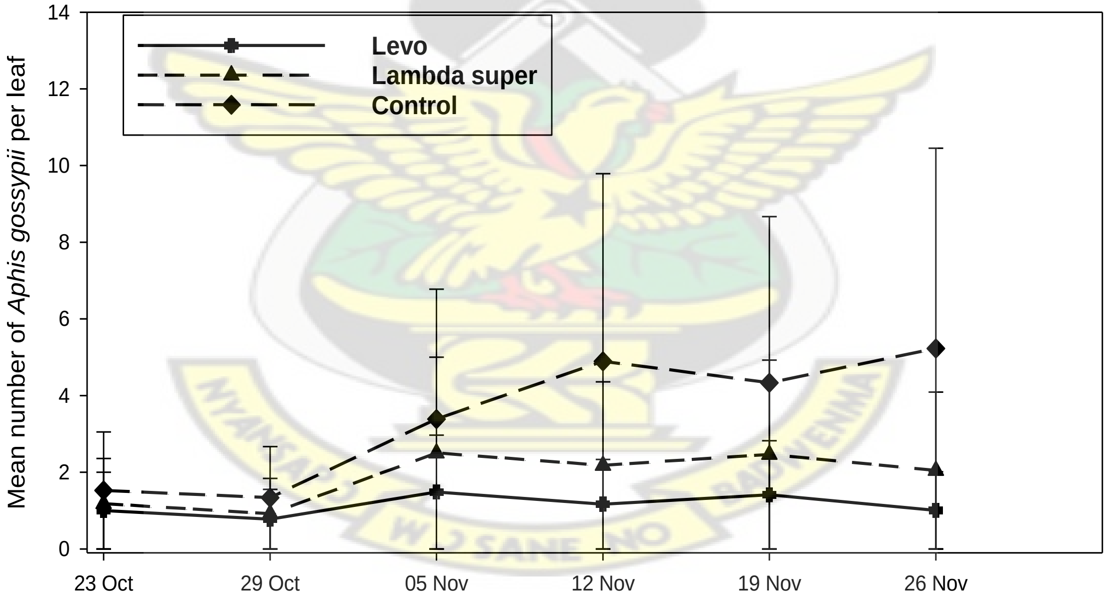

Figure 4.4: Effect of insecticides application on mean number of *A. gossypii* per eggplant (*Solanum melongena*) in the minor season in Kumasi in 2013.

Eggplant shoot and fruit borer (*L. orbonalis*)

The mean number of *L. orbonalis* at the beginning of the insecticide application in the major season was about one per leaf for all the treatments. After the second insecticide applications, a mean number of two *L. orbonalis* per leaf was recorded in the control plots up till the end of the application regime. However, *L. orbonalis* densities in the insecticide-treated plots were kept below one per leaf throughout the period (Figure 4.5).

During the minor season, a similar trend was observed except that mean number of *L. orbonalis* in the control after the first treatment was about two per leaf which reduced slightly by 19th November (Figure 4.6).

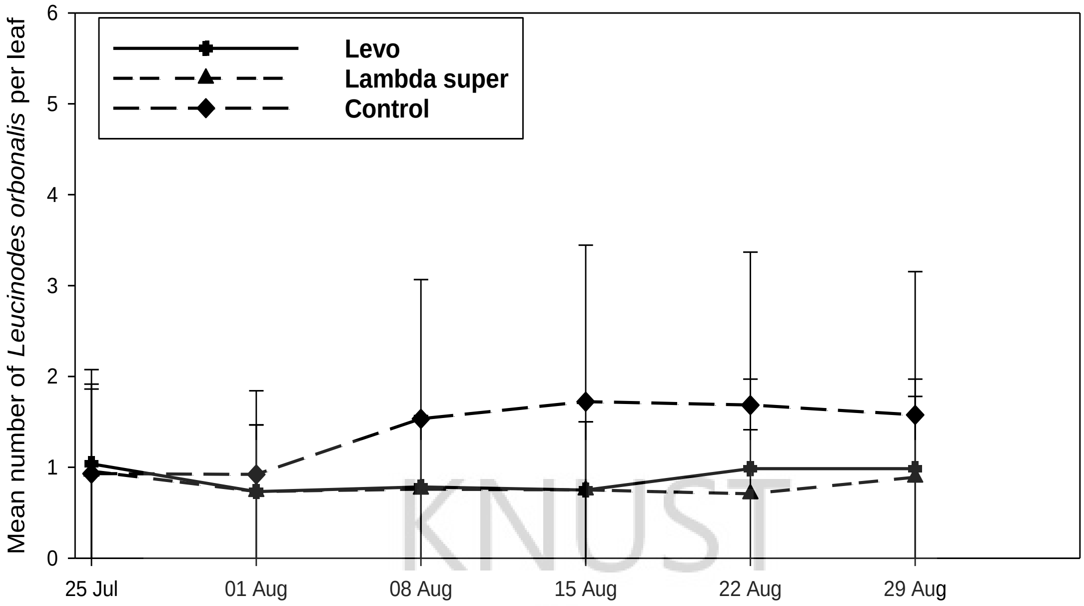

Figure 4.5: Effect of insecticides application on mean number of *L. orbonalis* per eggplant (*Solanum melongena*) in the major season in Kumasi in 2013.

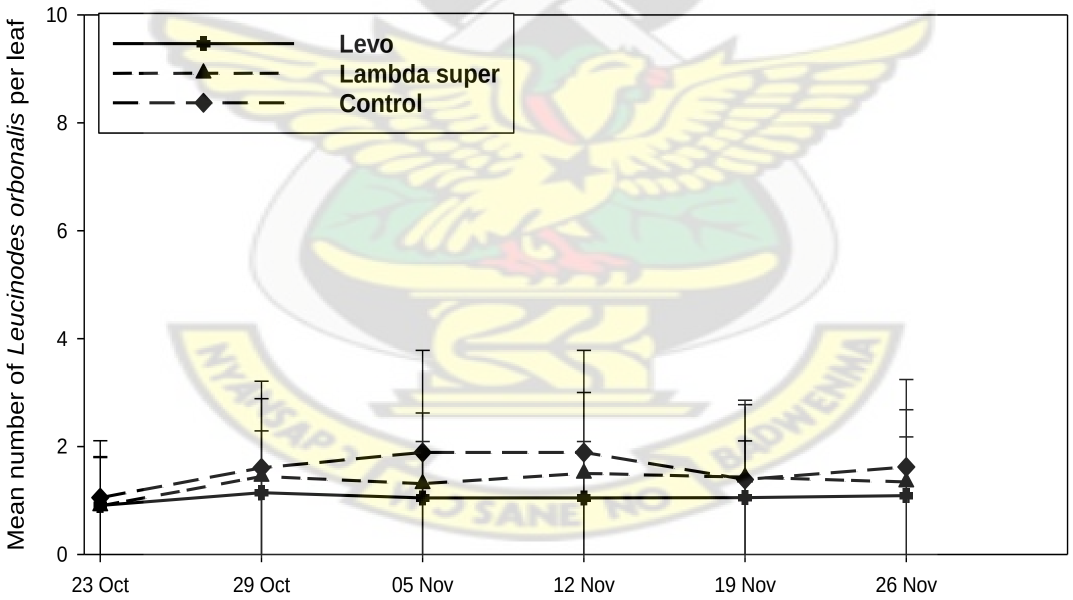

Figure 4.6: Effect of insecticides application on mean number of *L. orbonalis* per eggplant (*Solanum melongena*) in the minor season in Kumasi in 2013.

Leaf roller (*E. olivacea*)

The mean number of *E. olivacea* was 0.8 per leaf in the insecticides treated plots till the end of the experiment in the major season. However, two per leaf of the insect inhabited the control plots after the second insecticide applications till the end of the experiment (Figure 4.7)

In the minor season, the mean number of *E. olivacea* recorded in the insecticide treated plots was about one per leaf throughout the treatment regime. Control plots however harboured a mean of two per leaf till the end of the experiment (Figure 4.8).

Figure 4.7: Effect of insecticides application on mean number of *E. olivacea* per eggplant (*Solanum melongena*) in the major season in Kumasi in 2013.

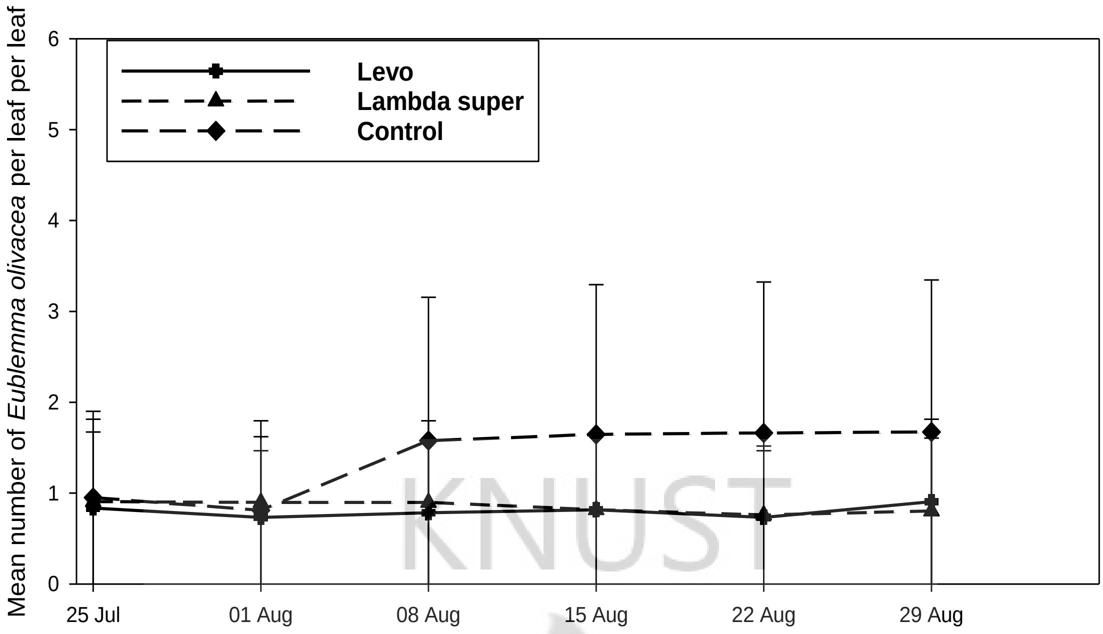

Figure 4.7: Effect of insecticides application on mean number of *E. olivacea* per eggplant (*Solanum melongena*) in the major season in Kumasi in 2013.

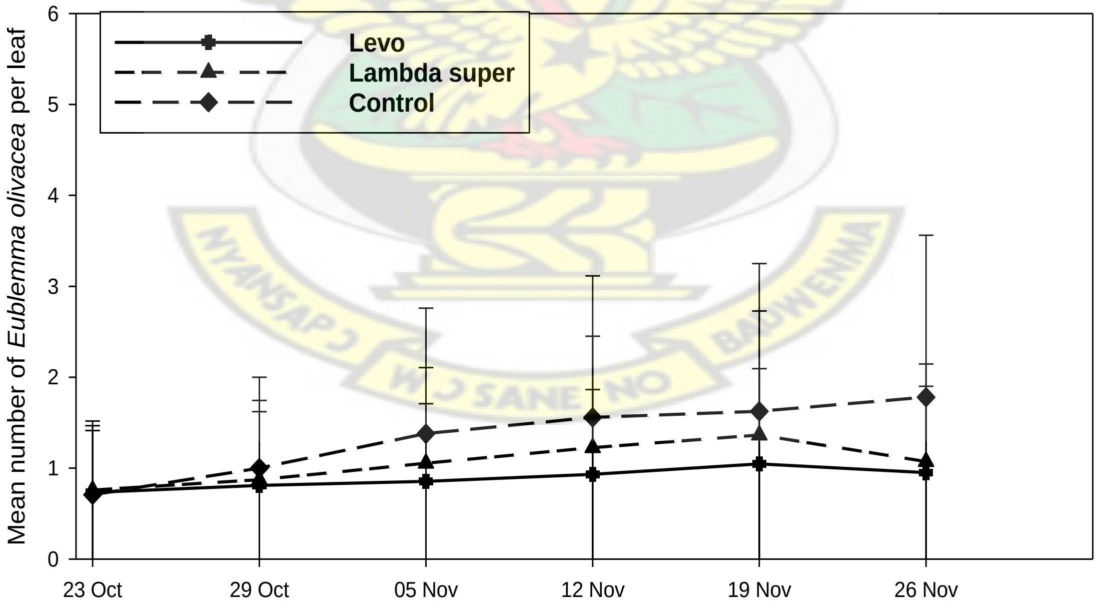

Figure 4.8: Effect of insecticides application on mean number of *E. olivacea* per eggplant (*Solanum melongena*) in the minor season in Kumasi in 2013.

4.6. Effects of Insecticide Treatments on Insect Pests Population dynamics on okra

Flea beetle (*Podagrica* spp.)

The density of *Podagrica* spp. on all plots before insecticide applications began was about two per leaf and increased to three per leaf on insecticide treated plots after the first application and remained the same till the end of the experiment. The control plots harboured a mean number of 4.2 per leaf after the first insecticide application till the end of the experiment in the major season (Figure 4.9).

In the minor season, *Podagrica* spp. numbers were two per leaf before the first spray application for all plots. Plots treated with Levo harboured densities of two per leaf throughout the experiment. The densities of the insects in the control plots however increased from two to four per leaf after the first application till the end of the experiment (Figure 4.10).

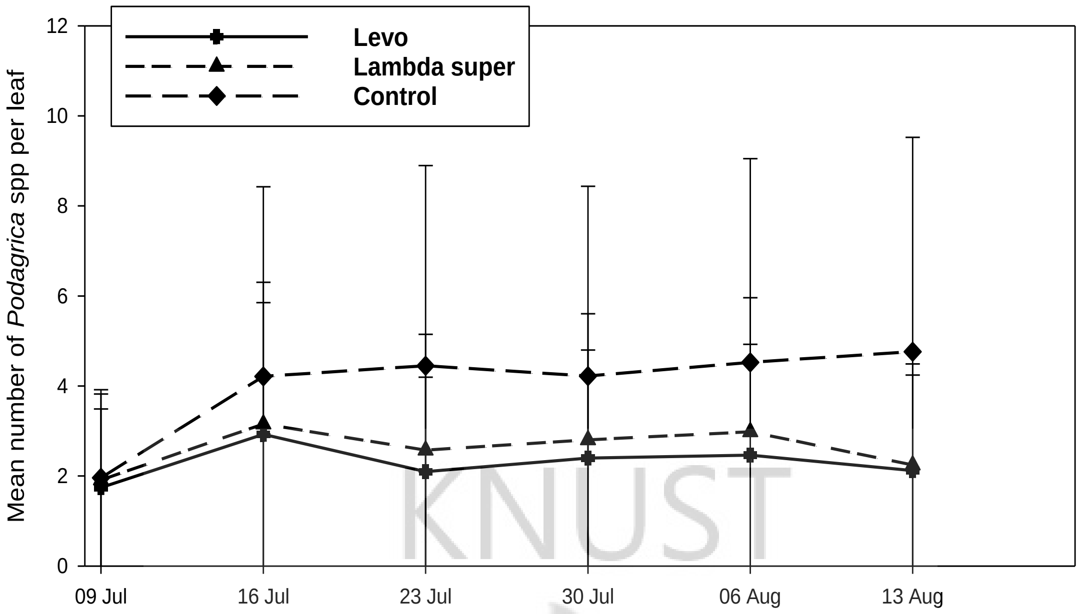

Figure 4.9: Effect of insecticides application on mean number of *Podagrica* spp per okra (*Abelmoschus esculentus*) in the major season in Kumasi in 2013.

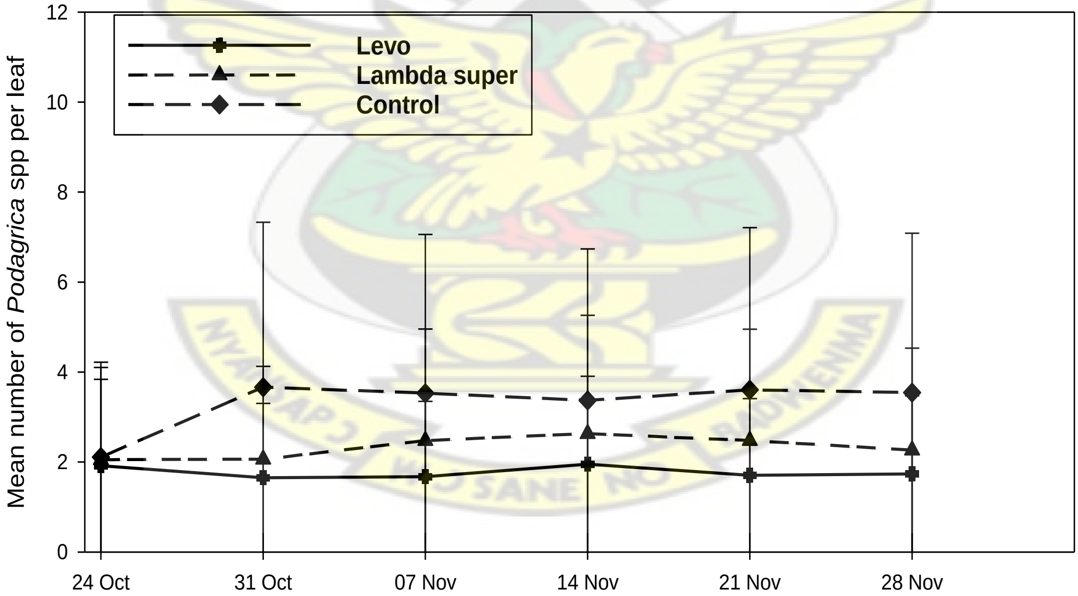

Figure 4.10: Effect of insecticides application on mean number of *Podagrica* spp per okra (*Abelmoschus esculentus*) in the minor season in Kumasi in 2013.

Whiteflies (*B. tabaci*)

The mean number of *B. tabaci* at the beginning of the experiment in the major season was 1.8 per leaf in all treatment plots but this increased slightly to two per leaf on insecticide treated plots after the first treatment on 9th July. However, Levo applications reduced the mean number of *B. tabaci* to one per leaf after the second spray application and remained same till the end of the treatment. Lambda super-treated plots harboured about two whiteflies per leaf. The mean number of *B. tabaci* in the control plots increased from 1.8 to four per leaf after the first application on 9th August.

In the minor season, treated plots harboured about two per leaf of *B. tabaci* at start of the experiment on 24th October till the end of the experiment. A mean number of three *B. tabaci* per leaf was recorded at the end of the experiment on 28th November (Figure 4.12).

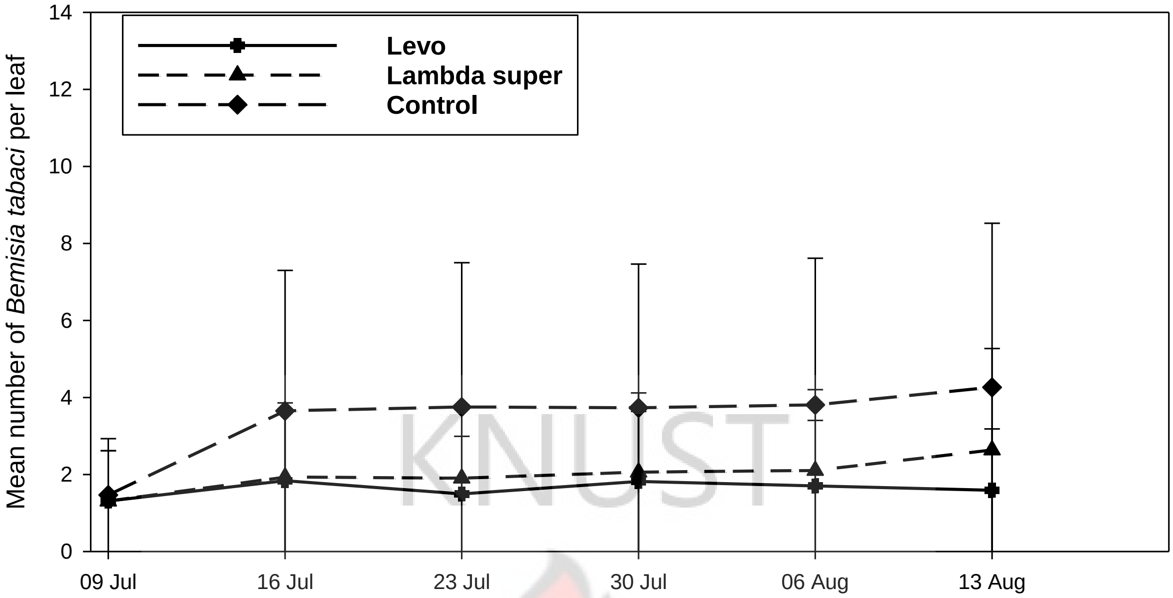

Figure 4.11: Effect of insecticides application on mean number of *B. tabaci* per okra (*Abelmoschus esculentus*) in the major season in Kumasi in 2013.

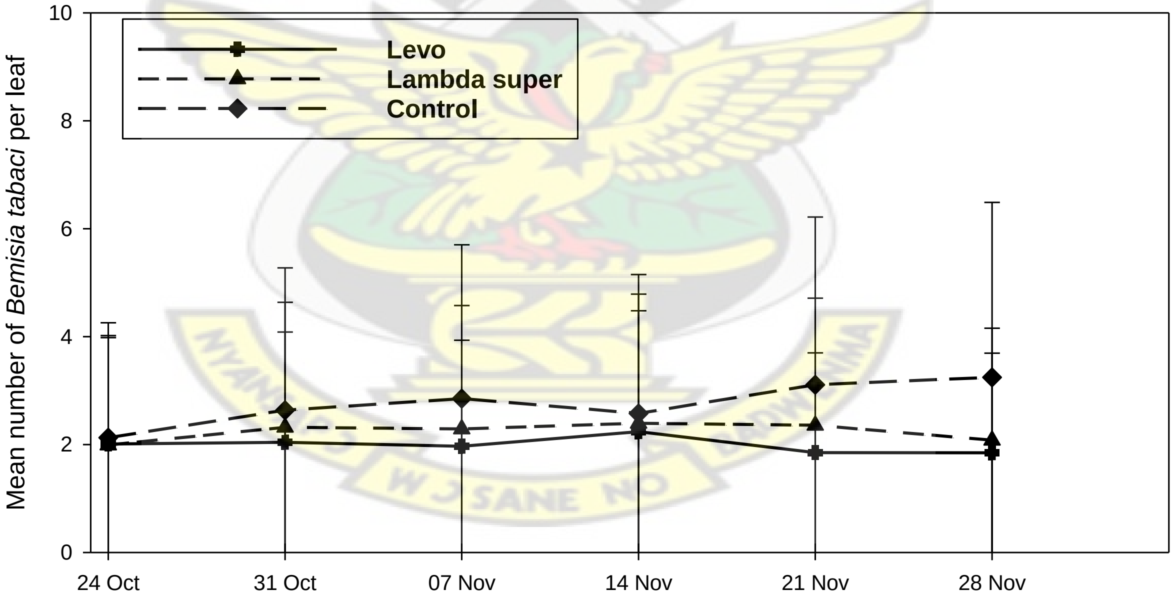

Figure 4.12: Effect of insecticides application on mean number of *Bemisia tabaci* per okra (*Abelmoschus esculentus*) in the minor season in Kumasi in 2013.

Aphids (*A. gossypii*)

During the major season, the mean number of *A. gossypii* was about 0.8 per leaf before the first application of insecticides which remained same till the end of the spray regime in the Levo-treated plots on 13 August. Lambda super-treated plots however haboured a sharp increase of the insect to five per leaf after the 4th treatment till the end of the experiment. Control plots harboured about seven *A. gossypii* per leaf by the end of the spray period.

In the minor season, Levo-treated plots harboured about one per leaf from the beginning to the end of the experiment. Lambda super-treated plots harboured a mean number of three per leaf by 14th November but this reduced to two per leaf at the end of the treatment regime. More than seven *A. gossypii* per leaf were recorded on the control plots by 28th November 2013.

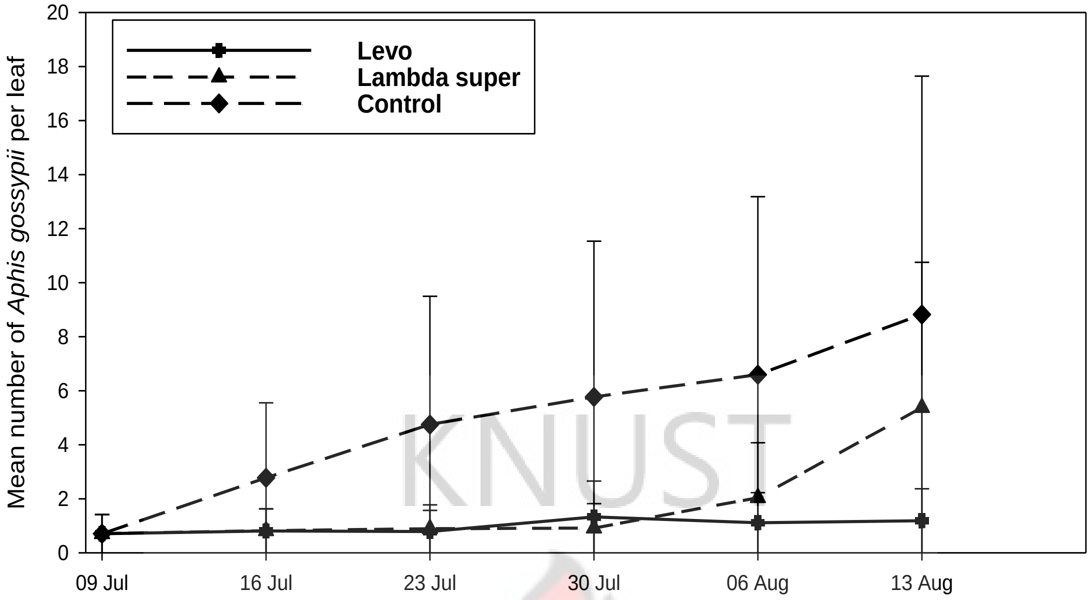

Figure 4.13: Effect of insecticides application on mean number of *A. gossypii* per okra (*Abelmoschus esculentus*) in the major season in Kumasi in 2013.

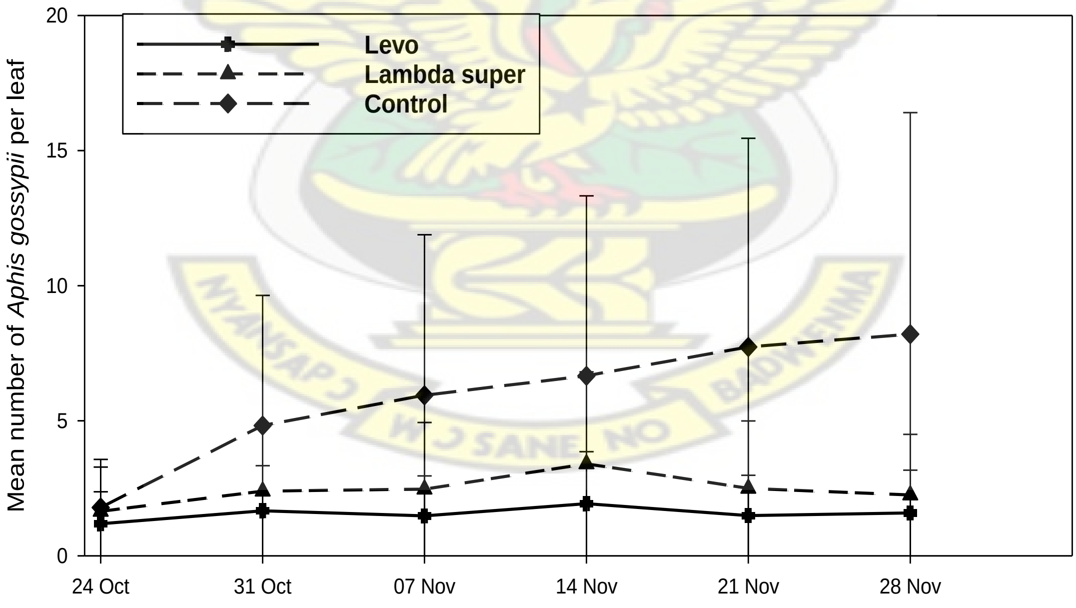

Figure 4.14: Effect of insecticides application on mean number of *A. gossypii* per okra (*Abelmoschus esculentus*) in the minor season in Kumasi in 2013.

4.7. Effects of insecticide treatments on defoliation of okra in the major and minor season in Kumasi in 2013

The damage caused by *Podagrica* species on okra leaves was significantly different ($P < 0.05$) among treatments plots in both seasons (Table 4.5). Feeding of *Podagrica* species on okra leaves resulted in a significantly higher defoliation of the untreated control plants as compared to insecticide-treated plots in both seasons. Again, significantly higher defoliation was observed in the Lambda super plots than the Levo-treated plots in both seasons

Table 4.5: Effects of insecticide treatments on defoliation of okra in the major and minor season in Kumasi in 2013.

	Defoliation (%)	
Treatments	Major season	Minor season
Levo	18^{c}	17^{c}
Lambda super	26^{b}	21^{b}
Control	44^{a}	46^{a}

Means with the same letter in a column are not significantly different from each other ($P < 0.05$, Tukey test)

Plate 4.1 Defoliated leaves of okra

4.8. Yield of eggplant as affected by various insecticide treatments in the major and minor season in 2013.

In the major season, significant differences (P < 0.05) were observed in the number of fruits per plant, percent fruit damaged, mean fruit weight per plant and yield (marketable fruits) between Levo-treated plots and Lambda super and Control plots (Table 4.6). There were no significant differences (P < 0.05) between the Lambda-super treated plots and the control with respect to the number of fruits per plant, percent fruit damaged, mean fruit weight and yield (marketable fruits) (Table 4.6). Levo-treated plots produced significantly (P < 0.05) higher yield (marketable fruits) than the Lambda-super and the Control plots (Table 4.6).

In the minor season significant differences (P < 0.05) were recorded with respect to the percent fruit damaged and yield (marketable fruits) between the Control and the insecticides-treated plots. However, no significant differences (P > 0.05) were observed in the number of fruits per plant and mean fruit weight among the treatments (Table 4.7).

Table 4.6: Yield (marketable fruits), yield components and mean damaged fruits as affected by various treatments of eggplant in the major season in 2013.

Treatment	Mean No. of fruits plant^{-1}	Mean % damaged fruits	Mean fruit weight (g)	Yield (marketable fruits) (kg ha^{-1})
Levo	56.50 ± 5.04 ^{b}	2.25 ± 0.95 ^{b}	2.44 ± 0.27 ^{a}	995.13 ± 89.51 ^{a}
Lambda super	42.50 ± 1.32 ^{c}	7.75 ± 0.63 ^{a}	1.61 ± 0.05 ^{b}	635.98 ± 20.92 ^{b}
Control	40.00 ± 2.31 ^{c}	9.50 ± 0.50 ^{a}	1.41 ± 0.06 ^{b}	553.01 ± 24.85 ^{b}

Means with the same letter in a column are not significantly different from each other (P < 0.05, Tukey test)

Table 4.7: Yield (marketable fruits), yield components and mean damaged fruits as affected by various treatments of eggplant in the minor season in 2013.

Treatment	Mean of No of fruits plant^{-1}	Mean % damaged fruits	Mean fruit weight plant^{-1}(g)	Yield (marketable fruits) (kg ha^{-1})
Levo	71.75 ± 7.93 ^{a}	7.00 ± 0.82 ^{b}	2.77 ± 0.50 ^{a}	1100.03 ± 78.38^{a}
Lambda super	71.75 ± 9.84 ^{a}	9.25 ± 1.25 ^{b}	2.44 ± 0.35 ^{a}	964.75 ± 31.19 ^{a}
Control	80.00 ± 6.87 ^{a}	19.00 ± 2.55 ^{a}	1.60 ± 0.17 ^{a}	619.25 ± 65.05 ^{b}

Means with the same letter in a column are not significantly different from each other (P < 0.05, Tukey test)

4.9. Yield of Okra as affected by various treatments in the major and minor season in 2013

There was no significant difference (P > 0.05) in the number of fruits per plant, mean fruit weight and yield (marketable fruits) between the control and the insecticides-treated plots. However, percent fruit damaged differed significantly (P < 0.05) between Levo-treated plots and Lambda super and control plots in the major season (Table 4.8).

No significant differences (P > 0.05) were recorded in mean fruit weight per plant and yield (marketable fruits) (kg ha^{-1}) among all treatment plots (Table 4.9). There were also no significant differences (P > 0.05) among treatments in terms of the mean number of fruits per plant. A significant difference was observed in the mean percent damaged fruits among all treatments. The yield (harvested fruits) per treatment in the major season ranged from 265.10 to 394.40 and 216.00 to 257.25 (kg ha^{-1}) for the minor season (Table 4.8 and 4.9).

Table 4.8: Yield (marketable fruits), yield components and mean damaged fruits as affected by various insecticide treatments of okra in the major season in 2013.

Treatment	Mean No. of fruits $plant^{-1}$	Mean % damaged fruits	Mean fruit weight (g)	Yield (marketable fruits) (kg ha^{-1})
Levo	88.50 ± 18.46 [a]	11.75 ± 1.65 [c]	0.86 ± 0.19 [a]	330.25 ± 73.81 [a]
Lambda super	77.00 ± 18.57[a]	19.25 ± 3.84 [b]	0.71 ± 0.20 [a]	265.10 ± 78.07 [a]
Control	107.25 ± 6.57 [a]	28.75 ± 1.65 [a]	1.06 ± 0.08 [a]	394.40 ± 31.91 [a]

Means with the same letter in a column are not significantly different from each other (P < 0.05, Tukey test)

Table 4.9: Yield (marketable fruits), yield components and mean damaged fruits as affected by various insecticide treatments of okra in the minor season in 2013.

Treatment	Mean No. of fruits plant^{-1}	Mean % damaged fruits	Mean fruit weight (g)	Yield (marketable fruits) (kg ha^{-1})
Levo	55.50 ± 0.87 ^{a}	4.25 ± 0.48 ^{c}	0.65 ± 0.03 ^{a}	257.25 ± 12.63^{a}
Lambda super	50.00 ± 4.45 ^{a}	7.25 ± 0.95 ^{b}	0.58 ± 0.08 ^{a}	216.00 ± 28.98 ^{a}
Control	57.25 ± 3.30 ^{a}	10.75 ± 0.48 ^{a}	0.63 ± 0.04 ^{a}	241.00 ± 17.34 ^{a}

Means with the same letter in a column are not significantly different from each other (P < 0.05, Turkey test)

Plate 4.2. Harvested okra fruits

Plate 4.3. Harvested eggplant fruits

CHAPTER FIVE

5.0. DISCUSSION

5.1. Effect of insecticide treatments on insect pests of eggplant and okra

Although synthetic pesticides are effective, their effect on the environment is mostly deleterious. Plant based pesticides contain active ingredients with low half-life period and their effects on the environment are not too detrimental making them more acceptable for pest management (Sharma *et al.*, 1995).

Control of Whiteflies (*B. tabaci*)

On eggplant, the results from the studies in both major and minor seasons showed that Levo botanical insecticide was effective against *B. tabaci* by keeping the mean number of whiteflies around 1.6 per leaf, comparable to that of Lambda super plots which had 2.3 and 2.2 per leaf in major and minor seasons respectively (Tables 4.1 and 4.3). The effectiveness of Levo against *B. tabaci* may be attributable to its possession of anti-feeding and repelling properties. Hussain *et al.* (1995) tested 2 g and 5 g leaf extracts of custard apple (*Annona squamosa*) on *Tribolium castaneum* (Herbst) and reported that they were successful in controlling the infestation of *T. castaneum*, which they explained could be attributed to the repellent properties of the acetogenins in the leaf extracts. Epino and Chang (1993) also reported that the seed extracts of *A. squamosa* had repellent and anti-oviposition properties against *C. capitata.*

Similarly on okra, Levo was almost as effective as Lambda super in reducing *B. tabaci* density as compared to the control (Tables 4.2 and 4.4), and this agrees with Siddig (1981) who used neem seed extracts (botanical) against *B. tabaci* on okra and reported a reduced occurrence of the adults.

Control of Aphis (*Aphis gossypii*)

The results of the study showed that the abundance of *A. gossypii* on eggplant and okra was significantly higher in the control plots than insecticide-treated plots in both major and minor seasons. Between the insecticides, Levo treated plots haboured lower numbers of *A. gossypii* as compared to Lambda super (Table 4.1 and 4.3). This could be due to the over-dependence on Lambda super by farmers within the experimental area for the management of pests, which might have contributed to the insects developing some resistance to the insecticide. Owusu (1997) observed that *A. gossypii* populations on eggplant are becoming resistant to commonly used insecticides in Ghana.

Levo was more effective in controlling *A. gossypii* on eggplant than okra (Table 4.1 to 4.4). The effectiveness of botanical insecticides in controlling aphids was reported by Ahmed (2000), who detected that aqueous neem seed extract was very effective in reducing the number of cotton aphids infesting okra, particularly when applied as a foliar spray. Lowery *et al.* (1993), who also used neem extract to control aphids, concluded that the neem extract suppressed moulting of the nymphs and inhibited reproduction of the adults.

Control of Eggplant shoot and fruit borer (*L. orbonalis*) and **Leafroller** (*E. olivacea)*

The results from the experiment for both crops in the major and minor seasons showed that *L. orbonalis* and *E. olivacea* densities throughout the experiment were low with a mean density of 1.4 per leaf recorded in the control. This notwithstanding, there were significant differences between the insecticides-treated plots and the control (Table 4.1 and 4.3). The low density of *L. orbonalis* and *E. olivacea* could be due to environmental factors that did not favour their activities within the experimental area. Levo was comparatively effective as lambda super in reducing *L. orbonalis* and *E. olivacea* densities on eggplant. Ahmed (2000) reported that lepidopterous insects are highly sensitive to neem compounds and that these insects are well controlled with many botanical insecticides including neem. The report concluded that the results indicated a promising control against the other members of this order, which attack okra and cotton.

Control of flea beetle (*Podagrica* spp.)

Two flea beetle species, *P. uniforma* and *P. sjostedti* (Coleoptera: Chrysomelidae) were collected on the leaves of okra. *P. sjostedti* population was very low. Infestation of flea beetles started two weeks after the emergence of the okra and a mean of two per leaf were recorded on the plants before treatment was effected. Similar trends were recorded in the major and minor seasons except that plots treated with Lambda super harboured an increased density of 2.6 and 2.3 per leaf respectively (Table 4.4). Again, the results showed that Levo was effective in controlling flea beetles and this could be attributed to a hostile environment created by Levo including hindering of feeding activities of the insects. Redknap (1981) reported of the effectiveness of neem extract against the *P. sjostedii* and *P. uniforma* in a field trial. However, Schmutterer (1987) reported that, the application of neem-based pesticides against adult insects, for instance bugs and beetles, does not normally lead to obvious mortality, but may result in a substantial reduction in the fecundity of these insects, so that the following generation may be reduced below the economic threshold level.

5.2. Effects of insecticides treatment on okra leave damage (defoliation)

Podagrica spp damage to okra leaves was low on all the insecticide-treated plots but high in the control plots in both seasons. Levo application reduced okra defoliation and this may be attributed to its an-feedant and repellent property. Mohammed-Ahmed (2000) used neem extracts on okra and recorded a decreased defoliation and attributed it to the anti-feedant and repellent nature of the neem extracts. Alao *et al.* (2009) also reported anti-feedant and repellent property of maize stover as being responsible for the significant reduction in damage caused by *Podagrica* species on okra leaves.

5.3. Effects of insecticides treatment on the yield of eggplant

The Levo-treated plots had increased yield of eggplant compared to Lambda super and control plots. Levo-treated plots had yield of 995.13 kgha^{-1} followed by Lambda super 635.98 kgha^{-1} and Control 553.01 kgha^{-1} in the major season. The minor season however recorded high yields of 1100.03 kgha^{-1}, 964.75 kgha^{-1} and 619.25 kgha^{-1} for Levo, Lambda super and Control respectively. The relatively higher incidence of insects might have contributed for the low yield in the untreated control plots. Thus the significantly higher yields obtained from the insecticide-treated plots could be attributed to the marked decrease in the densities of insects collected from those plots in addition to reduced defoliation.

5.4. Effects of insecticides treatment on the yield of okra

Low yields were recorded in both seasons but more pronounced in the minor season possibly as a result of the drier environmental conditions experienced during the latter part of the minor season (Table 4.8 and 4.9). *Podagrica* spp, one of the important pests of okra which was responsible for heavy defoliation on untreated control plots did not affect the yield (Table 4.8 and 4.9), which is contrary to Obeng-Ofori and Sackey (2003) and Ahmed *et al*. (2007) who reported significant yield losses in Ghana and Nigeria, respectively as a result of heavy defoliation of okra leaves; but agrees with Dabiré-Binso *et al*. (2009) who reported that despite heavy infestations of *Podagrica* spp. no significant yield loss was recorded in untreated control plots compared to the treated. It is evident from the study that Levo application contributed to a yield similar to the Lambda super and can therefore be a good substitute for the management of insect pests of eggplant and okra.

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The study has shown that *A. gosspyii*, *B. tabaci*, *L. orbonalis*, and *E. olivacea*, were the most important insect pests of eggplant. *Podagrica* spp, *B. tabaci*, and *A. gossypii* were also identified as the important insect pests of okra in the study area. The incidence and abundance of these pests were found to have been reduced in all insecticides-treated plots while yield increases were also recorded in all treated plots of eggplant. However, there was no significant difference between insecticide-treated and control plots on the yield of okra. Damage caused by *Podagrica* spp. to okra leaves was low on all the insecticide-treated plots but high on the control in both seasons.

The study also showed that Levo was as effective as the Lambda Super and could be a potential substitute for synthetic insecticides in the management of insect pests of eggplant and okra since it is environmentally friendly.

6.2. Recommendation

It is recommended that further work be done to validate the efficacy of levo botanical insecticide in multiple locations.

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APPENDICES

Appendix I. Descriptive statistics of the initial soil properties taken at the experimental site-2013

Soil property	Mean
ORG. C (%)	1.52 (0.4)
Total N (%)	0.12 (0.01)
Available P (mg / kg soil)	6.9 (0.4)
Soil PH	5.8 (0.1)
Exchangeable cations (cmol kg /soil)	
Ca	5 (0.6)
Mg	2.6 (1.1)
K	0.1 (0.01)
Na	0.2 (0.01)
Al^{3+}	1.5 (0.1)
H	1.1 (0.1)

Mean with standard deviation in parenthesis

Appendix 2. Fruit of Okra (Asontem)

Appendix 3. Fruit of eggplant (Aworoworo)