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COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE

DEPARTMENT OF CROP AND SOIL SCIENCES

EFFECT OF CRUDE ETHANOLIC LEAF EXTRACT OF SOURSOP

(*Annona muricata* L.) ON EGGPLANT SHOOT AND FRUIT BORER

(*Leucinodes orbonalis* Guen.)

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS

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PROTECTION

(ENTOMOLOGY OPTION)

BY

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DECLARATION

I 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 Science (M.Sc.) degree at the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi-Ghana.

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ABSTRACT

Eggplant is an important source of income to rural farmers who grow the crop either once or twice a year to augment income from other farming activities. The main production constraint apart from unpredictable weather is damage to shoots, flowers and fruits of the plant by the eggplant shoot and fruit borer, *Leucinodes orbonalis* (Guen.). The use of synthetic insecticides for the control of this borer has been the standard practice. However, an increasing awareness of the environmental hazards associated with insecticide use as well as the high costs of control is intensifying the demand for a less hazardous form of control. Biopesticides have long been an alternative to synthetic chemical insecticides for pest management because botanicals apparently pose little threat to the environment and to human health. Literature documenting bioactivity of plant derivatives to insect pests continue to increase, yet only a handful of botanicals are currently used in agriculture. Products based on pyrethrum, rotenone and azadirachtin have been used at different levels of sophistication. This study investigated the bioactivity of *Annona muricata* ethanolic leaf extract against *L. orbonalis* on eggplant in the field. Three levels of the leaf extract - 0.25%, 0.50% and 1.0% - were tested along with a synthetic insecticide Dimethoate and water control to assess the potency of the extract in controlling the damage inflicted on the shoots, flowers and fruits of eggplant by *L. orbonalis*. Results from the investigation showed that the leaf extract was fairly effective against *L. orbonalis*. Even though the extract could not completely prevent damage to shoots, flowers and the fruits of the eggplant, it significantly reduced the damage even though not as effective as Dimethoate.

CHAPTER ONE

1.0 INTRODUCTION

Vegetables are important sources of vitamins, minerals, and plant proteins in human diets throughout the world (Srinivasan, 2009). Vegetable cultivation is one of the dynamic branches of agriculture, and from the point of view of economic value of the produce, it is one of the most important. Vegetables are rapidly becoming an important source of income for the rural population (Alam *et al.*, 2003). At the same time, vegetable cultivation is becoming more costly due to the increasing use of purchased inputs such as pesticides and fertilizers to sustain production levels. These inputs are also a cause for concern due to their deleterious effects on human health and the environment. Eggplant, *Solanum melongena* L., is one such typical vegetable whose cultivation helps to improve human nutrition and income generation, yet the activities in the production degrade the environment (Alam *et al.*, 2003).

Eggplant is a common and 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 the minor seasons (Akpabi, 1989). This vegetable is cultivated largely on small, family-owned farms in Ghana where weekly sale of its produce brings in income.

Eggplant is a potential export crop for Ghana, but only a very small share of the total production in Ghana is exported. However, the exports are on the ascendancy (Asante, 2004). The marketable surplus of eggplant is about 20% of the annual production.

Despite its importance in terms of nutrition and export potential for foreign exchange, increasing damage by arthropod pests is affecting eggplant cultivation (Alam *et al.*, 2003). Eggplants are infested by a plethora of insect pests throughout the world. A survey of vegetable pests conducted by AVRDC—the World Vegetable Center indicated that *Leucinodes orbonalis* (Guen.) is the most destructive pest in most major eggplant producing countries (Alam *et al.,* 2003). *L. orbonalis* larvae tunnel inside plant shoots (or fruit if available), adversely affecting marketable fruit yield. Estimates of loss or damage caused by *L. orbonalis* vary considerably. According to Mehto *et al.* (1983), yield reduction ranges from 50-60%. Mall *et al.* (1992) also reported that average losses in the field are about 13% and Patnaik (2000) reported that damage to fruit in the field ranges from 47.6% to 85.8%. These are clear indications that this pest is capable of causing significant level of damage in areas where it has become established.

Various control measures have been adopted by farmers to combat the pest. Mechanical or physical control is one method used by farmers. This method involves the use of physical force with or without the aid of special equipment. Mechanical control techniques give immediate and tangible results, even though they are time consuming. Some of the common practices include: handpicking of large larvae or adults; 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. The use of Insect-resistant cultivars for planting has also been successfully developed and used to control the infestation of the pest.

Currently, farmers rely exclusively on the application of pesticides to control *L. orbonalis* and to produce blemish-free eggplant fruit. The use of pesticides is considered the most potent control measure for the pest. Blay (1986) and Parker *et al.* (1995) reported that Cypermethrin, Dimethoate, Endosulfan and Deltamethrin are the major insecticides used by farmers in eggplant pest control programmes in Ghana and other major producing countries, and they have been very effective. Pesticide use is very intensive for killing the larvae before they bore inside shoots or fruits; once in the shoots or fruits, larvae are inaccessible to the killing action of surface applied chemicals. Since neonate larvae can enter fruits or shoots within only a few hours of hatching from eggs, pesticides have to be applied frequently in order to have sufficient toxic residues on the plant surface to kill the crawling larvae. Research activities to combat *L. orbonalis* have largely been confined to screening pesticides to select the most effective chemical and determining the frequency of their use. At one time, researchers developed pesticide spray schedules that involved calendar spraying whether the pest was present or not (Atwal, 1976; Srivastava and Butani, 1998). This approach has led to increased dependence on pesticides and consequent adverse effects of higher costs of production, environmental pollution, destruction of natural enemies, and development of pesticide resistance in *L. orbonalis* (Pimentel *et al.*, 1980; Schmutterer, 1981; Sighamony *et al.*, 1990).

Although synthetic pesticides will remain a primary measure for agricultural pest control for the foreseeable future, it is evident that society cannot continue to tolerate the way conventional chemicals are used. The current pesticide use is not only non-sustainable but, if continued, it will adversely affect eggplant and other vegetable production. This situation can be avoided by the development of pest management systems based on the judicious application of insecticides. Thus there is the urgent need for developing alternative control strategies.

The existence of naturally occurring insecticidal plant components has been known for centuries (Isman, 2006). However, relatively few of these compounds are currently used in crop protection. Increasing problems associated with the use of conventional synthetic insecticides have caused renewed interest in naturally occurring pesticides. Because these compounds are often less toxic and also less persistent than synthetic ones and are in some instances a component of mammalian diets, they are assumed to be environmentally more acceptable and less hazardous to humans. The plant kingdom is a rich source of various compounds with high potential for development as effective pest control agents (Isman, 1997). Interactions between phytophagous insects and plants over ages have led to the evolution of numerous secondary plant chemicals which influence insect behaviour, development, and physiology. These chemicals can be used to control specific pests in appropriately designed strategies. Such plant derived products have a potential advantage over synthetic compounds in terms of ecological suitability. Their development as successful pest control agents can also be economically feasible, especially if the source materials are plants available in abundance.

It is for the above reasons that it has become necessary to look for a more efficient and environmentally acceptable plant-based chemical that will be capable of controlling the eggplant shoot and fruit borer pest to increase production and also to enhance food security in the country. The aim of the study was to investigate the insecticidal activity of ethanolic crude extract of *A. muricata* leaves on *L. orbonalis* in the field.

The specific objectives were:

1. To evaluate the efficacy of ethanolic crude extract of *A. muricata* leaves in controlling shoot, flower and fruit damage caused by *L. orbonalis.*
2. To evaluate the effect of the *A. muricata* leaf extract on fruit yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Botany of eggplant

S. melongena belongs to the family Solanaceae. It is a native of India and has been in cultivation for a long time in the Asian continent. The Indians call it Brinjal and the Europeans call it Aubergine (Doijode, 2001). Various forms, colours and shapes of eggplant are found throughout Southeast Asia, suggesting that it is an important centre of variation and possibly of origin (Vavilov, 1951). Its somatic chromosome number is 2n = 24 (Choudhury, 1976). Eggplant is a bushy plant and grows to a height of 60 to 120 cm. The plant is erect, compact, and well branched. It has a rather fibrous or lignified root system. The leaves are large, simple, lobed and alternate on the stems. The sepals are large, violet- or white-coloured, and solitary, or in clusters of two or more. The stems, leaves, and calyx of some cultivars are spined. The fruit is a pendant, fleshy berry, whose shape varies from ovoid through oblong to long cylindrical. The colour of fruit is either (shiny) purple, white, green, yellowish, or striped with white and yellow. The seeds are borne on the fleshy placenta filling the locular cavity completely. Eggplant is usually self-pollinated, but the extent of cross-pollination has been reported as high as 48% due to its heteromorphic structure or heterostyly. Out-crossing primarily takes place with the help of insects (Choudhury, 1976).

2.2 Varieties of eggplant

The name eggplant derives from the shape of the fruit of some varieties, which are white and shaped very similarly 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 the world and Ghana

The eggplant is grown on more than 2 million ha of land worldwide with a production of nearly 33 million tons per annum. It is grown extensively in India, Bangladesh, Pakistan, China, Japan, and the Philippines, but also very popular in Egypt, France, Italy, and the United States (FAO, 2007). In China, eggplant has been known for the last 1,500 years (AVRDC, 1990). China is the world's top eggplant grower, accounting for more than half of world acreage and India is second, with about one quarter of the world total. Indonesia, Egypt, Turkey, Iraq and the Philippines are the other major eggplant producing countries. Asia accounts for about 94% of the world eggplant area, with about 92% of world output (FAO 2007).

In 2008, a total land area of 1,600 ha was used for the cultivation of eggplant in Ghana. This yielded 37,500 t ha^{-1} (FAO, 2009). The Ashanti Region is the leading producer in Ghana followed by the Volta Region (FAO, 2009).

2.4 Economic importance of eggplants

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, for example white eggplant 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). Rural and urban families in Ghana consume the crop 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 the house-hold income comes from eggplant production (Danquah-Jones, 2000; Owusu-Ansah *et al*., 2001).

2.5 Nutrient composition of eggplant fruit

Horna *et al*. (2006) reported that eggplant is the most important vegetable crop in West Africa and probably the third most consumed vegetable in Ghana. Eggplant has been a common vegetable in diets in West Africa and its composition per 100 g of edible portion is shown in Table 2.1.

Table 2.1: Nutrient composition per 100 g of edible portion.

Calories	24.0	**Sodium (mg)**	3.0
Moisture content (%)	92.7	**Copper (mg)**	0.17
Carbohydrates (%)	4.0	**Potassium (mg)**	2.0
Protein (g)	1.4	**Sulphur (mg)**	44.0
Fat (g)	0.3	**Chlorine (mg)**	52.0
Fiber (g)	1.3	**Vitamin A (I.U.)**	124.0
Oxalic acid (mg)	18.0	**Thiamine**	0.04
Calcium (mg)	18.0	**Riboflavin**	0.11
Magnesium (mg)	16.0	**B-carotene (mg)**	0.74
Phosphorus (mg)	47.0	**Vitamin C (mg)**	12.0

It has been reported that on the average, the oblong-fruited eggplant cultivars are richer in total soluble sugars, whereas the long-fruited cultivars contain a higher amount of free reducing sugars, anthocyanin, phenols, glycoalkaloids (such as solasodine), dry matter, and amide proteins (Chen and Li, 1996). High anthocyanin content and low glycoalkaloid content are considered essential, regardless of how the fruit is to be used. For processing purposes, the fruit should have high dry matter content and a low level of phenolics. Bitterness in eggplant is due to the presence of glycoalkaloids which occur in many Solanaceae. The glycoalkaloid contents in the Indian commercial cultivars vary from 0.37 mg/100 g fresh weight to 4.83 mg. Generally, the high content of glycoalkaloids (20 mg/100 g fresh weight) produce a bitter taste and off flavour. The discolouration in eggplant fruit after harvest is attributed to high polyphenol oxidase activity. The cultivars which are least susceptible to discolouration are considered suitable for processing purposes (Chen and Li, 1996).

2.6 Constraints to eggplant production in Ghana

2.6.1 Major pests of eggplant

The eggplant is attacked by many disease causing organisms and insect pests, which cause damage at all growth stages of the plant. Diseases that occur in the plants are mostly caused by bacteria, viruses, fungi and nematodes. Attacks by pathogens and insect pests have become a major constraint to eggplant production in Ghana.

2.6.1.1 Major pathogen pests of eggplant

The fungi *Pythium* sp., *Phytophthora* spp. and *Rhizoctonia* spp. cause damping off disease in the 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).

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).

There are several viruses which can 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).

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).

2.6.1.2 Major insect pests of eggplant

Insect infestation is one of the most important limiting factors to economic eggplant cultivation. The crop is prone to damage by various insects, although there is a wide variability in the degree of infestation (Critchley, 1995). Frimpong and Buahin (1978) reported the presence of 146 insect species on eggplant, with 58 species of these feeding on different parts of the plant at various stages of growth. The major insect pests of the crop include the shoot and fruit borer, *L. orbonalis*, which attacks the shoots and fruits; the flower borer, *Scrobipalpa blapsigona* (Meyrick), which oviposits into the flowers and the feeding activities of the larva lead to abscission of the flowers. *Pachnoda cordata* (Drury) which scrapes and chews the stem and shoots is also quite important. The defoliators of the plant include the *Acraea peneleos peneleos* (Ward), *Acraea pharsalus pharsalus* (Ward), *Zonocerus variegatus* (L.), *Eulioptera* sp., *Urentius hystericellus* (Richter), *Aphis gossypii* **(**Glover**)** and *Phaneroptera nana* (Stal.)

(Frimpong, 1979; Owusu-Ansah *et al*., 2001). Owusu-Ansah *et al.* (2001) reported that, among these insects, the shoot and fruit borer is the most damaging pest of eggplant in eggplant growing areas. Its larvae feed inside eggplant shoots and fruits, resulting in the withering and drying of the shoots and also makes the fruits unmarketable and unfit for human consumption. At times, yield loss could be total (Alam *et al.,* 2003).

2.7 Biology and importance of *Leucinodes orbonalis*

The shoot and fruit borer belongs to the family Pyralidae of the insect order Lepidoptera. All damage is done by the larval stage, which is practically monophagous, feeding principally on eggplant; however, other plants belonging to the family Solanaceae are reported to be hosts of this pest. They include tomato (*Lycopersicon esculentum* Mill), potato (*Solanum tuberosum* L.), selected nightshades (*Solanum nigrum* L. and *Solanum indicum* L.), and turkey berry (*Solanum torvum* Sw.) (AVRDC, 1990).

The adult females lay eggs on the foliage. The number of eggs laid by a female varies from 80 to 253 (Alam *et al.*, 2003). Oviposition takes place during the night and eggs are laid singly on the lower surface of the young leaves, green stems, flowers, or calyces of the fruits. Eggs are flat, elliptical, and 0.5 mm in diameter. They are creamy-white soon after they are laid, but change to red before hatching. The pre-oviposition and oviposition periods are 1.2 to 2.1 and 1.4 to 2.9 days, respectively (Mehto *et al.,* 1983). The eggs hatch in 3 to 6 days. Soon after hatching, the young caterpillars search for and bore into tender shoots near the growing point, or into flowers or fruits. The caterpillars prefer fruits over other plant parts. The larvae go through at least five instars and there are reports of the existence of six larval instars (Sandanayake and Edirisinghe, 1992). In their research in Sri Lanka Sandanayake and Edirisinghe (1992) showed that the larval period lasts 12 to 15 days in the summer and up to 22 days in the winter. They also studied the larval distribution in eggplant and reported that the first instars were most prevalent in flowers and buds, the second instars were equally distributed in all susceptible parts of the plant, third and fourth instars were more in the shoots and fruits, while the fifth instars were restricted to the fruits. Larval feeding in the fruit and shoot is responsible for the damage to the eggplant crop. A full-grown larva measures 18 to 23 mm in length. Fully grown larvae come out of the fruit and other feeding sites and pupate in tough silken cocoons among the fallen leaves and other plant debris on the soil surface near the base of the plants. The colour and texture of the cocoon match their surroundings, making it difficult to detect. Some studies indicate the presence of cocoons at soil depths of 1 to 3 cm (Mehto *et al.,* 1983). The pupal period lasts 6 to 17 days depending upon temperature. Adult emergence occurs at night. The young adults are generally found on the lower leaf surfaces following emergence. The females are slightly bigger than males and the abdomen of the female moth tends to be pointed and curl upwards, whereas the male moth possesses a blunt abdomen. The moth is white but has pale brown or black spots on the dorsum of thorax and abdomen. Wings are white with a pinkish or bluish tinge and are ringed with small hairs along the apical and anal margins. The forewings are ornamented with a number of black, pale and light brown spots. The moth measures 20 to 22 mm across the spread of wings. Longevity of adults is about 1.5 to 2.4 days for males and 2.0 to 3.9 days for females. Within one hour after hatching, the larva bores into the nearest tender shoot, flower or fruit. Soon after boring into shoots or fruits, they plug the entrance hole with excreta. In young plants, caterpillars are reported to bore inside petioles and midribs of large leaves. As a result, the affected leaves may drop off (Butani and Jotwani, 1984). Larval feeding inside shoots results in wilting of the young shoot. Presence of wilted shoots in an eggplant field is the surest sign of damage by this pest. The damaged shoots ultimately wither and drop off. This reduces plant growth, which in turn, reduces fruit number and size. New shoots can arise but this delays crop maturity and the newly formed shoots are also subjected to larval damage. Larval feeding in flowers is relatively rare, but results in floral abscission. Larval feeding inside the fruit results in destruction of fruit tissue. The feeding tunnels are often clogged with frass, which makes even slightly damaged fruit unfit for marketing (Owusu-Ansah *et al*., 2001).

Plate 2.1: **Adult female** *L. orbonalis*

Plate 2.2: Eggplant fruit damage by larva of *L. orbonalis*

Plate 2.3: Shoot damage by larva of *L. orbonalis*

2.8 Management of *Leucinodes orbonalis*

2.8.1 Cultural control

Various control measures have been adopted by farmers to combat the pest. The intercropping of Coriander (*Coriandrum sativum* L.) sown in a single or double line(s) with eggplant is very effective in reducing fruit and shoot borer (*L. orbonalis*) injury to fruits (Khorsheduzzaman *et al.,* 1997). The sprinkling of ash and the broth of goat faeces on the leaves of eggplant is also used to prevent defoliation.

2.8.2 Mechanical control

This method involves the use of physical force with or without the aid of special equipment. Mechanical control techniques give immediate and tangible results, even though they are time consuming. 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.

2.8.3 Biological control

I. Natural enemies

Most insect pests have natural enemies, which can be other arthropods, or entomopathogens such as fungi, bacteria, viruses, or nematodes. Under natural conditions these natural enemies keep the pest populations under reasonable control. As many as 16 parasitoids, three predators, and three species of entomopathogens have been reported as natural enemies of *L. orbonalis* from all over the world (Khorsheduzzaman *et al.,* 1997). Sandanayake and Edirisinghe (1992) reported a high level of parasitism of *L. orbonalis* larvae by the parasitoid, *Trathala flavo-orbitalis*

(Cameron) (Hymenoptera: Ichneumonidae). This method of control is contributing immensely to the reduction of *L. orbonalis* damage in Bangladesh.

II. Biopesticides

The use of biopesticides to control *L. orbonalis* is gaining popularity in southern Asia where production is very high, because they are inherently less harmful than conventional pesticides. Products from Neem tree (*Azadirachta indica* A. Juss) have been tested in Ghana and some other eggplant growing areas, and have been reported to have reduced *L. orbonalis* population drastically (Raja *et al*., 1998; Singh, 2000; Owusu-Ansah *et al*., 2001).

2.8.4 Host plant resistance

Insect-resistant cultivars have been successfully developed in numerous field crops including rice, wheat, sorghum, and soybeans. These cultivars can be used alone or in combination with other control measures in an IPM program. Advantages of the use of pest-resistant varieties include low cost, easy transferability to farmers' fields, no danger to humans and domestic animals, and compatibility with all other control practices. Several attempts were made in the past in Southern Asia to develop eggplant cultivars resistant to *L. orbonalis*, but no commercial cultivar was developed with appreciable level of resistance. Only recently that a resistant cultivar E0508 was successfully developed by AVRDC and is being used to control the infestation of the pest in the leading producing countries (AVRDC, 2000).

2.8.5 Chemical control

Insecticides are currently the main method of control for *L. orbonalis*. Contact insecticides are the most commonly used and show varying degrees of efficacy against the pest (Paul and Ghosh, 1990; Yein, 1985). Deltamethrin, Endosulfan, Dimethoate, Cypermethrin and a host of other synthetic insecticides are some of the chemicals used across the world to control *L. orbonalis* in eggplant production (Thanki and Patel, 1991).

2.9 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). Secondary products from higher plants represent an enormous diversity of biologically active compounds that have been exploited as pesticides. These products however 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 (Reed *et al.*, 1982). Among the well represented plant pesticides is 'Pyrethrums' obtained from *Chrysanthemum cinerariaefolium* (L.). The pesticidal plant that has received global attention for the last two decades is the wonder tree of Indian origin, neem (*A. indica*). Its seeds are a rich storehouse of over 100 tetranotriterpenoids and diverse non-isoprenoids (Devkumar and Sukhdev, 1993). The leaves of the wild shrub *Ocimum suave* (Wild) and the buds (cloves) of *Eugenia aromatica* (L.) are traditionally used as effective stored grain protectants. Eugenol, a common constituent of *E. aromatica*, was found to be a repellent to the maize weevil, *Sitophilus zeamais* (Motsch). Hildecarpan, a pterocarpan from *Tephrosia* is an antifeedant against the legume pod borer *Maruca vitrata* (Fabricius), and the rotenoids and rotenone are very potent antifeedants against a number of Lepidoptera (Hassanali *et al*., 1990). Plants such as *Vernonia amygdalina* (L), *Annona squamosa* (L.) and *Annona reticulata* (L.) have been reported to have insecticidal properties (Sinchaisri *et al.*, 1991; Dharmasena *et al.*, 2001; Leatemia and Isman, 2004; Tandon and Sirohi, 2009).

2.10 Biologically active products from plant

Plants produce an extremely diverse array of biologically active products that adversely affect the growth and development of other organisms. Usually these products are considered defensive substances useful to the plants in discouraging or preventing attack from herbivores and microorganisms or in protecting the plant from stress exerted by the environment and competing species. These products are called secondary plant substances because their explicit physiological functions are rarely known even though many are actively metabolized within the plants (Epino and Chang, 1993).

Numerous functions have been suggested for the various members of these complex substances. Among these are; regulators of plant growth biosynthetic activities; storage forms of plant growth regulators, energy reserves, transport facilitators, and waste products; detoxication products of environmental poisons; shields against excessive radiation; and effectors of allelochemical interactions between plants and their competitors and between plants and heterotrophic organisms (Epino, 1991).

The role of plant secondary chemicals in mediating the interactions of insects and their host plants is well established (Bowers, 1983); such compounds may serve as feeding or oviposition stimulants and attractants, deterrents or toxins (Bryers *et al*., 1986). There are several reviews of evidence for antiherbivore function of secondary substances. Among secondary plant substances that have a negative effect on herbivore fitness or a deterrent effect on herbivore feeding are alkaloids, pyrethrins, rotenoids, long chain unsaturated isobutylamines, cyanogenic glycosides, phytoecdysones and Juvenile Hormone, cardenolides and saponins, sesquiterpene lactones, non-protein amino acids, glucosinolates and isothiocyanates, oxalates, protoanmonin, hypericin, flurofatty acids, selenoamino acids, 6-mithoxybenzoxazoline, gossypol, condensed tannin, phenolic resin and phenol oxidase, and proteinase inhibitors of the soybean trypsin inhibitor (Romeo and Simmonds, 1989), chromenes (Isman, 1997), and acetogenin (Alkofahi *et al.*, 1989).

2.11 Botany of *Annona muricata*

A. muricata, soursop belongs to the family Annonaceae, comprising about 119 species in the family. These include *A. squamosa, A. reticulata, A. cherimola, A. senegalensis* etc (Pinto, 2002). The soursop tree is low branching and bushy but slender because of its upturned limbs, and reaches a height of 25 or 30 ft (7.5-9 m) (Morton, 1987). Young branchlets are rusty-hairy (Morton, 1987). The malodorous leaves, normally evergreen, are alternate, smooth, glossy, dark green on the upper surface, lighter beneath; oblong, elliptic, pointed at both ends, 6.25-20 cm long and 2.5-6.25 cm wide (Morton, 1987). The flowers, which are borne singly, may emerge anywhere on the trunk, branches or twigs. They are short stalked (about 4.5 cm long), plump, and triangular-conical, the three fleshy, slightly spreading outer petals are yellow-green, and the three close-set inner petals are pale-yellow. The fruit is more or less oval or heart-shaped, sometimes irregular, lopsided or curved, due to improper carpel development or insect injury. The size ranges from 10-30 cm long and up to 15 cm in width and the weight may be up to 4.5-6.8 kg (Pinto, 2002). The fruit is compound and covered with a reticulated, leathery-appearing but tender, inedible, bitter skin from which protrude few to-many stubby, or more elongated and curved, soft, pliable "spines". The tips break off easily when the fruit is fully ripe. The skin is dark-green in the immature fruit, becoming slightly yellowish-green before the mature fruit is soft to the touch. Its inner surface is cream-colored and granular and separates easily from the mass of snow-white, fibrous, juicy segments - much like flakes of raw fish - surrounding the central, soft-pithy core. In aroma, the pulp is somewhat pineapple-like, but its musky, sub-acid to acid flavor is unique. Most of the closely packed segments are seedless. In each fertile segment, there is a single oval, smooth, hard, black seed (1.25-2 cm long); and a large fruit may contain from a few dozen to 200 or more seeds (Pinto, 2002).

2.12 Economic importance of *Annona muricata*

Economically the family Annonaceae is of appreciable importance as a source of edible fruits. Other uses reported from *Annona* are the timber for wooden implements, e.g. tool handles and pegs, and for the production of a yellow/brown dye (Pinto, 2002). *Annona* also offers the potential for agro-forestry, although this potential is seldom exploited. In addition, many members of this family are used in traditional folk medicine for various purposes. However, pharmaceutical products, for example the graviola capsule, have been developed for the international market (Pinto, 2002).

In 1976, an investigative program in medicinal plants carried out by the National Cancer Institute of the United States, discovered that the leaves and stems of *A. muricata* are cytotoxic against cancer cells (Taylor, 2002). The major part of anticancer searching in

A. muricata has been concentrated in a series of novel phytochemicals called annonaceous acetogenins. *A. muricata* produces these natural products in its leaves, stems, bark, and seeds. These acetogenic compounds have shown significant antitumor and anticancer activities, as well as a selective toxicity against several types of cancer cells, without any damage to healthy cells (Taylor, 2002).

Stem bark has been used in tannery while bark fibers have been used in textiles (Taylor, 2002). The bark has also been used, as well as roots and seeds, as venom for fishing. In the Peruvian Amazonia, the bark is used against diabetes, and also as sedative and antispasmodic. In Guyana, native tribes prepare a bark tea and use it as sedative and heart tonic. The bark is also used as sedative and nervine (it is, to tone up and stimulate nerves), for heart diseases, cold, flu, childbirth difficulties, asthma, asthenia, hypertension, and against parasites.

2.12 Insecticidal properties of *Annona muricata*

A large number of chemical compounds have been extracted from *Annona* seeds and many other parts of the plant. These include flavonoids, alkaloids and acetogenins that act as a poison to deter insect feeding (Pinto, 2002; Sampson *et al.*, 2003). Flavonoids and alkaloids have shown both insecticidal and antibacterial properties. They have been used for treatment of medical conditions, such as skin disease, intestinal worms and inflammation of the eye (Pinto, 2002).

Annona extracts have been found to act as both contact and stomach poisons. Contact toxicity was equivalent to that of rotenone or nicotine while stomach poisoning was variable (Sinchaisri *et al.*, 1991). In an experiment conducted by Grainge and Ahmed (1988), results showed contact insecticidal properties of *A. muricata* seeds to the pea aphid (*Acyrthosiphum pisum* Harris), the Chrysanthemum aphid (*Macrosiphoniella sanborni* Gillette), the armyworm (*Pseudaletia unipuncta* Haworth) and the southern armyworm (*Spodoptera eridania* Cramer), the diamondback moth (*Plutella xylostella* L.) larvae and antifeedant activity on the yellow fever mosquito (*Aedes aegypti* L.). Epino and Chang (1993) stated that extracts of seeds of *A. squamosa* had repellent and antioviposition properties when applied to *Ceratitis capitata* (Wiedemann).

Plate 2.4: A fruit of soursop (*Annona muricata)*

Plate 2.6: Fruits of *Annona reticulata*

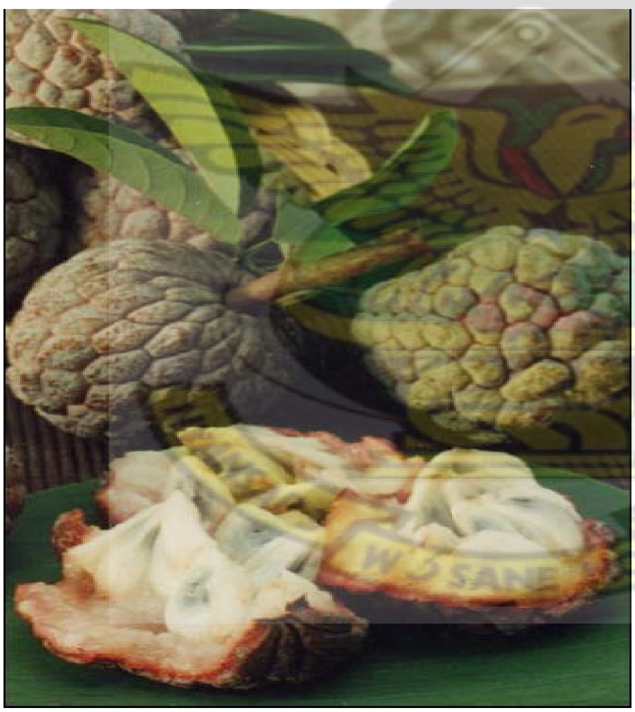

Plate 2.5: Fruits of *Annona squamosa*

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

This study was conducted in the field, at the Faculty of Agriculture plantation site at Ayeduase New Site.

3.2 Eggplant variety

The variety of eggplant used for the experiment was the local Okatakyie, which was obtained from commercial seedling dealers at the Kajetia market.

3.3 Preparation of extracts and the stock solution

Fresh leaves of *A. muricata* were collected from a tree behind the plant house at the Faculty of Agriculture. The leaves were pounded in a wooden mortar with a wooden pestle. One hundred grams (100 g) of the pounded leaves were added to 100 ml of local dry gin and left overnight. The mixture was then filtered and the filtrate poured into a flat bottom flask as stock for the field spraying.

3.4 Field experimental design and botanical treatments

The field studies were carried out in both the major and the minor crop growing seasons. The field design was a randomized complete block with 20 plots in four blocks. Each block measured 40 m x 4 m and was divided into five plots in each block, which had a dimension of 6.3 m x 4 m per plot. A total of 40 eggplant seedlings were transplanted on each plot, which had eight rows with five plants in each row. The planting distance was 0.9 m X 0.8 m. One-meter alleys were left between the plots.

There were four chemical treatments and a control (water only). The chemical treatments were three levels of crude stock of *A. muricata* leaves applied at 0.25%, 0.50% and 1.0%, and Dimethoate (40 EC), an organophosphate applied at 0.40%. Starting from one week after transplanting, each plot was sprayed once a week, until the fruits were matured for harvesting, with a CP 15 Knapsack sprayer. Treatments were applied four times in each growing season. Weeding was done manually when necessary.

3.5 Shoot and flower damage assessment

Data on damage of the shoots, flowers and the fruits were taken from the six middle rows of each plot 72 h after each spraying. The first and the eighth rows were left as boundary plants.

Data taken included average number of shoots and flowers produced and the number of shoots and flowers damaged per plant.

3.6 Yield and fruit damage assessment

The shoots were classified damaged or undamaged based on the following indices; presence of frass and emergent holes on the shoots and leaves and shoots losing their freshness and drooping (Owusu-Ansah *et al.*, 2001). The flowers were also classified as damaged or undamaged when they could not develop into fruit and found either on the plant or fallen on to the ground (Owusu-Ansah *et al.*, 2001). In both cases, the number of damaged flowers or shoots out of the total number of flowers or shoots produced per plant was recorded and the percentage of the flowers or shoots damaged was calculated.

Data taken during harvesting included total yield, the number of fruits damaged and undamaged per plant. The weights of the damaged and undamaged fruits from each plant were also taken and the percentages of damaged and undamaged fruits calculated. A fruit was considered damaged when it had feeding scar, frass or entry or emergence hole with or without frass emerging from it (Owusu-Ansah *et al.*, 2001). The damaged fruits were then split and the number of larvae per fruit per treatment was recorded.

3.7 Data Analysis

GenStat Release 7.2 Discovery 2007 edition Computer package was used to analyse variances and least significant differences were used to separate means that showed significant differences at 5% Probability level ($P \leq 0.05$). All count data were squared root transformed and the percentage values were arcsine transformed before analyses.

CHAPTER FOUR

4.0 RESULTS

This chapter reports the results obtained from the field experiment carried out to assess the effect of the five treatments, Dimethoate 40% EC and 0.25%, 0.50%, 1.0% *A. muricata* ethanolic leaf extracts and a control (water only) on the damage caused by *L. orbonalis* on the shoots, flowers and the fruits of *S. melongena*, and its effect on the fruit yield.

4.1 Minor season results

4.1.1 Damaged caused to the shoots in the minor season

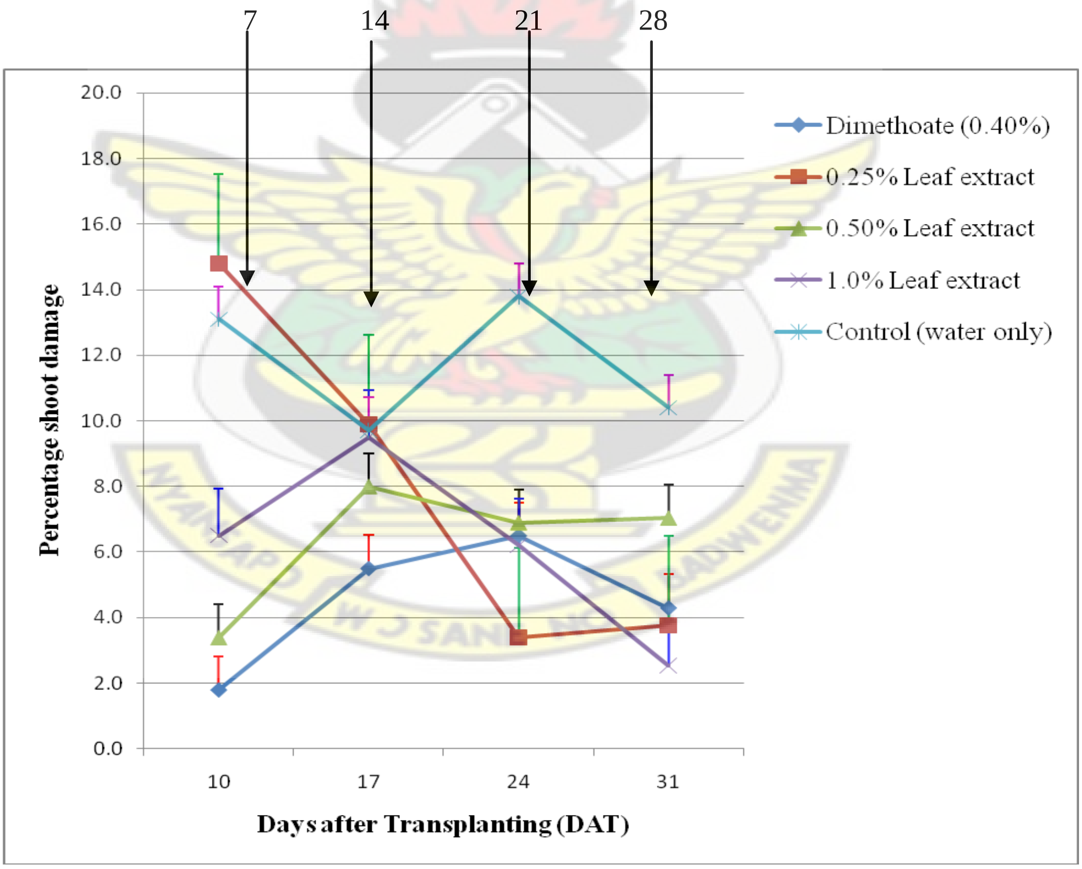

Figure 4.1: Effect of chemical treatments on the damage caused by *Leucinodes orbonalis* **to the shoots of** *Solanum melongena* **during the minor season (2009) in the field.** Arrows at the top of the figure indicate the days of treatment application.

From figure 4.1, the treated plants recorded numerically lower percentage shoot damage than the control but this difference was not statistically significant (see Appendix 2).

4.1.2 Damage caused to the shoots in the major season

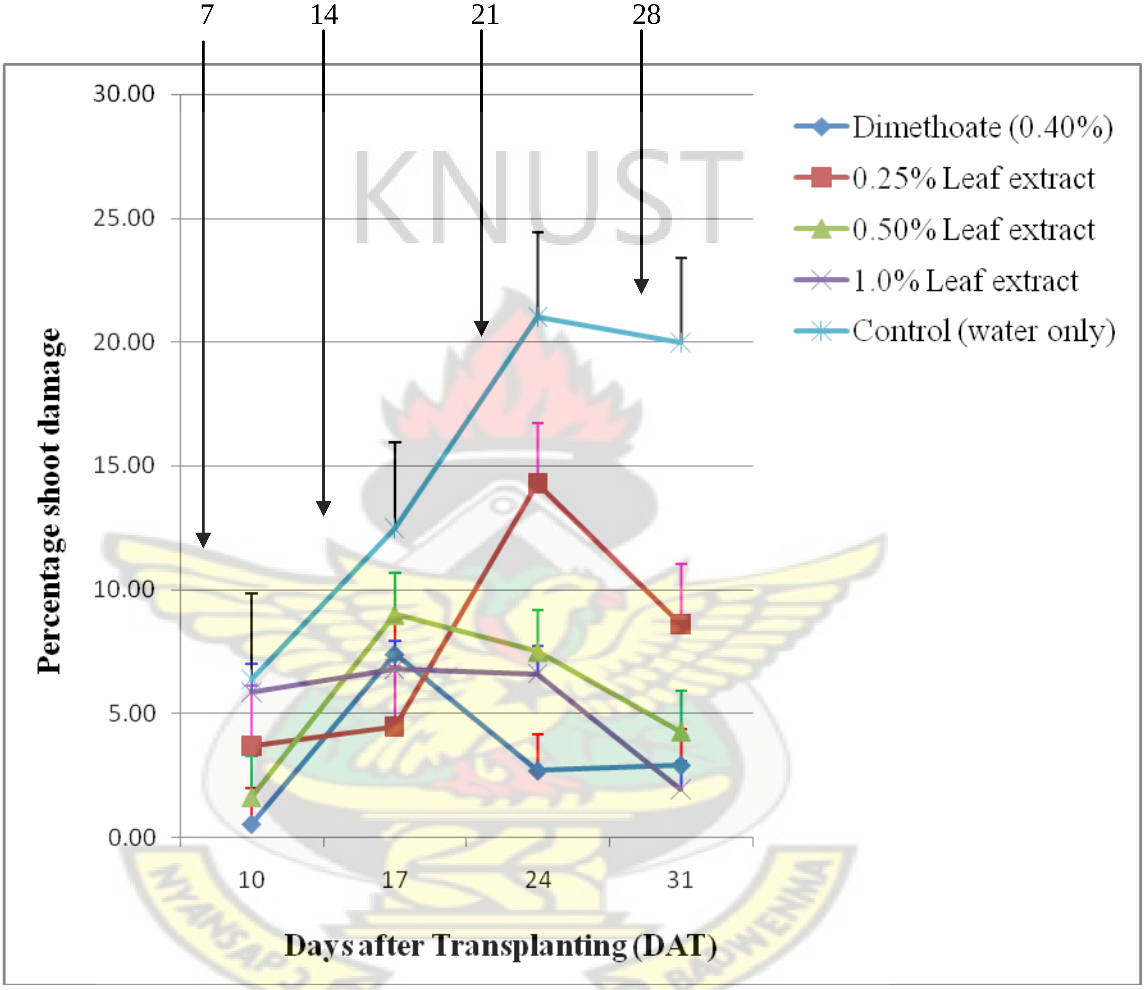

Figure 4.2: Effect of chemical treatments on the damage caused by *Leucinodes orbonalis* **to the shoots of** *Solanum melongena* **during the major season (2010) in the field.** Arrows at the top of the figure indicate the days of treatment application.

During the major season chemical treatments significantly reduced the percentage shoot damage compared to the untreated plants at 24 and 31 days after transplanting (Figure 4.2). The differences between the effectiveness of the leaf extract (particularly the 0.5% and 1%) and the synthetic insecticide was not significant. Among the three levels of the leaf extracts, the 1.0% leaf extract was the most effective.

4.1.3 Damaged caused to the flowers in the minor season

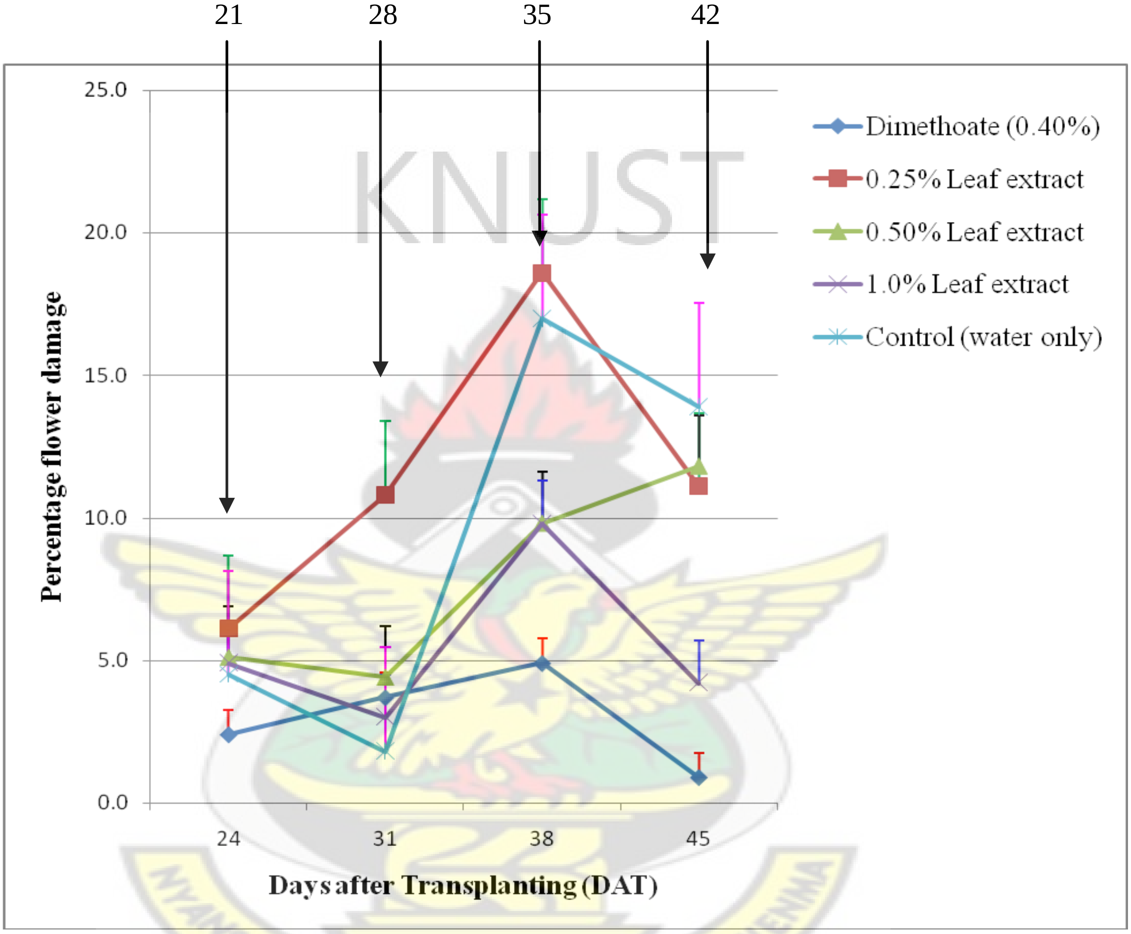

Figure 4.3: Effect of chemical treatments on the damage caused by *Leucinodes orbonalis* **to the flowers of** *Solanum melongena* **during the minor season (2009) in the field.** Arrows at the top of the figure indicate the days of treatment application.

The percentage flower damage was not significantly different among the treatments at 24 – 38 days after transplanting (Figure 4.3). However, with the subsequent chemical applications, the 1.0% leaf extract and Dimethoate treatments significantly lowered flower damage when compared with the water control at 45 DAT. There were no significant difference between the other leaf extract treatment and the control (Figure 4.3).

4.1.4 Damage caused to the flowers in the major season

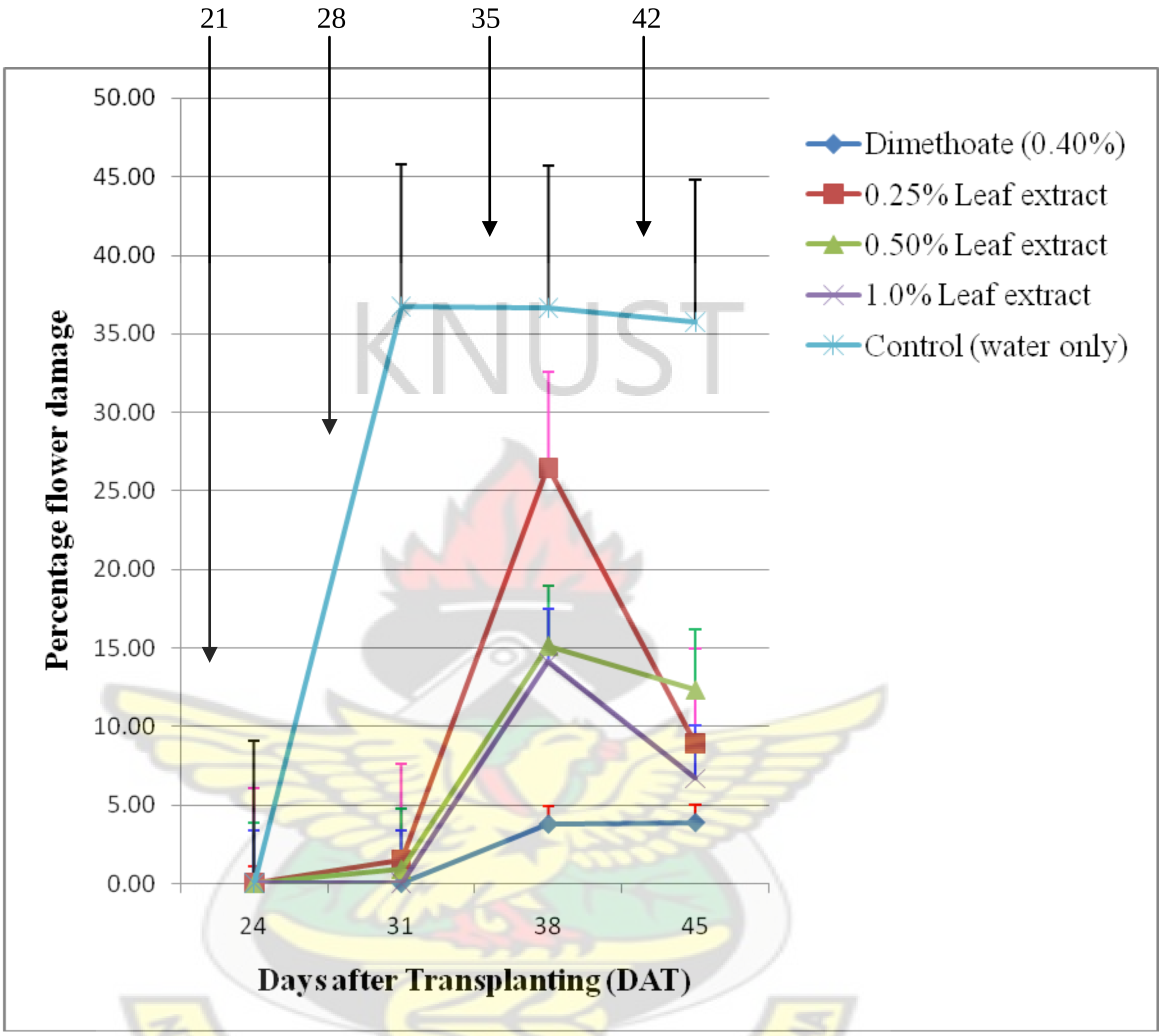

Figure 4.4: Effect of chemical treatments on the damage caused by *Leucinodes orbonalis* **to the flowers of** *Solanum melongena* **during the major season (2010) in the field.** Arrows at the top of the figure indicate the days of treatment application.

The treated plants recorded a lower percentage flower damage compared to the untreated plants during the major season. The chemical treatments, therefore, were effective in controlling flower damage by *L. orbonalis*. The efficacy of the leaf extracts was comparable to the synthetic chemical, dimethoate. Comparing the performance of the leaf extracts, the 1.0% leaf extract was the most effective among the three, followed by the 0.50% and then the 0.25% leaf extracts (Figure 4.4).

4.1.5 Fruit damage assessment in the minor season

Table 4.1: Effect of Dimethoate and *Annona muricata* leaf extract on *Leucinodes orbonalis* damage to eggplant fruits at 45 DAT during the minor season (2009) in the field.

Treatments	Mean number of fruits per plant		Mean fruit weight		Mean No. of Larvae per fruit	Percent damaged fruits
	Undamaged	Damaged	Undamaged (g)	Damaged (g)		
Dimethoate (0.40%)	13.2	9.0	87.0	110.0	1.15	41.0
0.25% Leaf extract	9.5	8.0	71.0	172.0	1.14	46.0
0.50% Leaf extract	11.2	9.1	92.0	295.0	1.42	45.0
1.0% Leaf extract	9.8	7.1	77.0	325.0	1.06	42.0
Control (water only)	7.7	7.4	39.0	425.0	1.12	49.0
CV%	13.9	13.3	58.6	81.9	24.2	76.4
LSD	NS	NS	NS	NS	NS	NS
F pr.	0.39	0.46	0.91	0.36	0.94	0.78

As shown in Table 4.1, the fruit data recorded 45 days after transplanting showed that, there were no significant differences among the means of the percentage fruit damage in the treatments. Similarly, the mean number of larvae per fruit did not differ significantly among the treatments during the minor season.

Table 4.2: Effect of Dimethoate and *Annona muricata* leaf extract on *Leucinodes orbonalis* damage to eggplant fruits at 52 DAT during the minor season (2009) in the field.

Treatments	Mean number of fruits per plant		Mean fruit weight		Mean No. of Larvae per fruit	Percent damaged fruits
	Undamaged	Damaged	Undamaged (g)	Damaged (g)		
Dimethoate (0.40%)	12.7	7.6	97.0	6.0	0.93	37.4
0.25% Leaf extract	10.9	8.8	64.0	67.0	1.00	45.0
0.50% Leaf extract	10.4	8.6	41.0	51.0	0.95	45.3
1.0% Leaf extract	9.3	7.5	33.0	39.0	0.71	45.0
Control (water only)	8.4	7.9	41.0	18.0	0.95	48.5
CV%	21.1	12.9	38.7	57.4	31.3	58.8
LSD	NS	NS	NS	NS	NS	NS
F pr.	0.76	0.80	0.79	0.77	0.84	0.80

The analysis of variance on the fruit data recorded 52 days after transplanting showed no significant differences among the means of the undamaged fruits, damaged fruits, undamaged fruits weight, damaged fruits weight, larvae per fruit and the percentage of damaged fruits for the treatments.

Table 4.3: Effect of Dimethoate and *Annona muricata* leaf extract on *Leucinodes orbonalis* damage to eggplant fruits at 59 DAT during the minor season (2009) in the field.

Treatments	Mean number of fruits per plant		Mean fruit weight		Mean No. of Larvae per fruit	Percent damaged fruits
	Undamaged	Damaged	Undamaged (g)	Damaged (g)		
Dimethoate (0.40%)	11.3	8.0	57.0	63.0	1.06	41.5
0.25% Leaf extract	9.1	9.1	0.0	163.0	1.51	50.0
0.50% Leaf extract	13.1	11.4	51.0	280.0	1.75	47.0
1.0% Leaf extract	12.7	8.3	138.0	336.0	1.89	40.0
Control (water only)	7.4	7.1	15.0	425.0	1.85	50.0
CV%	26.1	20.6	73.9	93.0	41.9	67.5
LSD	NS	NS	80.0	NS	NS	NS
F pr.	0.44	0.31	0.02	0.17	0.29	0.32

The fruit data recorded 59 days after transplanting indicated that the mean number of undamaged fruits, damaged fruits, larvae per fruit, weight of damaged fruits and the percentage of damaged fruits did not differ significantly among treatments. However, the differences among the mean weights of undamaged fruits were significant. The mean weight of undamaged fruits was significantly greater in the 1.0% leaf extract treatment than the other treatments.

Table 4.4: Effect of Dimethoate and *Annona muricata* leaf extract on *Leucinodes orbonalis* damage to eggplant fruits at 66 DAT during the minor season (2009) in the field.

Treatments	Mean number of fruits per plant		Mean fruit weight		Mean No. of Larvae per fruit	Percent damaged fruits
	Undamaged	Damaged	Undamaged (g)	Damaged (g)		
Dimethoate (0.40%)	13.9	7.8	72.0	39.0	1.03	36.0
0.25% Leaf extract	9.7	8.4	22.0	125.0	1.22	46.4
0.50% Leaf extract	18.0	12.9	84.0	280.0	1.51	41.7
1.0% Leaf extract	12.1	7.9	84.0	376.0	1.84	40.0
Control (water only)	10.6	10.2	6.0	473.0	2.11	49.0
CV%	20.8	22.2	23.5	88.3	43.9	65.1
LSD	NS	NS	NS	261.0	NS	NS
F pr.	0.47	0.26	0.40	0.02	0.07	0.45

The analysis of variance for the fruits harvested 65 days after transplanting (Table 4.4) showed, there were no significant differences between the mean numbers of undamaged and damaged fruits, mean number of larvae per fruit, mean weight of undamaged fruits and the percentage of damaged fruits. However, the mean weights of the damaged fruits were significantly different and damage increased with extract concentration. The least damage occurred in the plants treated with the synthetic insecticide.

Table 4.5: Effect of Dimethoate and *Annona muricata* leaf extract on *Leucinodes orbonalis* damage to eggplant fruits at 45 DAT during the major season (2010) in the field.

Treatments	Mean number of fruits per plant		Mean fruit weight		Mean No. of Larvae per fruit	Percent damaged fruits
	Undamaged	Damaged	Undamaged (g)	Damaged (g)		
Dimethoate (0.40%)	16.1	7.2	50.0	35.0	0.97	31.0
0.25% Leaf extract	13.9	7.8	48.0	156.0	1.39	36.0
0.50% Leaf extract	15.8	7.9	73.0	240.0	1.66	33.3
1.0% Leaf extract	15.9	8.0	46.0	347.0	1.93	33.5
Control (water only)	12.6	9.2	59.0	475.0	2.17	42.2
CV%	9.1	6.1	47.4	93.5	35.6	37.5
LSD	2.0	NS	NS	266.0	0.69	6.0
F pr.	0.01	0.12	0.17	0.03	0.02	0.01

There were significant differences among the treatments for the number of undamaged fruits, the percentage damaged fruits, damaged fruits weight and the number of larvae per fruit (Table 4.5). However, the number of damaged fruits per plant and the undamaged fruit weight were not significantly different among the treatments.

Table 4.6: Effect of Dimethoate and *Annona muricata* leaf extract on *Leucinodes orbonalis* damage to eggplant fruits at 52 DAT during the major season (2010) in the field.

Treatments	Mean number of fruits per plant		Mean fruit weight		Mean No. of Larvae per fruit	Percent damaged fruits
	Undamaged	Damaged	Undamaged (g)	Damaged (g)		
Dimethoate (0.40%)	16.5	7.2	51.0	26.0	0.97	30.4
0.25% Leaf extract	14.7	8.7	54.0	155.0	1.52	37.2
0.50% Leaf extract	15.6	9.1	51.0	237.0	1.60	36.8
1.0% Leaf extract	16.1	8.5	54.0	339.0	1.85	34.6
Control (water only)	12.9	9.8	54.0	459.0	2.22	43.2
CV%	4.2	8.4	41.4	99.7	34.9	29.0
LSD	NS	NS	NS	269.0	0.72	8.7
F pr.	0.07	0.32	1.00	0.04	0.03	0.03

Table 4.6 shows the results that were recorded 52 days after transplanting. The treatment means showed no significant differences among undamaged fruits weight, number of undamaged and damaged fruits per plant. However, the percentage of damaged fruits, damaged fruits weight and the number of larvae per fruit were significantly different. The percentage of damaged fruits and the number of larvae per fruit were significantly lower in the Dimethoate treatment than the water treated control. The mean weights of damaged fruits were significantly lower in the Dimethoate and 0.25% leaf extract treatments than the control.

Table 4.7: Effect of Dimethoate and *Annona muricata* leaf extract on *Leucinodes orbonalis* damage to eggplant fruits at 59 DAT during the major season (2010) in the field.

Treatments	Mean number of fruits per plant		Mean fruit weight		Mean No. of Larvae per fruit	Percent damaged fruits
	Undamaged	Damaged	Undamaged (g)	Damaged (g)		
Dimethoate (0.40%)	17.3	8.5	55.0	44.0	1.34	32.9
0.25% Leaf extract	14.5	9.3	66.0	94.0	1.21	39.1
0.50% Leaf extract	16.0	9.2	60.0	41.0	1.18	36.5
1.0% Leaf extract	18.4	8.3	61.0	28.0	0.93	31.0
Control (water only)	10.9	8.7	36.0	39.0	1.22	44.2
CV%	6.3	6.4	38.6	39.8	9.9	26.2
LSD	3.6	NS	NS	NS	NS	NS
F pr.	0.01	0.81	0.57	0.11	0.50	0.51

There were no significant differences among the treatments for all the parameters measured except for the mean number of undamaged fruits which were significantly lower in the Dimethoate and 0.5% and 1.0% leaf extract treatments than the control. The mean number of undamaged fruit per plant in the 0.2% leaf extract treatment did not differ from the control treatment.

Table 4.8: Effect of Dimethoate and *Annona muricata* leaf extract on *Leucinodes orbonalis* damage to eggplant fruits at 66 DAT during the major season (2010) in the field.

Treatments	Mean number of fruits per plant		Mean fruit weight		Mean No. of Larvae per fruit	Percent damaged fruits
	Undamaged	Damaged	Undamaged (g)	Damaged (g)		
Dimethoate (0.40%)	18.2	8.8	45.0	38.0	1.38	32.6
0.25% Leaf extract	17.6	11.4	73.0	51.0	1.43	39.3
0.50% Leaf extract	18.3	11.2	41.0	72.0	1.46	38.0
1.0% Leaf extract	19.4	9.4	83.0	55.0	1.49	32.6
Control (water only)	17.2	12.4	76.0	61.0	1.47	41.9
CV%	17.7	12.3	48.7	35.2	1.0	17.5
LSD	NS	NS	NS	NS	NS	3.6
F pr.	0.86	0.07	0.25	0.33	0.81	<.001

There were no significant differences among the treatments for all the parameters measured except for the percentage of damaged fruits. The percentage of damaged fruits were significantly lower in the Dimethoate and 0.5% and 1.0% leaf extract treatments than the control. There were no significant differences between the 0.25% leaf extract treatment and the control.

Plate 4.1: Symptoms of an infested shoot.

CHAPTER FIVE

5.0 DISCUSSION

The adult female of *L. orbonalis* only lays its eggs on the eggplant but do not feed on the plant. It is the larva that bores and feeds on the shoots and fruits of eggplant. The larvae after hatching bore immediately into the young soft shoots or the flowers or the developing fruits and seal off their entrance to prevent attack from predators. This cryptic feeding behaviour of the larvae within the plant tissue also makes it very difficult to be reached by insecticide for control. Control efforts should therefore be directed at the adult. The chemical that would be used to control or prevent the adults from laying eggs should either have contact poison properties, repellent or anti-oviposition properties on the adult insects. The chemical should also be able to prevent the eggs from hatching. Therefore, for the *A. muricata* ethanolic leaf extract to effectively control the shoot, flower and fruit damage, it is expected to posses one of these properties.

5.1 The efficiency of the plant extracts in controlling shoots, flowers and fruits damage by *L. orbonalis* in the minor and the major crop growing seasons

5.1.1 Reduction of shoot damage

From the results obtained, it was apparent that the effect of the chemical treatments was significant only in the major season. The leaf extracts were as effective as the Dimethoate treatments at 24 and 31 days after treatment in reducing shoot damage by *L. orbonalis* compared to the untreated control. This suggests that the leaf extracts possess either repellent or anti-oviposition properties or both against the adult *L. orbonalis*. These findings agree with those of Hussain *et al.* (1995) who tested 2 g and 5 g leaf extracts of custard apple (*A. squamosa*) on *Tribolium castaneum*

(Herbst) and reported that they were successful in controlling the infestation of *T. castaneum*, which they 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*.

5.1.2 Reduction of flower damage

From the flower damage assessment results, the leaf extracts could not control the flower damage effectively in the minor season. Dharmasena *et al*. (2001) reported that acetone extracts of fresh and stored leaves of *A. squamosa* were toxic to adult *Callosobruchus maculatus* (F.), whereas ethanol extracts were not active. Hence, the inability of the leaf extracts to control the flower damage could probably be attributed to the ethanol solvent used for the extraction. This lack of effectiveness could also be attributed to breakdown of the active ingredient by sunlight as there was a high light intensity during the period.

In the major season the leaf extract treated plants, however, did effectively control the flower damage, which was directly opposite to the situation in the minor growing season. There was a low light intensity during the major season.

5.1.3 Efficiency of *Annona muricata* leaf extract on fruit damage

Acetogenins, the major active ingredient in Annonaceae (Bermejo *et al.*, 2005) is a slow-acting stomach poison like rotenone (Rosell *et al.*, 2008). Leatemia and Isman (2004) conducted an experiment and found that 1% crude ethanolic seed extract of *A. squamosa* was 2.5 times more effective than 1% rotenone against *Plutella xylostella* (Linnaeus) larvae on cabbage. Therefore, it was expected that the damage to the fruits of the leaf extract treated plants by the larvae would be less, if not completely controlled, by poisoning the larvae when they ingest the treated fruits in the process of boring into them. In general, the treated plants suffered lower percentage fruit damage than the untreated control in the major season. However, there were no significant fruit damaged detected among the treatments in the minor season. The probable reason that may be ascribed to this occurrence is the faster degradation of the botanical in the minor season than in the major season. The ability of the leaf extracts to have recorded lower percentage fruit damage in the major season, suggests that the acetogenins in the leaf extracts might have affected both the adults and larvae of *L. orbonalis*.

CHAPTER SIX

6.0 CONCLUSION

This field experiment was carried out in both the minor and the major crop growing seasons with the application of a registered synthetic insecticide Dimethoate and three levels of *Annona muricata* ethanolic leaf extracts at 0.25%, 0.50% and 1.0% concentrations to control the damage caused to the shoots, flowers and fruits of eggplant (*Solanum melongena*) by the fruit and shoot borer (*Leucinodes orbonalis*).

From the results, the leaf extracts did not control the damage by *L. orbonalis* as effectively as the registered synthetic insecticide, Dimethoate. However, it showed a fair efficacy in the reduction of *L. orbonalis* damage to the shoots, flowers and fruits of (*S. melongena*). Thus, the ethanolic leaf extract of *A. muricata* is a potential substitute for synthetic insecticides employed in pest management in eggplant, which have harmful effects on the environment.

6.1 Recommendations

From the result obtained, the leaf extract of *Annona muricata* is a potential biopesticide. It is however recommended that high concentrations such as the highest rate of 1.0% used in this study should be used for effective control of *L. orbonalis* and similar pests. It is further recommended that future evaluations should include rates higher than those used in the present studies for a more efficacious control. Also, other solvents such as acetone should be used for the extraction to test the efficacy of the plant on the insect.

Plate 6.1: Egg plant (*Solanum melongena*) plant with fruits

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APPENDIX

Appendix 1: Vegetables export in Ghana from 1995 to 2002 (in tons)

	Total volume (tons) exported each Year							
Crop	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Pepper	121	732	1420	2088	2420	2819	5281	4687
Onion	-	29	25	75	39	58	46	58
Okra	-	44	392	38	56	64	67	65
Tomatoes	130	1814	817	534	471	2033	4539	4961
Egg Plant	-	513	1018	1184	1338	1080	1295	1512
Tinda	-	-	822	879	878	1126	1256	1137
Condiments	1741	2319	625	495	389	980	988	1548

Appendix 2: Effect of chemical treatments on the damage caused by *L. orbonalis* to the shoots of *S. melongena* in the minor season.

	Days after Transplanting			
Treatments	**10**	**17**	**24**	**31**
Dimethoate (0.40%)	1.8	5.5	6.5	4.3
0.25% leaf extract	14.8	9.9	3.4	3.8
0.50% leaf extract	3.4	8.0	6.9	7.0
1.0% leaf extract	6.5	9.5	6.2	2.5
Control (water only)	13.1	9.7	13.8	10.4
CV%	41.3	53.4	53.0	92.6
LSD	NS	NS	NS	NS
F pr.	0.19	0.95	0.20	0.11

Appendix 3: Effect of chemical treatments on the damage caused by *L. orbonalis* **to the flowers of** *S. melongena* **in the minor season.**

	Days after Transplanting			
Treatments	**24**	**31**	**38**	**45**
Dimethoate (0.40%)	2.4	3.7	4.9	0.9
0.25% leaf extract	6.1	10.8	18.6	11.1
0.50% leaf extract	5.1	4.4	9.8	11.8
1.0% leaf extract	4.9	3.0	9.8	4.2
Control (water only)	4.5	1.8	17.0	13.9
CV%	56.4	86.3	5.9	18.3
LSD	NS	NS	NS	7.98
F pr.	0.98	0.20	0.10	0.02

Appendix 4: Effect of chemical treatments on the damage caused by *L. orbonalis* **to the shoots of** *S. melongena* **in the major season.**

	Days after Transplanting			
Treatments	**10**	**17**	**24**	**31**
Dimethoate (0.40%)	0.3	4.3	1.5	1.7
0.25% leaf extract	2.1	2.6	8.3	5.0
0.50% leaf extract	0.9	5.2	4.3	2.5
1.0% leaf extract	3.4	3.9	3.8	1.1
Control (water only)	3.7	7.2	12.1	11.5
CV%	22.2	51.0	28.3	25.1
LSD	NS	NS	5.65	3.96
F pr.	0.15	0.57	0.01	<.001

Appendix 5: Effect of chemical treatments on the damage caused by *L. orbonalis* **to the flowers of** *S. melongena* **in the major season.**

	Days after Transplanting			
Treatments	**24**	**31**	**38**	**45**
Dimethoate (0.40%)	0.0	0.0	2.2	2.2
0.25% leaf extract	0.0	0.9	15.4	5.1
0.50% leaf extract	0.0	0.5	8.7	7.1
1.0% leaf extract	0.0	0.0	8.2	3.8
Control (water only)	0.0	21.8	21.6	21.1
CV%	0.0	45.6	34.4	27.9
LSD	0.00	6.75	8.18	7.52
F pr.	0.00	<.001	0.00	<.001