EVALUATION OF NEEM SEED WATER EXTRACT, BIOBIT AND KARATE ON INSECT ABUNDANCE AND YIELD OF LOCAL GARDEN EGG *(Solanvm integrifolium* L.)

Owusu-Ansah Fred (BSc. Hons.), Legon, Ghana.

A thesis presented in partial fulfilment of the requirements for the degree of Master of Philosophy in Entomology of the University of Ghana, Legon.

Insect Science Programme*
University of Ghana, Legon.

July, 1999

**Joint interfaculty international Programme for the training of entomologists in West Africa.*
Collaborating Departments: Zoology (Faculty of Science) & Crop Science (Faculty of Agriculture).

CONTENTS

Chapter 1:

Chapter 2:

Chapter 3:

Chapter 4

Chapter 5:

Chapter 6:

DECLARATION

I hereby declare that except for the references to literature, which have been duly cited herein, this work is the product of my research.

I am to be held responsible for any error in this work.

SUPERVISORS/STUDENT

PROF. K. AFBEH-NUAMAH
(PRINCIPAL |BWPE^VISOR)

DATE---
Agricultur,Z)R< Research Station (ARS)
University ibfinGiKade.

DR. D. OBENG-OFORI
(CO- SUPERVISOR)

Crop Science Department,
Faculty of Agriculture,
University, of Ghana.Legon.

DR. OFOSU-BUDU
(CO- SUPERVISOR)

DATE_______ **ffr-* 0b
Cro^%^£encS ^Oepartmen t,
Faculty of Agriculture,
University, of Ghana.Legon.

OWUSU-ANSAH FRED
(STUDENT) nf/t?'? *I^COQ*
DATE------- -j-'-f----

ARPPIS, University of Ghana, Legon.

DEDICATION

This research is dedicated to Almighty God whose bountiful care has sustained me to this day, my Uncle Mr. K. Opoku-Darko, my parents, my brother in-law (Mr. Amos Asanti) and all those who have made me what I am today.

ACKNOWLEDGEMENTS

I wish to express my indebtedness to my supervisors, Prof. K. Afreh-Nuamah, Dr. D. Obeng-Ofori and Dr. Ofosu-Budu all of Faculty of Agriculture for guiding me to the completion of this thesis.

I would like to thank Dr. I. Ofori of Crop Science Department for statistical advice and Mr. Elvis Nyarko of the (Oceanography and Fisheries Department) for helping me type this manuscript.

This research was funded by the National Agricultural Research Project (NARP) to whom I am most grateful.

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The effect of Neem Seed Water Extract (NSWE) on insects and growth performance of eggplant (local garden egg) was evaluated in the field from June to October 1998 at Ekoso in the Eastern region, Ghana. The extract was applied at the rate of 75 g of seed per litre of water and compared with a standard insecticide (Karate), a registered *Bacillus thuringiensis* Berl. (Biobit) and water only as control. The effect of each treatment on leaf, shoot and fruit damage caused by defoliators, shoot, bud, and fruit borers were determined. The influence of the treatments on plant biomass and other vegetative growth indices such as plant height, plant girth, number of functional leaves and branches per plant, flower production as well as fruit yield were also assessed. Water traps were used to monitor the effects of the various treatments on the abundance of insects associated with the crop. Economic benefits of each pesticide-use programme based on crop value, cost of pest control and net profits were determined.

Karate and NSWE treatments significantly ($P<0.05$) reduced percentage fruit damage, number of borers per fruit and defoliation. Although NSWE could not effectively control shoot

and bud borers as Karate, it performed better (P<0.05) in reducing percentage borer damage than either Biobit or control.

The neem seed extract significantly (P<0.05) promoted vegetative growth than the rest of the treatments, but delayed flower initiation. Fruit yield per plant did not differ significantly (P>0.05) among Karate, NSWE and Biobit treatments. All three treatments, however, produced higher yields than the control plots with Karate-treated plots recording numerically higher yield followed by NSWE.

Net profit obtained from Karate treatment was higher ((211,187,772.00) per hectare compared with that of NSWE treatment ((£8,747,772.00). However, NSWE performed better than Biobit, which recorded a net profit of (£6,283,852.00/ha. Control plot had the least net profit of ct5,752,772.00/ha.

Insects from seven major orders (Coleoptera, Lepidoptera, Odonata, Orthoptera, Diptera, Hymenoptera and Hemiptera) were found associated with the local garden egg. Fewer numbers of predators, mainly hymenopterans, were collected from plants treated with Karate compared to either NSWE- or Biobit- treated plots. This indicates that Karate had adverse effects on beneficial insects in the garden egg ecosystem.

The major pest complex of garden egg included *Leucinodes orbonalis* Guen. which attacked the shoots and fruits, the bud borer *Scrobipalpa blapsigona* Meyrick, *Pachnoda spp.* which scraped and chewed stem and defoliators comprising *Acraea peneleos peneleos* Ward., *A. pharsalus pharsalus* Ward., *Zonocerus variegates* L., *Eulioptera spp.* and *Phaneroptera nana* Stal.

Neem seed water extract can be used as alternative to synthetic insecticide for the control of local garden eggs by resource poor farmers.

CHAPTER ONE

1.0 General Introduction

Worldwide interest in vegetable crop production is increasing. This is because vegetables are essential in the diet (Oomen and Grubben, 1978; Hollingsworth, 1981). In terms of global crop production, vegetable is estimated to be 60% of world crop production (FAO, 1988).

In Ghana, garden egg (*Solanum integri folium* L.) is one of the most important vegetable crops extensively cultivated during both the wet (major) and the dry (minor) seasons throughout the country especially in the forest zone. One of the major problems associated with garden eggs production is the damage caused by insect pests at various physiological stages of the plant growth. The pest coirplex of garden egg in Ghana include *Leucinodes orbonalis* Guen. which attack the stem and fruits, the leaf feeder, *Selepa docilis* Butler, the bud borer (budworm) *Scrobipalpa blapsigona* Meyrick and the scraping bug, *Urentius hystericellus* Richter (Forsyth,•1966; Owusu, 1980; Coffie-Agblor, 1982; Osei, 1986). These pests inflict severe damage to the crop resulting in drastic reduction in yield.

The most widely used method of controlling garden egg pests in Ghana and other West African countries is frequent application of synthetic insecticides, throughout the growing season. Growers in

Ghana apply different kinds of insecticides such as Malathion, Perfekthion, Cypermethrin, Diaxocarb, Roxion, Lindane, Karate, Cymbush, Actellic and Basudin (Blay, 1986; Akpabi 1989), to produce marketable crops. A survey conducted by the Crop Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR) in 1991, in the commercial garden egg production areas of Ejura showed a greater reliance on the use of these insecticides for crop protection (Asante, 1992).

The extensive use of synthetic insecticides has resulted in pest resistance problems and the destruction of non-target organisms in most vegetable growing areas in the country. For instance, until 1998, the whitefly was not recorded as a serious pest in Ghana but currently, it is reported as a major vegetable pest due to the destruction of its natural enemies (NARS, 1998). Toxic residues have also been found to be very high in market produce in most vegetable cultivation areas (NARS, 1998).

In order to achieve sustainable vegetable production in Ghana, it is imperative to develop alternative' methods and products that are effective but less detrimental to applicators and the environment as a whole. Neem extracts have been found to be effective against many economically important pests (Schmutterer, 1990; Jackai, 1993). A wide range of aqueous neem concentrations (5-100 g of seed powder per litre of water) have been quoted as being effective in reducing pest damage in vegetable field trials (Ruscoe, 1972; Asari and Nair, 1972; Sombatsiri and Tigvattanont, 1984; Dreyer, 1987; Cobbinah and Osei-Owusu, 1988). Preliminary field experiments (unpublished data) conducted by a team of scientists at the Agricultural Research Station, of the University of Ghana at Kade, showed that neem seed water extract at the rate of 75 g/1 was effective in reducing damage caused by *Selepa docilis* and *Leucinodes orbonalis* on garden egg. The fruit sizes were, however, observed to be smaller than the rest of treatments.

Neem is locally available, easy to prepare, safer to use and environmentally friendly. In Ghana, vegetable growers are subsistent farmers who cannot afford to purchase expensive synthetic pesticides. The use of homemade neem products will increase and stabilize the yields of the crop.

However, studies on the use of neem products on vegetable crops have concentrated on their efficacy against insect pests under laboratory conditions. Very little research has been done on the efficacy of neem extracts against pests of local garden egg under field conditions. The possible effect of neem extract on the growth and development of the crops themselves have seldom been investigated. Furthermore, it is not certain whether insect pests of the crop differ from one locality to another in the country. The economic benefits associated with specific pesticide-use programme on local garden egg production in Ghana are also not available. Information on the benefits from the use of a specific pesticide is needed by growers to enable them derive maximum benefits from the product.

The primary objectives of this field study were to:

(a) determine the insect fauna associated with the local garden egg production in the field at Ekoso in the Asamankese district, Eastern region of Ghana.

(b) investigate the growth promoting properties and yield effects of neem seed water extract (NSWE) on the crop.

(c) evaluate the efficacy of NSWE, Biobit and Karate under field and laboratory conditions against the major pests that attack the crop

(d) assess the performance of the various treatments on the relative abundance of the insect fauna in the garden egg ecosystem.

(e) determine total fresh-market crop value, cost of control programmes and net profits resulting from each treatment.

1.1. Expectation

The research work involved the participation of extension officers and small-scale vegetable growers in the Asamankese district where Karate is widely used because of its effectiveness in controlling pests of vegetables. For this reason, Karate was used as a standard agro-chemical and its efficacy compared with NSWE and

Biobit.

Biobit is a biopesticide with *Bacillus thuringxensis* as active ingredient. Its use is being encouraged for the control of pests of vegetables in Ghana. However, its performance is inconsistent due to edaphic and changes in environmental factors (Rodgers, 1993). It is only effective against particular stages in the life cycle of pest and disease organisms. This limits its potency under field conditions.

Therefore, the successful performance of NSWE comparable to Karate and Biobit will be an alternative biological product and serve as a demand-driven material for local growers in managing vegetable pests. This will reduce excessive use of synthetic insecticides and residue levels in vegetable produce in the market. Sustainable vegetable production in the country will also be achieved.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1 Origin, types and distribution of the eggplant

Eggplants are a group of Solanaceous crops belonging to the genus *Solanum.* They are usually perennial but commonly grown as annuals (Irvine, 1969). According to Watts and Watts (1951) , eggplants were thought to have originated from tropical India or China where they were mentioned by early writers in some 1,500 years ago.

Eggplants are widely grown in the Caribbean, Malaysia, Indonesia, Central, East and West Africa, Central and South America and France. The plant has been given different names in different places. According to Herklot (1972), colour forms and shapes of the crop have contributed to the different names given to it. In France, the eggplant *(Solanum melongena* L.) is known as "aubergine" while in India, it is known as "brinjal". (Larbi, 1978). The long purplish-red and purple forms of aubergine are the two most important eggplants in Taiwan. These are called "Fergyuan purple" and "Pingtung longed", respectively (Larbi, 1978). Similar cultivars are grown in Thailand and in Hongkong; the purplish red is the most popular. The cultivars that are commonly grown in Europe and America are the short forms of the purple-red aubergine. However, in Japan, the long straight or curved purple-red types are most popular (Larbi, 1978).

In Ghana, two species commonly grown are the *Solanwa integrifolium,* called garden eggs and the exotic types *S. melongena,* commonly referred to as aubergines. *Solanwa. melongena* is thought to have been domesticated in India where wild varieties now grow. It is a favourite vegetable in the warm tropics especially in the West Indies and Southern United States (Cobley and Steele, 1956) . According to Irvine (1969), they were introduced into Ghana in 1924 and spread quickly throughout the country. Aubergines have enormous, shinning, smooth, oblong or ovoid berries up to 15 cm long. They are low bushy plants with large leaves, whitish flowers and an average height of 60 cm. They are variously coloured in different cultivars as dark purple, green, red or white (Cobley and Steele, 1956). The garden egg, *S. integrifolium* originated in Africa but are also grown in the Far East where it is called Chinese eggplant (Norman, 1974). The local garden eggs have smaller-sized fruits. These are sometimes lobed but are usually smooth. Some cultivars are coloured white, others cream or yellow (Irvine, 1969).

Eggplants are considered to be the most thermophilic (heat loving) of all the solanaceous vegetables (Boswell and Jones, 1941). They are typically warm season crops and do well on light soil, rich in organic matter with soil pH range of 5.0 - 6.8 (Larbi, 1978) . In Ghana, eggplants are grown throughout the country, especially in the forest zones. The plants are often intercropped with other vegetables such as okro, tomato and pepper. Under favourable conditions, the eggplant produces 8 - 14 fruits per plant (Tindall, 1968). However, Torkpo (1994) has reported that an average number of fruits per plant were 20 fruits with mean single fruit weight of 40.5 g. Variation in yield could be attributed to differences in moisture content of the soil, soil fertility status, frequency of harvest, varietal susceptibility, plant spacing, disease and pests infestation and cultural practices.

2.2. Economic importance of eggplant

2.2.1. Ghanaian diet

Traditionally, the fruits are very useful vegetables in the diet of Ghanaians. Both the local and the exotic eggplants are predominantly used for food preparation in stews and thickening of soups. The fruits are sometimes fried or baked and eaten with other dishes. The leaves of some varieties are also used as leafy vegetables in some localities in the country (Dei-Tutu, 1973). Some researchers have estimated the nutritional value of 100 g edible portions of the fresh raw vegetable. According to Oscar and Donald (1988), *S. melongena* contains 0.70 mg vitamin A; 0.09 mg Thiamine; 0.02 mg Riboflavin; 0.60 mg Niacin; 1.6 mg Ascorbic acid and 0.09 mg Vitamin B_6. The local garden egg *(S. integrifolium)* is also reported to contain 92% water; 26 (kcal) energy; 1.1 g protein; 0.1 g fat; 6.3 g carbohydrate; 1.0 g fiber; 36 mg calcium; 33 mg phosphorus; 0.6 mg iron; 4 mg sodium and 21.9 mg potassium per 100 g fresh raw vegetable (Eyeson and Ankrah, 1976; Oomen and Grubben, 1978; Hollingsworth, 1981). Thus, it contributes modest amounts of protein, calories, vitamins and mineral salts in the diet.

2.2.2. Foreign exchange earning capacity

The eggplant is a potential foreign exchange earner to the country. Between 1980 and 1990, the estimated production of garden egg was quoted as 152.1 tonnage (1000 mT) (PPMED, 1991). This earned the country over 4000 US dollars. This amount does not account for the possible overland exports to the neighbouring countries. Though this amount is low, opportunities exist for Ghana to export substantial quantities to the U.K., Holland, Sweden and France. Already, countries such as Senegal, Niger and Ivory Coast export large quantities of garden egg to Europe (Ampong, 1979).

2.2.3. Source of employment

In Ghana, the Nkulenu and Baah Economic Industries have successfully canned garden eggs whole or as slices for local consumption and for export. Garden egg production for the local industries serves as a very important source of employment and income feneration business for men, children and women in the country.

2.3 Crop growth in relation to yield performance

Vegetative growth and flower formation of the eggplant depends on the environmental conditions and cultural treatments. Depending on the cultivar and rate of growth, fruits are harvested within 80-120 days from transplanting (Rice *et al.* 1992) . In their research, these workers recorded 8-14 fruits per plant with fruit weight varying from 0.25-0.40 kg per fruit. Average plant height and fruit length was reported to be 105 cm and 15 cm respectively.

In an experiment to evaluate the effect of sowing date on flowering and yield in varieties of eggplant, Nsowah (1970) observed that cultivars of eggplant vary in earliness in flowering and yield potentials. He reported that yield in eggplant is affected by different parameters such as number of flowers, percentage fruit set, number of fruits and fruit weight per plant. According to him, floral initiation of *S. melongena* lies within 58.9-66.4 days after sowing and 93.3-112.5 days for maturity. The fruit weight per plant was estimated between 240.0-558.8 g.

Baha-Eldin et al., (1968) observed that, height of eggplant and early flowering habits showed positive correlation with high yielding ability. According to Ofosu-Budu (1984), the number of branches per plant at first flowering gave the highest positive correlation with

.eld. He recorded that mean number of fruits per plant of *S. zlongena* ranged between 2 and 4 fruits and yield per plant was 0.73 j-0.77 kg. He also indicated that mean plant height, mean number of ays to first flowering and number of primary branches at first Lowering ranged between 34.20 cm and 45.32 cm, 66.89 days and 75.43 ays and 2.25 and 3.21 respectively.

In his studies on *S. Integrifolium*, Torkpo (1994), recorded an average of 82 days to first flower at an average height of 26 cm. lays to first maturity was reported as 95 days. Number of branches at fruiting and number of fruits per plant were recorded as 12 branches and 20 fruits respectively. The mean fruit weight (in grammes) and yield per plant (kg/ha) were also reported as 40.5 g and 4625.5 kg/ha respectively.

2.4. Problems associated with eggplant cultivation

2.4.1. Environmental

Among the problems affecting the production of the eggplant are the environmental conditions under which the crop is cultivated. According to Balls (1951) and Arnon (1972), maximum crop yield per unit area could be achieved when the prevailing environmental conditions are optimal. Various researchers have observed that soil fertility status, moisture content of the soil, plant density and spacing, varietal susceptibility, seed viability and frequency of harvest can influence the productivity of the crop (Watts and Watts, 1951; Donald, 1963; Palevitch, 1969; and Norman, 1974).

2.4.2. Diseases

Diseases and insect pests appear to be the major constraints to eggplant production (Brader, 1982). The major diseases affecting the eggplant include *Fusarium* wilt (Cooke), bacterial wilt and phomopsis (vexan), which may affect the stem, fruits and the leaves of the crop (Larbi, 1978).

2.4.3. Insects

Several insects have been found to be associated with the eggplant. Like any other solanaceous crop, the eggplant is susceptible to insect pest attack at various physiological stages (Table 1).

Table 1. Insects associated with eggplant

Name of insect	Family	Parts attacked or status of insect	References
Leucinodes orbonalis	Lepidoptera: Pyralidae	Stem, fruit and shoot borer	Forsyth, 1966, Osei, 1986.

Assasin bugs	Hemiptera: Reduviidae	Predator	Kirkpatrick, 1957.
Selepa docilis	Lepidoptera: Noctuidae	Defoliator	Norman, 1974; Owusu, 1980.
Scrobipalpa blapsigona	Lepidoptera: Pyralidae	Flower andbud borer	Coffie-Agblor, 1982.
Diplognatha Gagates (Tors ter)	Coleoptera: Cetoniidae	Young shoot	Division of Agriculture, Ghana 1962.
Acanthocoris abscuricomis (Dali.)	Hemiptera: Coreidae	Sap-sucker, Young shoot	Division of Agriculture, Ghana 1962.
Deilephila nerii (L.)	Lepidoptera: Sphingidae	Larva feeds on fruits and Leaves	Division of Agriculture, Ghana 1962.

Ootheca mutabilis (Sahib.)	Coleoptera: Chrysomelidae	Adults/Larvae eat Leaves	Division of Agriculture, Ghana1962.
Euzephera Villora (Fldr.)	Lepidoptera: Pyralidae	Stem borer	Norman, 1974
Bemisia sp.	Homoptera: Aleyrodidae	Vector of mosaic virus; leaves and shoot.	Larbi, 1978
Hctmorococyphus Subittatus (Wlk.)	Orthoptera: Tettigoniidae	Leaves	Larbi, 1978
Sphodromantis lineola (Burm.)	Orthoptera: Mantidae	Leaves	Larbi, 1978
Podagrica unifozmis (Jac.)	Coleoptera: Chrysomelidae	Leaves	Larbi, 1978

Cheilomenes lanata (F.)	Coleoptera: Coccinelidae	Predator	Larbi, 1978
Lagria villosa (F.)	Hemiptera: Lagriidae	Leaves, flowers andstem	Larbi, 1978
Paederus spp.	Coleoptera: Staphylidae	Predator	Larbi, 1978
Mylabris lemoulti (Pic.)	Coleoptera: Meloidae	Flowers and buds	Larbi, 1978
Graptostethus sexvus (Dali.)	Hemiptera: Lagriidae	Leaves	Larbi, 1978
Coptosoma sp.	Hemiptera: Pentatomidae	Sap-sucker Leaves.and buds	Larbi, 1978
Sphedanolestes pictunithes (Schout.)	Hemiptera: Reduvidae	Leaves and young shoots	Larbi, 1978

Qxycarenus spp.	Hemiptera: Lygaeidae	Suck sap from buds and young fruits	Larbi, 1978
Riptortus spp.	Hemiptera: Coreidae	Leaves	Larbi, 1978
Tetramorivm spp.	Hymenoptera: Formicidae	Predator	Larbi, 1978
Camponotus acvapimensis (Mayr.)	Hymenoptera: Formicidae	Predator	Larbi, 1978
Chxysops spp.	Neuroptera: Chrysopidae	Buds	Larbi, 1978
Epicauta albovittata (Gestro)	Coleoptera: Meloidae	Adults eat Leaves, Larvae are predators	De Pury, 1968

Empoasca Lybica (DeBerg)	Hemiptera: Cicadellidae	Leafhopper Infest foliage,	Schmutterer, 1969
Urentius hystricellus	Hemiptera: Tingidae	Leaves	Schmutterer, 1969
Epicauta aethiops (Latr.)	Coleoptera: Meloidae	Adults eat Leaves and flowers	Schmutterer, 1969
Scrobipalpa heliopa (Lower)	Lepidoptera: Pyralidae	Leaves, shoot, stem and fruits	Schmutterer, 1969
Euzophera sp.	Lepidoptera: Pyralidae	Leaves, shoots and fruits	Schmutterer, 1969
Euzophera ossaettella (Treit)	Lepidoptera: Pyralidae	Leaves., shoots and fruits	El-Sherif, 1971

Centrococcus insolltus (Green)	Homoptera: Pseudococcidae	Leaves and buds	Rawat andModi, 1969
Camponotus spp.	Hymenoptera: Formicidae	Predator	Rawat and Modi, 1969
Para *trechina spp-*	Hymenoptera: Formicidae	Predator	Rawat and Modi, 1969
Leptomastrix spp.	Hymenoptera: encyrtidae	Predator/ Parasite	Rawat and Modi, 1969
Kyperaspis spp.	Coleoptera: Coccinelidae	Predator/ Parasite	Rawat andModi, 1969
Nephus spp.	Coleoptera: Coccinelidae	Predator/ Parasite	Rawat andModi, 1969

Trinervitemis biformis (Washman)	Isoptera: Termitidae	Predator	Katiyar, 1972
Microtermes spp.	Isoptera: Termitidae	Predator	Katiyar, 1972
Epilachna gagentica (F.)	Coleoptera: Coccinelidae	Adult and Larvaeeat leaves	Saddappaji, 1973
Euzophera perticella (Rag.)	Lepidoptera: Pyralidae	Shootj and stem borer	Butani and Varma, 1976
Eublema olivacea (Wlk.)	Lepidoptera: Tortricidae	Leaf roller	Butani and Varma, 1976

2.5. The use of synthetic pesticides to control garden egg pests

The most widely used method of controlling pests of garden egg in West Africa and other parts of the world is the application of synthetic insecticides throughout the growing season. Growers typically use different kinds of insecticides as plant protection measures to produce marketable crops.

Pal (1971) found that sprays of phosphamidon and endrin were superior to lindane, malathion and BHC dust for the control of *Urentius echnlnus* Dist. (Hemiptera: Tingidae). Sidhu and Singh (1971) recorded methyldematon as the best of the eight tested insecticides for the control of *Tetranychus curcvbitae* Rahman. ((Acarina: Tetranychidae) on garden egg. They also recommended chlorobenzilate for its effectiveness and low toxicity. Joshi and Sharma (1973) observed that in descending order of effectiveness, carbaryl, formothion, phosphamidon, endosulfan and a mixture of endrin and malathion proved good for controlling brinjal aphids (*Aphis gossypii)*, Jassids (*Amarasca devastans*) Dist. and fruit borer *L. orbonalis* in Rajasthari. In the evaluation of insecticides for the control of *Epilachna vigintioctopvnctata* (F.) on garden egg, Sandhu et *al.* (1973) recommended carbaryl, endosulfan, dichlorvos and malathion. Ulthamasamy et *al.* (1973). also reported carbaryl, endosulfan and carbophenothion as effective in controlling the spotted leaf beetle and ash weevil on garden egg.

Studying compatibility and effectiveness of Urea mixtures in India, Chakraborty et *al.*, (1974) recorded a reduction in leafhopper and fruit borer infestation in brinjal as a result of foliar application of Urea - endrin and urea - phosphamidon. Satpathy et al., (1974), working on insecticidal residues on eggplant *(Solanum melongena)* concluded that persistence of dimethoate and diazinon in brinjal was of shorter duration than phorate and disulfoton. Conducting a research on the efficacy of eighteen insecticides for the control of the fruit borer of eggplant, Krishnaiah et al. (1976) reported that carbaryl, even at 1 kg/ha was successful. Kumaresan and Baskaran (1976) using seventy-day old potted *S. melongena* infested with aphids observed that mephosfolan (Cytrolane) and Phorate persisted for a longer time than dimethoate and carbaryl when sprayed on the plants.

Experiments of Mohan et al. (1988) showed a remarkable reduction in the populations of the cotton aphid, *Aphis gossypii* (Glover) and the leafhopper, *Amrasca biguttula biguttula* (F.) on eggplant by foliar sprays of 0.1% monocrotophos. According to Dreyer and Hellpap (1991), a weekly spray of the carbamate insecticide butacarboxin gave a good protection of the eggplant against the attacks of the leaf attacking lace bug, *Corythaica spp.* and .the whitefly, *Bemisia spp.*

2.5.1. Crop protection methods in Ghana

The main eggplant growing areas in the country are Wenchi, Atebubu, Kintampo, Ejura, Sekyere - dumase, Akpo near Boti falls, Ekoso, Kade, Kpandu, Tokor, Vakpo, Weija, Mankesim and Swedru.

Local vegetable growers in these localities predominantly use synthetic chemicals such as Benzene hexachloride (BHC), malathion, perfekthion, cypermethrin, diaxocarb and actellic, (Blay, 1986, Akpabi, 1989). Local growers at Ekoso, in the Asamankese district of eastern region, Ghana, prefer karate for the control of eggplant pests because of its effectiveness in controlling shoot borers. Karate (2.5EC), a product of Zeneca Agro Chemical Limited, is a pyrethroid insecticide with Lambda-cyhalothrin as the active ingredient. These agro-chemicals are used by growers to reduce damage caused by pests and to increase yield.

Currently, some farmers have adopted the use of biopesticides such as Biobit/Dipel to manage pest of vegetables in some parts of the country.

2.6 Side effects of synthetic pesticides

To reduce damage caused by insect pests, most farmers use different types of pesticides throughout the growing season. A survey carried out by the Crop Research Institute (CRI) in 1991, in the commercial garden egg producing areas of Ejura in the Ashanti Region of Ghana showed the indiscriminate use of karate, cymbush, actellic, basudin and roxion for crop protection (Asante, 1992).

These chemicals, though effective, have adverse effects on human health and the environment. The high doses of the chemicals have created major problems in Ghana. These include contamination of food, soil, groundwater, air and destruction of non-targets organisms in most vegetable growing areas. For instance, until 1998, the whitefly was not recorded as a serious pest in Ghana, but currently, it is reported as a major vegetable pest due to the destruction of its natural enemies. Toxic residues have also been found to be very high in market produce in most vegetable cultivation areas (NARS, 1998). High toxic residues may result in the rejection of fruits at the International markets.

The consequence of the undesirable side effects of a number of these synthetic chemicals has increased the awareness, of the toxicological and environmental problems associated with the use of synthetic pesticides in both industrialized and developing countries (Randhawa and Parmar, 1993) . The need for alternative approach to pest control for sustainable agriculture to preserve and protect the environment and human health as well as to increase yield is therefore of paramount interest or concern to both researchers and governments.

2.7 The role of biopesticides in agriculture.

The study of the interactions among living organisms has led to the identification of many potential opportunities for the use of living organisms as biopesticides to protect agricultural crops against insect pests (Rodgers, 1993). The bacterium, *Bacillus thuringiensis* Berl. has been studied in detail for over 30 years because of its insecticidal properties. At present, it is the most widely used bacterium in microbial control (Rodgers, 1993).

Rodgers (1993) observed that over 90% of biopesticide sales are insecticides containing *Bacillus thuringiensis* for the control of insect pests. The current biopesticide products with *Bacillus thuringiensis as* active ingredient for the control of vegetable and forestry pests include biobit, dipel, delfin, trident, novodor, foil, cutlass and agree (Rodgers, 1993).

According to de Barjac (1978), products containing *Bacillus thuringiensis* are remarkably safe. Over 500 tons have been used without harm and no harmful effects have been recorded in safety tests with bees, vertebrates, mammals and man (Rodgers, 1993). Most beneficial insects are also unharmed even at higher doses. The advantages of using *Bacillus thuringiensis* are that it is highly compatible with natural enemies because of its narrow host range, receptive to genetic engineering and biodegrades rapidly (Bauer, 1995). However, according to Miller (1990), the richness and diversity of Lepidopteran species may be reduced when large expanses of forests and woodlands are treated with *Bacillus thuringiensis*

2.7.1 Identification and origin of *Bacillus thuringiensis*

Bacillus *t-hnri nrji* on.cls is a virulent entomo-pathogenic bacterium. Taxonomically, *B. thuringiensis* is a spore-forming bacterium characterized by the production of a crystalline toxic protein body (delta-endotoxin or crystalline parasporal body) in the cell during the phase of spore formation (Buchanan and Gibbons, 1974) .

It belongs to the Kingdom Prokaryotae (Division II: The Bacteria) and of the family Bacillaceae. The members of this family, particularly *B. thuringiensis* and *B. popillae* have received considerable attention as microbial control agent (Yoshinori and Barry, 1993). The genus *Bacillus* is aerobic or a facultative aerobe. They are gram-positive, motile or non-motile rods (Claus and Berkeley, 1986).

About 1000 isolates of *Bacillus thuringiensis* have been obtained from the soils of five continents; Africa, Asia, Europe, North and South America (Steinhaus, 1960). Loius Pasteur, between 1865 and 1870 found *Bacillus thuringiensis* in the dusts from silkworm rearing menageries (Steinhaus, 1960). In 1911, Berliner isolated from the Mediterranean flour moth, *Anagasta spp.* a bacillus, which he named in 1915 as *Bacillus thuringiensis* after the Province Thuringia in Germany from which the infested flour was obtained (Steinhaus, 1960).

Other researchers have also reported and demonstrated that the parasporal body was the source of the toxin for the silkworm and had certain degree of pathogenicity in some insects (Hannay, 1953; Angus, 1956; Hannay and Fitz-James, 1995)

The first field experiment with *Bacillus thuringiensis* was made by Husz (1929) under an international program developed to control the European cornborer, *Ostrinia nubilalis* (F.) In 1947, Steinhaus (1975) attracted the attention of insect pathologists and industrial organisations to *Bacillus thuxingiensis* through his basic and applied studies that demonstrated the potential of this bacterium in insect pest control. Ohba et al. (1984) have also isolated numerous subspecies of the bacterium from the litter of sericulture farms in Japan.

2.7.2 Mode of action of *Bacillus thuringiensis*

Proposed designated toxins discovered from *Bacillus thuringiensis* are alpha-exotoxin, beta-exotoxin and delta-endotoxin (Heimpel, 1967). According to Krieg (1971), these are highly toxic to certain insects by oral and intrahomocoelic inoculations. Yoshinori and Harry (1993) have also reported that, as a pathogenic bacterium, *Bacillus thuringiensis* infects insects mostly through the mouth and digestive tract but less commonly through the *egg,* integument and the trachea.

Upon infection by a susceptible insect, the bacteria multiply and produce toxins in the midgut lumen. Within the digestive tract, it produces enzymes such as proteinase, chitinase and lecithinase that act on the midgut cell and enable the bacteria to enter the homocoel. The insect loses its appetite, becomes diarrheic, discharges watery faeces and may vomit (Yoshinori and Harry, 1993). The mouthparts and the gut become paralyzed and the gut epithelium destroyed. The insect dies in four hours to about three weeks, depending on the insect species, dose taken and the type of pathogenic action (septicemia, bacteremia or toxemia) induced. According to Sebesta *et al.* (1981), *Bacillus thuringiensis* interferes with RNA transcription and affects all mitosis particularly during moulting and metamorphosis. The toxin may kill the larvae or transform them to deformed pupae. Adults exposed to the toxins may develop abnormal antennae, wings and legs. Affected adults may be infertile or have reduced fecundity and longevity. The bacterium is rarely able to spread among pest populations but persists on foliage for periods varying three days to six weeks depending on environmental conditions.

Against most susceptible insects, the crystal is the most important component. They are insoluble in water hence constitute particulate insecticides, formulated usually as a wettable powder or emulsion. This microbial insecticide is comparable to a stomach poison. It is effective only when eaten by the insect and has no contact action (de Barjac, 1978).

2.7.3 Effects of *Bacillus thuringiensis* on insect pests in laboratory and field experiments

The use of microbial pest control agents such as *B. thuringiensis* has been accepted as an alternative to the use of chemical pesticides (Rosalind et al. 1993). Commercial spray formulations of *Bacillus thuringiensis* has been used extensively as biological control agent for the control of pest of several crops including; vegetables, potato, corn and cotton. According to Atwood et *al.* (1997), *Bacillus thuringiensis* has become an integral component in resistance management strategies to suppress populations of *Heliothis virescens, Helicoverpa zea* (Boddie), the cotton bollworm and pests of other crops. Luttrell *et al.* (1987) has also reported that the use of *Bacillus thuringiensis* as microbial larvicide is an important tool for mitigating pyrethroid insecticide resistance.

In an IPM - programme involving the application of *Bacillus thuringiensis,* Truirible et al. (1994) showed that pest populations and damage were drastically reduced in fresh-market tomatoes resulting in better yield and net profit. A wide variety of lepidopterous forest insect pests had been controlled using *Bacillus thuringiensis* (Harper, 1974; Morris, 1982). Numerous publications cite examples of the pathogenicity of *Bacillus thuringiensis* to larvae of Lepidoptera

(Dulmage, 198

et *al.* 1983,

(Goldberg and

on *Heliothis*

been reported

important pests (Schmutterer, 1990, Jackai, 1993). Recently, the importance of neem has been recognized by the U.S. National Academy of Sciences resulting in a 1992- report entitled "Neem - a tree for solving global problems" (Schmutterer, 1995). Because of its outstanding suitability for use in integrated pest management, numerous studies on the use of neem products against insect pests of vegetables, grain legumes and other crops have been reported and confirmed by various researchers. A variety of extraction techniques and wide range of extract concentrations (5 g - 150 g of plant product per litre of water) have been used. One of the most effective extraction techniques is the aqueous extract suspension prepared from ground and dried neem seeds or leaves (Schmutterer and Hellpap, 1988; Schmutterer, 1995).

2.8.1 Origin and distribution of the neem tree

According to Ermel (1995), the neem tree *(Azadirachta indica* A Juss*.)* is a native of parts of India and Myanmar. Today, it is widely distributed throughout tropical and 'Sub-tropical Asia, Africa, Australia, Central and South America and the South-pacific islands especially in the western parts of Viti Levu Island. Thus, the neem tree has adapted to different climatic and edaphic conditions.

Taxonomically, the neem tree belongs to the order: Rutales; Suborder: Rutineae; Family: Meliaceae (Mahogany family) ; Sub Family;

Melioidae; Tribe: Melieae; Genus: *Azadirachta;* and Species: *indica.* (Schmutterer, 1995).

Azadirachta indica is a fast growing plant that usually reaches a height of 15 m - 20 m. It is famous for its drought resistance and normally thrives well in areas with sub-arid to sub-humid conditions, with an annual rainfall between 400 mm and 1,200 mm. As a rule, it does not form a part of the forest but rather grows in the vicinity of human settlements (Schmutterer, 1995).

2.8.2 Active ingredients and mode of action of neem extracts

The harmful effects of neem products or extracts from leaves, bark and seeds on insects have been studied (Rembold, 1995). Owing to its various effects on insects, *azadirachtin* is considered the most important active ingredient (Schmutterer, 1990). However, a considerable number of other active compounds such as *salannin, salaxmol, salannolacetate* and *gedunim* had been isolated from neem kernels (Schmutterer, 1995).

Neem is known for its bitter taste. The active compound interferes with the feeding activity of pests and insects which do consume the compound have their moulting and growth delayed and may eventually die (Green et al. 1987; Saxena, 1989). The natural extract is strongly repellent (Schmutterer, 1990). It has distinct antifeedant, growth and metamorphosis disrupting, anti-ovipositional, fecundity and fitness-reducing properties on insects (Jackai, 1993; Warthen, 1989; Schmutterer, 1990; Rembold, 1995).

At the hormonal level, a dramatic effect of the morphogenetic hormones has been reported (Rembold, 1995). The active compound has been found to interfere with several protein biosynthesis at the molecular level (Rembold, 1995).

2.8.3 Commercial neem formulations as agricultural insecticides

In 1992-1993, various commercial neem-based insecticides for use in agriculture and horticulture were reported in the United States of America. These included Align (E.C. 3% aza), Azatin and Turplex (Wood et al. 1995).

In India, pest control chemicals with *azadirachtin* as active ingredient includes Azadit, Biosol, Neemhit, Neemplus, Neemtop, Neemasol and Neembecidine. These chemicals are recommended by researchers and manufacturers for the control of pests of crops such as cotton, vegetables, rice, pigeon pea, peanut, plantation crops and forestry products (Parmar, 1995) .

2.8.4 Efficacy of neem extracts against pests of vegetables

Schmutterer (1995) reported that 25 and 50 g/1 of aqueous neem seed kernel extract (ANSKE) gave 100% protection against the diamondback moth, *Plutella spp.* Other researchers such as Ruscoe

(1972) and Kirsch (1987) obtained similar promising results using various extract concentrations in the laboratory and field trials.

A reduction in the number of damaged tomato fruits and hence a considerable increase in marketable fruit yield was achieved when 50-g/1 aqueous neem seed extract was weekly- applied in tomato field experiments (Schmutterer, 1995). Good results against various pests of tomato plant; *Helicoverpa spp., Spodoptera sp., Keiferla spp. and Liriomyzae spp.* with aqueous neem seed extract concentrations 40, 50, 60 and 90 g/1 have also been achieved (Schmutterer, 1990).

The efficacy of neem extracts on pests of okra and other malvaceous plants in field experiments had been evaluated. Redknap (1991) observed an antifeedant effect of an aqueous neem fruit extract against the flea beetles, *Podagrica sjostedi* and P. *uniformis.* Siddig (1981) recorded similar effects of neem seed and leaf water extract on *P. puncticollis.* According to Dreyer and Hellpap (1991), a satisfactory control of the cotton aphid *(A. gossypii)* was achieved when 50 g/1 of ANSE and 2% neem oil were sprayed on okra. The effects of the. treatments were equal to synthetic carbamate, butocarboxim.

Experiments in India confirmed the repellent effect of a 10-day interval spraying of 10 g/1 ANSE against leafhoppers (*Empoasca* sp.), aphids *(A. gossypii)* and *Epilachna* beetles on brinjal (eggplant) (Asari and Nair, 1972) . According to Reed and Reed (1985) , damage by the flea beetle *Epitrix spp.* and the Colorado potato beetle, *Leptinotarsa decemlineata* was significantly reduced by weekly applications of ethanolic extract of neem seeds. Other studies showed a reduction of 63% in the population of the phytophagous coccinellid *Henosepilachna spp.* after treatment with neem oil (Dhandapani et *al.* 1985) .

Weekly applications of aqueous neem kernel extracts, at concentrations of 6 to 50 g/1 and neem oil at dosages of 5 and 10 g/ha, strongly reduced damage caused by the leaf-mining larvae, *Scrobipalpa spp.,* the leafhoppers, *Jacobiasca spp.* the leaf roller, *Phycita spp.* and the leaf-eating caterpillar, *Selepa docilis* in local garden egg *(Solatium aethiopicum* L.) field trials. All treatments gave better yields than the untreated control (Schmutterer, 1990). Investigations by Cobbinah and Osei-Owusu (1988) revealed that 5, 10 and 20% neem oil applied to eggplant at the fruiting and post-fruiting stages, efficiently controlled the leaf-eating larvae of *S. docilis* with 10% and 20% treatments causing immediate mortality. The same treatments strongly repelled the lace bugs *(Urentius sp.)* and the variagated grasshopper, *Zonocerus variegatus* from treated plots. Experiments in the Carribean with weekly sprays of 2% neem oil gave good results against the leaf attacking lace bug, *Corythaica cyathicollis.* Good protection was also obtained against the *B. tabaci* (Dreyer and Hellpap, 1991).

CHAPTER THREE

3.0. MATERIALS AND METHODS

1.1. FIELD EXPERIMENTS

Field studies were conducted to assess the performance of NSWE, *iobit and Karate on vegetative growth and yield of the garden egg. The efficacy of the various chemical treatments against key pests and general insect spectrum under field conditions was also investigated, These studies were carried out during the wet (major) growing season, between March and October 1997 at Ekoso, about 40 kilometres from Cade in the Asamankese district of the Eastern region. Ekoso is one of the major vegetable growing areas in the Eastern region of Ghana. The experimental plot measured 108 m x 51 m. The study area (latitude 3°49 West, 0°6 North and 135.90 m above sea level) falls within the semi-deciduous rainforest belt of Ghana. It has mean annual rainfall of 165 cm - 180 cm and an average temperature of 26°C.

3.2. Source of neem seeds

Dropped neem fruits were picked from Kodiabe, a village near Dodowa between March and May 1997. The fruits were depulped by hand and dried for 10 days by spreading the seeds on a mat for four hours and then in the shade. By so doing, moisture is reduced and the seeds were prevented from deterioration. After the 10 days of drying the ieds were stored in baskets in dry and well-ventilated room lintained at 27° C and 24% at the Agricultural Reseach Station (ARS) , ide.

3. Formulations of NSWE, Karate and Biobit for field trials.

The dried neem seeds were ground into fine powder with an .ectric mill. Seventy-five grammes of the seed powder was weighed id dissolved in a litre of water. The suspension was allowed to and overnight and then filtered through fine white cloth to obtain ve clear extract, which contained the active ingredient. Thus, 75 g sr litre of the neem seed powder was applied.

Karate (2.5 EC), a product of Zeneca Agro Chemical Limited and .obit, VAR KURSTAKI, distributed by Agri-Mat Limited, Accra, were irehased from an Agro-based chemical shop in Accra. Karate is a rrethroid insecticide with Lambda-cyhalothrin as active ingredient. : is widely used by vegetable growers in Ghana to control vegetable ssts. Biobit is a biopesticide with *B. thuringiensis* as the active lgredient. Karate and Biobit were applied at the recommended rate of .5 ml/litre and 0.8 g per litre of water, respectively.

.4. Cultural practices

arden egg seeds of Legon I variety were obtained from the Crop :ience Department of the University of Ghana, Legon and nursed in ursery boxes at ARS, Kade in March, 1997. The soil in the nursery ©xes was sterilized at 60°C for one and half-hours. The nursed seeds ere watered when necessary and were transported to the experimental ite after germination. Five weeks old healthy seedlings were ransplanted in May 1997. One seedling per stand was used. Local egetable growers at Ekoso were involved in the acquisition, clearing nd preparation of the land. Transplanting of seedlings, fertilizer pplication and general maintenance of the experimental plot were Iso done by these local famers. One of the major diseases that onfronted local farmers at the study area was *Fusarium* wilt (Fungal isease). As a prophylactic measure, Pentachlor was applied two weeks fter transplanting to protect the crops from fungal attack. The umber of garden egg seedlings per plot was twenty.

irst fertilizer application was done three weeks after ransplanting. Each plot received NPK (23: 15: 5) compound fertilizer t a rate of 50 g per plant. Second fertilizer application was arried out at flowering (that is, when about 20% of the plants had lowered). Each plot at this stage received.N.P.K (15:15:15) compound artilizer at a rate of 100 g per plant.

• 5. Treatments

total number of 12 plots in three blocks were planted with the arden egg seedlings. Each block measured 55.0 m x 10.5 m and was plit into four plots. Each plot measured 10.5 m x 7.5 m. Twenty eedlings were planted on each plot with five plants in each row. lants were spaced 1 m x 1 m apart. Six plants from the two center ows were tagged on which data was collected.

'he following four chemical treatments were evaluated in a Randomized lomplete Block Design (RCBD) ;

■| - Karate (2.5 ml/1) ,

'2- 'Biobit' - *B. thuringiensis* (0.8 g/1) ,

'$_3$ - Neem seed water extract (75 g/1) ,

!* - Water only as control.

pplications of all treatments were made with knapsack sprayers Model CP 15 of Cooper Peggler Limited, UK). In all treatments, tap rater was used as diluent. Plots were treated at two-weekly intervals md when it rained, the application was terminated and repeated after he rains or on the next day. A total of eleven insecticide ipplications were made during the period of experimentation. The ipplication of insecticides commenced four weeks after transplanting.

1.6. Sampling methods for insect fauna in the garden egg ecosystem

1.6.1. Water trapping studies

Tater traps made up of white plastic bowls measuring 35 cm x 5 cm and 1 height of 6 cm, filled with soapy water, were placed in the middle >f each plot. In all, a total of 12 traps were set up. The dissolved (emergent supposedly reduced surface tension of the water and enhanced the arrestant effect of the traps. Trapping was done between June and October 1997. Traps were set before each pesticide implication and were inspected after the application of NSWE, Biobit and Karate treatments. The traps were left to stand in the field overnight. The content of the traps from each plot was sieved separately through white nylon cloth. Insects were picked Individually with a forceps or camel's hair brush where applicable, trapped insects were preserved in 70% ethyl alcohol and transported to the laboratory where they were counted and grouped into their respective orders. Individual insects were air-dried for 24 hours, sinned up in insect collection boxes and sent to the Entomology Museum at the Zoology Department, University of Ghana for further Identification. Visual observations of insects' activities on each slot were also assessed at two weekly intervals. Insects encountered were either captured using sweeping net or handpicked and then put in a killing jar. Two-weekly counts of the insects captured were sorted into orders and their relative abundance" calculated.

3.6.2. Sampling for leaf feeders, bud and shoot borers

The larvae of garden egg defoliators were handpicked from the leaves during feeding. Insects that looked similar (by visual assessment) were separated, grouped and put into perforated plastic cups. They are then placed in ventilated field cages and maintained to adult tage. The larvae were reared on untreated fresh garden egg leaves, fee developmental stages of the larvae were monitored. Field ollected buds showing signs of larval infestation were transferred o the laboratory. The larvae were reared to adults, in square-shaped lastic containers of size, 13 cm x 13 cm x 10 cm. Each container was overed with nylon mesh and held at 24.5°C ± 1°C under laboratory onditions with a photoperiod of 16:8 (L: D) h. The adults that merged were captured using a killing jar. They were then pinned up n insect collection boxes for identification. Rearing of shoot orers on severed garden egg stem tissue under laboratory conditions as not successful. This was probably due to the fact that the stem issue-diet lost its freshness faster than could support the life ycle of the insect. Sampling for the adults were therefore done on he field. Shoots showing signs of borer attack were randomly elected and tagged. The leaves on such shoots were removed. Shoots ere then covered with white nylon net sown in a form of small sacks f dimensions 45 cm x 10 cm. The sacks were tied at the base of the hoots and left until the borer emerged from the stem tissue, pupated nd developed into adult in the net.

. 7. Assessment of pest damage

.7 1. Damage caused by leaf feeders (defoliators)

etermination of leaf damage was carried out at two-weekly intervals, 'resh leaves produced by each plant within 14 days were recorded, lamage to the total leaf area of the individual leaves was visually tssessed and the number of leaves defoliated recorded. Leaves were lonsidered defoliated when 75% of the leaf was missing (Rosalind et 11.1993). Percentage of leaves defoliated was calculated as follows;

>LD (%) = TLD x100

• TL_{14}

(here PLD is the percentage of leaves defoliated, TLm is the total lumber of leaves produced by the plant within 14 days and TLD is the :otal number of leaves defoliated.

?he number of feeding punctures or marks made by defoliators was sstimated at each sampling period between July and October. Three tranches from each plant were selected at random. Where a plant had jnly three or less number of branches, all were used for the assessment. Three leaves from each branch were also randomly selected. Feeding punctures with diameter of 0.5 cm on each leaf were counted and recorded. Where a larger area of leaf tissue was consumed, the number of feeding punctures was estimated based on the umber of times 0.5cm diameter leaf area could fit into the surface rea of leaf tissue consumed. This was done to ensure some degree of onsistency in the estimation. The average number of feeding unctures for each plot was pooled and the mean number of feeding •unctures per plant was calculated.

.1.2. Damage caused by shoot borers

he incidence of shoot damage as a function of infestation level of he shoot borer was observed in the field. Shoots were examined at wo-weekly intervals. The total number of shoots produced by each •lant were counted and recorded. Shoots were classified as damaged non-functional) and undamaged (functional) based on the following .nfestation indices; drooping of shoots, leaves losing their reshness, presence of frass and emergent hole on the shoot. The lumber of damaged shoot per plant was estimated based on the total lumber of shoots produced between sampling periods. Shoots showing signs of borer attack were severed from the plant after each count ind sent to the laboratory where they werfe dissected to ascertain the >resence of shoot borer larvae. Percentage shoot damaged was :alculated as follows;

$$Psd\ (\%) = \frac{Tsd}{Tsu} \times 100$$

Here Tsd is the total number of shoots damaged, Tsu is the total umber of shoots produced within 14 days.

.7.3. Damage caused by bud borers

ad damage caused by bud boref(was monitored visually between July ad October. Buds were presumed damaged when they could not develop nto flowers or fruit and found either on the plant or fallen on to he ground. Number of damaged buds out of the total number of buds traduced per plant was recorded and the percentage bud damage ialculated at each observation period.

1.74. Damage caused by fruit borers

to estimate percentage of damaged fruits, 150 fruits were sampled and sorted into damage and undamaged groups. A fruit was considered lamaged if it had feeding scar, frass or emergent hole on it. The iamaged fruits were then dissected and examined for the presence of fruit borer larvae. The number of larvae per damaged fruit was counted and recorded.

3.8. Biomass determination

This study was carried out between July and August 1998, when about B0% of the plants from each plot had flowered. Two plants from each ilot were cut off at the base and separated into leaves, flowers and Item. The various plant parts were then dried in an oven to constant reight at 105°C (Berrie et. al. 1987) to obtain dry biomass. Other regetative growth- related parameters such as plant height (taken from ground level to the tip of the growing shoot) ; plant girth [taken at 40 cm above ground level); number of branches and number of functional leaves per plant were recorded at flowering,

flower production and dropping were monitored between July and August. The numbers of flowers developed by individual plants were recorded by inspecting all shoots. Percentage of flower which dropped >er plant was estimated as; (number of flowers found on the ground and leaves divided by the total number of flowers) x 100

3.9. Yield assessment

rruit yield per plant was determined between September and October 1997. Matured fruits (green-to-yellow) were handpicked and the total fruit weight determined for individual plants. Individual fruit sizes (diameter and length) were determined using a pair of calipers. One .'lUndred and fifty fruits were randomly selected for each treatment (50 fruits sampled per plot). The number of marketable fruits per plant, single fruit weight and yield per hectare were calculated asing plant spacing measured at harvest, plot size and average fruit weight.

i. 10. Assessment: of economic benefits

fhe costs associated with pesticide applications were calculated by letermining the cost of the pesticide on per-hectare basis. The total ralue of the harvested fruits was determined based on the prevailing 5rice of <21,000.00 per kilo. All costs of labour, land cultivation, raintenance of experimental site, seed and transportation were similar for all treatments. Values recorded were standardised on per lectare basis by scaling up yield from the research plots. Net srofits were then calculated as the total output from each treatment linus the costs of pesticides and their applications.

J'.ll. Data analysis

LL1 data collected from field experiment were subjected to one-way slassification analysis of variance (ANOVA) . This was followed by .east significant difference test (LSD) to separate the means. Significance was determined at P = 0.05 level. Percentage values were ircsine transformed before analysis. The relationship between >ercentage leaf damage and mean number of feeding punctures was letermined by linear regression.

J. 12. Laboratory experiments

?ield studies showed that two-weekly application of NSWE at 75 g/1 Hid biobit (0.8 g/1) could not offer adequate protection of the crop against *L. orbonalls,* although, translocation of azadirachtin, is reported to occur in vegetable crops (Osman and Port, 1990).

rhe laboratory experiments were therefore conducted to test the feeding responses of *L. orbonalls* ('larvae) when exposed to NSWE, Biobit and Karate under laboratory conditions. The study was also aimed at determining the LC_So of neem extract concentrations for larval mortality and to ascertain if contact toxicity of NSWE, Biobit and Karate contributed significantly to the death of the larvae of *L. orbonalls.*

3.12.1. Preparation of NSWE, Karate and Biobit formulations for laboratory experiments.

The dried neem seeds were ground into fine powder with an electric mill. Neem seed powder of 20, 30, 50,' 60 and 75 g were weighed separately into different 250 ml - conical flasks. A litre of distilled water was added to each to give estimated 20%, 30%, 40%, 50%, 60% and 75% wt/vol. suspensions respectively, and allowed to stand overnight. The suspensions were then filtered through fine white cloth to obtain the extract, which supposedly contained the active ingredient. Karate and Biobit were applied at the recommended rate of 2.5 ml/litre and 0.8 g per litre of water, respectively. Distilled water was used as diluent for all treaments.

3.12.2. Insects for laboratory assays

Naturally infested garden egg (fruits) from the field at Ekoso were harvested in August 1997. The fruits on control plots infested by various instar stages of the fruit borer (*L. orbonalis)* were placed in plastic buckets and transported to the International Institute of Tropical Agriculture (IITA) laboratory at Agricultural Research Station (ARS), Kade. The infested fruits were transferred into ventilated field cages made from plywood and mosquito net measuring 35 cmx 40 cmx 30 cm. The floor of the cages was perforated and Lined with nylon cloth to drain off fruit juice. The cages were held under a porch, at 27°C ± 1°C over soapy water to prevent any insect From entering or escaping unnoticed. This served as a stock of test Insects from which fruit borers were sampled for all laboratory experiments. The adults that emerged were captured through a small sliding window (12 cm x 12 cm) using a killing jar.

3.12.3. Bioassay procedures

Ml laboratory experiments were conducted from August - September L997 in the IITA Laboratory at ARS, Kade. Two tests were carried out bo investigate feeding responses and mortality of larvae of the *L. orbonalis* on the garden egg when exposed to different pesticides. Fruit -dip- bioassay was used to determine the responses of the actively feeding 3rd instar larvae of the fruit borer to ingestion of leem extracts. The experiment was conducted at a room temperature of 24.5°C ± 1°C and held under normal day and night photoperiod of 16:8 (L: D). The neem seed water extract (NSWE) was applied at the rate of 20 , 30 , 40 , 50 , 60, and 75-g seed powder in a litre of distilled rater. Larvae were selected individually, based on visual assessment sf the " headwidth and body size". About 6 pieces of fruit tissues *ere cut from untreated fruits picked from control plots of the garden egg field trials. Fifteen pieces of fruit tissues were randomly selected for each treatment. The fruit tissues were treated separately by putting them into the prepared NSWE suspensions and Left overnight. The pieces of fruits were then removed from the suspensions and air-dried for one hour. Control fruits were treated similarly with distilled water only. Five pieces of treated fruit :issues of each dose were placed in clean plastic cups (200 ml) with perforated cover. Each treatment was replicated three times with five Pieces of treated fruit tissues per replicate. Ten larvae, randomly sicked with camel's hairbrush, were introduced individually into each elastic cup. Thus, a total of 30 larvae were used for each dose, .larvae were allowed to feed on the treated fruit-tissues and mortality was recorded after 24, 48 72 and 96 h. Larvae were considered dead if they remained immobile and did not respond when gently prodded three times with camel's hairbrush after a five-minute recovery period. In a similar test the effect of three different chemical treatments on feeding activity and mortality of *L. orbonalls* was investigated. The treatments consisted of NSWE (75 g) ; Biobit (0.8 g); Karate (2.5 ml) each dissolved in a litre of distilled water and control (distilled water only). All mortality data were analyzed by probit analysis (Finney, 1971) to obtain LC_{S0} slope values and chi-square (X^8) values.

CHAPTER FOUR

4.0. RESULTS

4.1 Toxicity of NSWE to the larvae of *L. orbonalis*

Analysis of variance revealed significant differences in larval mortality between the treatments and control (F =22.17, df =6,14, P <0.05). The percentage mortality of *L. orbonalis* to different dosages of NSWE is shown in Table 2. After 24-hours of larval exposure to treatments, no mortality was recorded for dosages of 20%-50% dosages as in the case of control. Only 3% of the larvae exposed to 60 and 75% neem extract concentrations died. Mortality increased with time and dosage and after 96 hours, about 97% of the larvae exposed to the highest dosage of 75% wt./v died (Table 2) . Interaction between dosage and time showed significant effect (F*=11.73, df = 18,56, P < 0.05).

Table 2: Percentage mortality of 3rd instar larvae of *L. orbonalis* to ingestion of different NSWE treatment over a period of 96 hours

Dosage (g/litre)	% mortality (hours after treatment)			
	24	48	72	96
20%	0^{j}	3.0 ± 0.3^{J}	16.7 ± 0.2^{b}	36.7 ± 0.3^{f}
30%	0^{j}	13.3±0.2 *	30.0 ± 0.3^{fg}	43.3 ± 0.2^{8}
40%	0^{J}	20.0± 0.1 ‘	33.3 ± 0.1^{1}	56.7 ± 0.1^{d}
50%	0^{j}	23.3 ± 0.3^{gh}	$46;7\pm0.3^{e}$	63.3 ± 0.4^{c}
60%	3.0 ± 0.3^{1}	26.0 ± 0.11^{gh}	50.0 ± 0.2^{d}	76.7 ± 0.2^{b}
75%	3.0 ± 3^{J}	50.0 ± 0.2^{d}	73.0 ± 0.5^{b}	96.6±0.1 *
Water only (control)	0^{j}	0^{j}	0^{j}	0^{J}

Means ± S.E of three replicates
Mean values in columns followed by the same letter are not significantly different at P > 0.05, LSD = 1.05

4.2 Probit analysis

Probit analysis of dosage mortality for *L. orbonalis* was performed. The average mortality values recorded for the NSWE after 96 hours of treatment were used for the analysis. The probit analysis (Finney, 1971) gave LC_{50} value of 31.5% NSWE (Table 3). The Chi-square value was not significant when calculated probits were compared with expected probits ($x^* = 5.0883$; $P > 0.05$; Slope = 0.1341; LC_{50} =31.5%)

Table 3. Estimated LC_{50} of the 3rd instar fruit borer when exposed to garden egg treated with NSWE after 96 h.

Dosage (g/litre)	Sample size (n)	No of larvae dead after 96 h	Expected Probits	Calculated Probit
20%	30	11	4.466	4.434
30%	30	13	4.935	4.939
40%	30	17	5.268	5.297
50%	30	19	5.527	5.575
60%	30	23	5.738	5.802
75%	30	29	5.996	6.080
Control	30	1	-	-

Slope = 0.1341; LC_{50}=31.5%; X^2 (df = 4) =5.0883; Upper Confidence limit = 36.9799; Lower Confidence limit = 24.8593 Probit Analysis (Finney, 1971).

4.3 Mortality of larval *L. orbonalis*

Table 4 shows the mortalities of 3rd instar larvae of fruit borer fed 3n fruits treated with Karate, NSWE and Biobit. Karate killed all the Larvae within 24 hours. For larvae exposed to NSWE and Biobit, nortality was related to time of exposure. For example, only 6% of Larvae exposed to NSWE died after 24 hours but this increased to 93% if ter 96 hours.

Table 4. Percentage mortality of 3rd instar larvae of *L. orbonalls* exposed to Karate, NSWE and Biobit in the laboratory.

Treatments	% mortality (hours after treatment)			
	24	48	72	96
Karate (2.5 ml / litre)	100.0± 0^{a}		-	"
NSWE (75 g / litre)	6.0± 0.3^{f}	46.7 ±0.4^{c}	76.6±0.8^{b}	93.3±0.8^{a}
Bt - Biobit (0.8 g / litre)	3.0±0.1^{f}	16.7±0.5^{8}	33.3±0.3^{d}	56.7 ±0.6^{c}
Untreated (control)	0^{f}	0^{f}	3.0±0.1^{f}	3.0±0.1^{f}

Means ± SE of three replicates
Mean values in columns followed by the same letter are not significantly different at P > 0.05, LSD = 10.15

4.4 Dry leaf weight

Analysis of Variance showed significant differences ($p < 0.05$) between treatment effects on dry leaf weight. NSWE treatment recorded significantly higher dry mean leaf weight than the rest of the treatments (Table 5). Average weight of the dry leaves did hot differ significantly ($p > 0.05$) among Karate, Biobit and Control treatments (Table 5, Fpr = 0.026; d.f = 3.6; LSD =8.27).

4.5 Dry stem weight

Variation in average dry stem weight yielded significant differences ($p < 0.05$) among treatments. NSWE significantly ($p < 0.05$) increased dry stem weight with mean weight of 123 g per plant (Table 5) .

This is about 48 g, 49 g and 50 g more than those recorded for

Karate, Biobit and control treated plots, respectively. There were no significant differences ($p > 0.05$) among Karate, Biobit and the control treated plant (Table 5, FprCO.OOl; d.f = 3.6; LSD = 10.84).

4.6 Dry flower weight

Analysis of variance performed on mean flower weight revealed significant difference ($p < 0.05$) among treatments. The least significant difference (LSD) test however did not show any significant differences ($p > 0.05$) among NSWE, Biobit and control plants. Karate treatment significantly ($p < 0.05$) yielded higher mean weight value than the rest of the treatments (Table 5, Fpr = 0.005; df =3.6; LSD = 1.95).

4.7 Whole plant biomass

Effect of treatments on total plant biomass was highly significant ($p < 0.05$) . LSD for mean comparisons did not show any significant difference ($p > 0.05$) between Karate, Biobit and control. Karate, however, had numerically higher whole plant biomass than Biobit and Control plants. NSWE application yielded significantly higher ($p < 0.05$) total plant biomass, about 56 g, 63 g, 65 g more than Karate, Biobit, and Control- treated plants (Fpr <0.001; df = 3.6; LSD=9.03, Table 5).

Table 5. Effect of the three protectants on the biomass of garden egg at flowering stage

	Plant biomass (g) [1]			
Treatment	**Whole plants**	**Leaves**	**Stems**	**Flowers**
Karate (2.5 ml / litre)	120.7 ± 1.7 *	35.5 ± 1.4 *	75.8 ± 2.7 ^{a}	9.37 ± 0.6 ^{a}
Neem seed water extract (75 g / litre)	176.6 ± 0.8 ^{b}	46.8 ± 3.1 ^{b}	123.3 ± 2.7 ^{b}	6.47 ± 0.5 ^{b}
Bt-Biobit (0.8 g / litre)	113.9 ± 1.5 *	34.1 ± 1.5 ^{a}	73.9 ± 3.2 ^{a}	5.93 ± 0.7 ^{b}
Water-only (Control)	112.1 ± 5.1^a	33.6 ±2.5*	72.9 ± 2.5 ^{a}	5.59 ± 0.3 ^{b}

In <
[1] Column means followed by common letters are not significantly different at P > 0.05.

4.8 Plant height and girth

Plant height differed significantly ($p < 0.05$) among the various treatments (Table 6, Fpr < 0.001, d.f = 3, 6; LSD = 4.570). Plants treated with Karate, Biobit, and water were similar ($p > 0.05$) in height. NSWE recorded significantly higher ($p < 0.05$) mean plant height. Similarly NSWE- treated plants were wider ($p < 0.05$) than plants treated with Karate, Biobit or water only (Table 6, Fpr = 0.026; df = 3,6; LSD = 0.715).

4.9 Branches and functional leaves per plant

NSWE- treated plots gave significantly ($p < 0.05$) greater number of branches per plant compared to the other treatments (Fpr = 0.005; d.f = 3.6; LSD = 1.998, Table 6). The number of functioned, leaves per plant was higher ($p < 0.05$) in plots treated with Karate. This was followed by NSWE. Plots treated with Biobit however did better than the control plots. Karate- treated plots produced the highest number of leaves per plant (Fpr < 0.001; df =3,6; LSD = 3.070, Table 6).

Table 6. Growth performance of garden egg in field plots treated with three different protectants

Treatment	Plant height (cm)	No. branches per plant	Plant girth (cm)	No of functional leaves per plant
Karate (2.5 ml/1)	55.63 ± 1.2 ^{b}	10.33± 0.3 ^{b}	3.4 ±1.4^{b}	43.0±1.3 *
NSWE (75 g/1)	84.63±1.7^{a}	14.33±0.3‘	4.67±0.2 ‘	37.0±0.9 ^{b}
Bt- Biobit (0.8 g/1)	58.93± 1.7 ^{b}	10.67±0.3 ^{b}	3.73±0.4 ^{b}	30.33±0.3^{c}
Water only (control)	50.73±1.1 ^{b}	10.34±0.8 ^{b}	3.90±0.1 ^{b}	31.33±0.7^{c}

Means of three replicates ± S.E

Means values in columns followed by the same letter are not significantly different at $P > 0.05$.

4.10 Flower production

Analysis of variance indicated that the two-weekly application of the treatments significantly ($P < 0.05$) influenced flower initiation and production.

The number of days to first flowering was significantly ($P < 0.05$) delayed by neem seed water extract application ((Table 7, $Fpr < 0.01$. d.f = 3, 6) . Karate and Biobit did not affect flower initiation. There was no significant difference ($P > 0.05$) between the treatments on the number of flowers produced per plant ($Fpr = 0.334$, df=3,6). The treatment also did not affect flower drop compared with control plots

Table 7. The effect of the different treatments on the flowering of garden egg[1]

Treatments	Number of days to first flower	Number of flowers produced per plant	Number of flowers dropped per plant
Karate (2.5 ml/litre)	79.00 ± 0.9'	7.33 ± 0.9 *	2.00 ± 0.6 *
NSWE (75 g/litre)	95.67 ± 0.9 ^{b}	9.33 ± 0.7 *	3.00 ±0.3*
Biobit (0.8 g/litre)	81.00 ± 0.6 *	6.00 ±1.2*	2.00 ± 0.6 *
Water only (Control)	82.33 ±1.2*	6.00 ±1.2*	2.00 ±0.6*

[1] Column means followed by the same letter are not significantly different at $p > 0.05$.

4.11 Activities of defoliators

Percentage of foliar damage and mean number of feeding punctures varied consistently with age of the garden egg for all treatments. Larval forms of lepidopterous pests constituted major leaf feeders during the vegetative phase of the crop growth. Similar trends in feeding activity by defoliators were observed on both Biobit- and control- treated plots. Population level of defoliators were consistently higher on both Biobit and control plants. Percentage of damaged leaves generally exceeded 30% per plant (Fig. 1) . This occurred during the vegetative growth phase in July (mid season where most plants had initiated flower production). Mean number of feeding ■ punctures per plant on the other hand exceeded 60 punctures per plants (Fig. 2). This also occurred in October during the period of harvesting.

Fig. 1. Effect of Karate, Neem seed - Water extract and Bt - "Biobit" on percentage leaf damage by leaf feeders on garden eggs

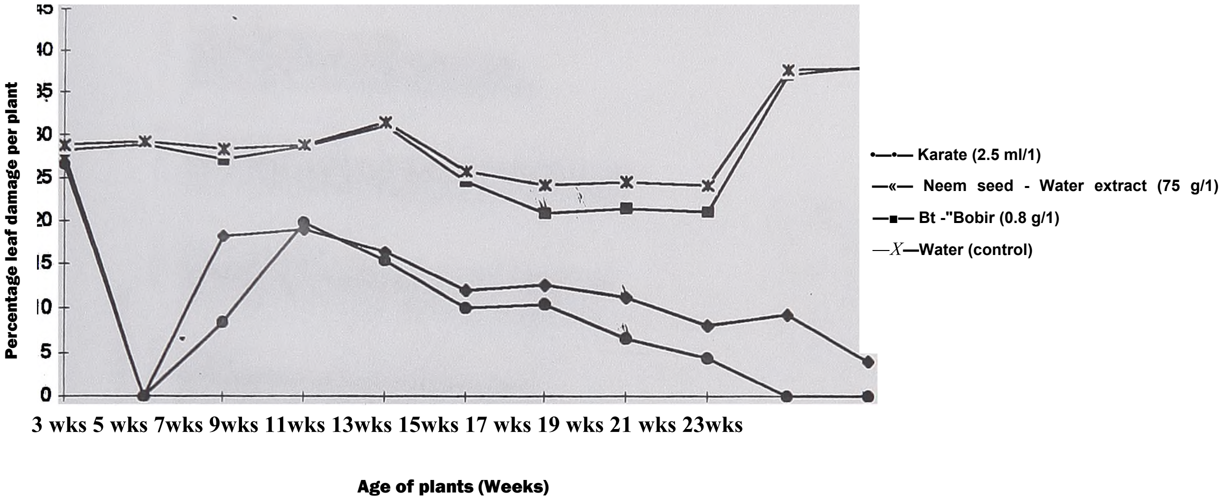
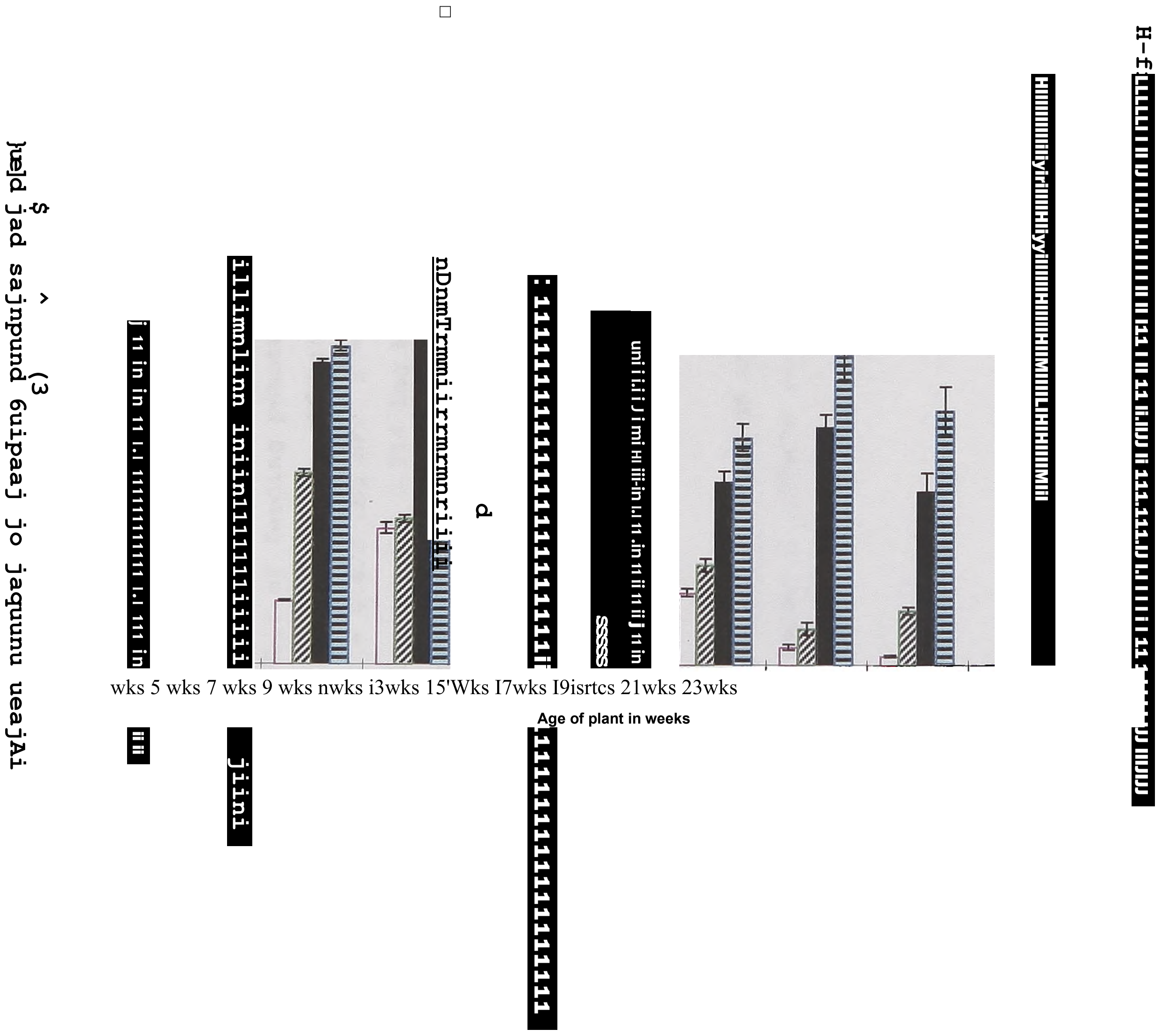


Fig 2. Effect of Karate, Neem seed water extract, Bt- "Blobit" on mean number of feeding puntures



Figures 3-6 illustrates the relationship between percentage leaf damage and mean number of feeding punctures per plant. The regression model of number of feeding punctures (x) on percentage leaf damage (y) and the correlation coefficients for both Karate and NSWE (Log PLD = 0.0917 +0.823 Log NFP, $R = 0.956$; $n = 18$; $F = 95.09$; $P < 0.05$) and (Log PLD =0.701 + 0.714 Log NFP; $R = 0.914$; $n = 18$; $F = 45.50$; $P < 0.05$), respectively were highly significant (Figs 3 and 4). Similarly, regression analysis for Biobit and control treatments (Log PLD = -0.115 +0.925 Log NFP; $R = 0.964$, $n = 18$; $F = 118.36$; $P < 0.05$ and (Log PLD =-0.063 + 0.893 Log NFP $R = 943$, $n = 18$, $F = 72.51$, $P < 0.05$) respectively, indicated significant relationship between percentage leaf damage and mean number of feeding punctures (Figs. 5 and 6) .

The correlations observed in the study reflect the damage caused by a pest complex of insects (defoliators) of garden egg rather than one particular insect species.

Fig. 3 Relationship between percentage of Leaf damage (PLD) and A Mean number of feeding puctures (NFP) after treatment with Karate

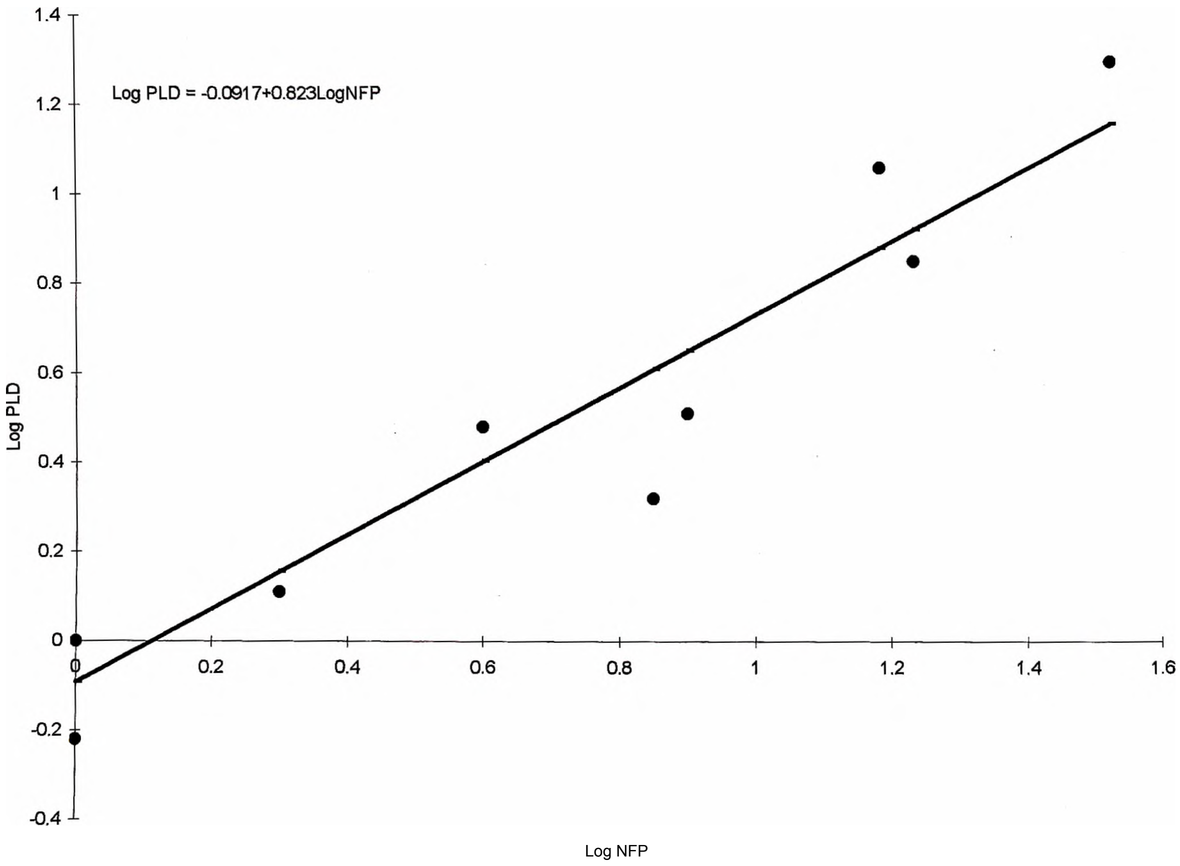


Fig.4. Relationship between percentage leaf damage (PLD) ■ ,and mean number of feeding punctures (NFD) after treatment with neem seed water extract

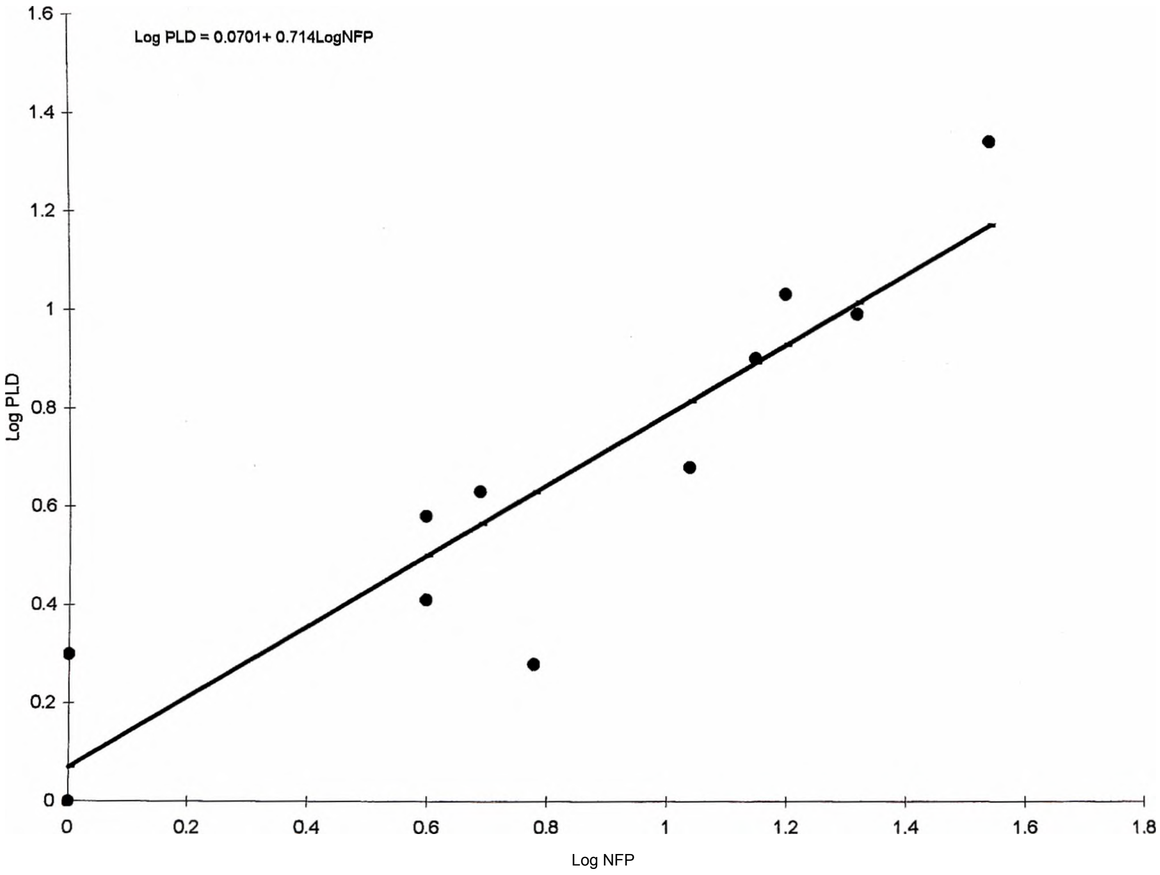


Fig. 5 Relationship between percentage leaf damage (PLD) and mean number of feeding punctures (NFP) after treatment with Bt- "biobit"

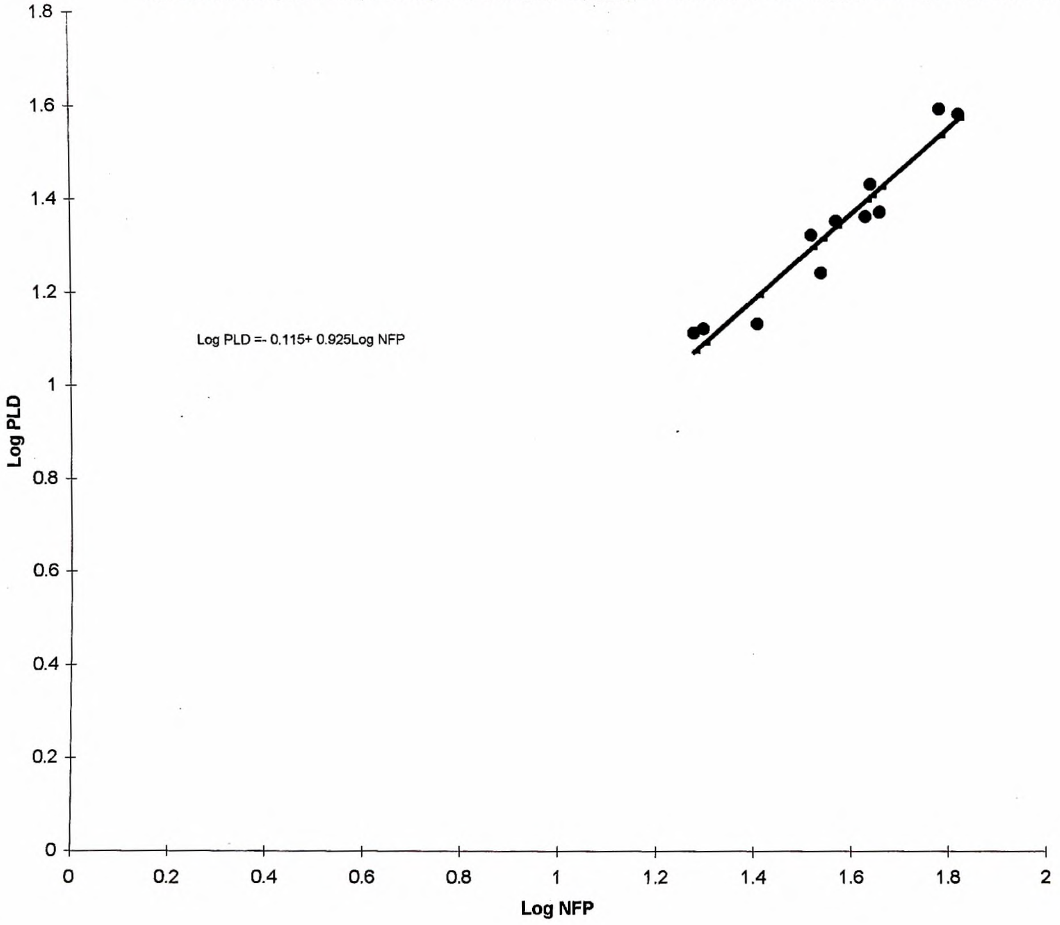
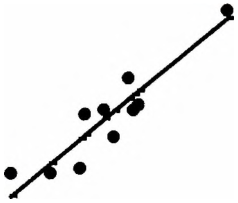


Fig. 6. Relationship between percentage leaf damage (PLD); and mean number of feeding punctures (NFP) after water treatment



Log PLD = -0.063 + 0.893 LogNFP

4.12. Shoot borer damage

Percentage of damaged shoots per plant varied consistently with age of plant for all treatments. Two peaks of infestation levels were observed across all treatments. Trends in shoot borer activity were notably similar for NSWE, Biobit and control (untreated) plots (Fig. 7). Levels of shoot borer activity were consistently higher on NSWE, Biobit and control plots, with percentage of damaged shoots per plant exceeding 40%, 45% and 50%, respectively, during the peak feeding periods (August to September). At the recommended field application rate of 2.5 ml/1 for the control of vegetable pests, two-weekly Karate sprays effectively controlled the feeding activity of the borers. Percentage shoot damage never exceeded 20%. Karate reduced shoot damage by 35% during the peak feeding periods when compared with control plots. NSWE and Biobit however reduced shoot damage by 10% and 5% respectively, when compared with control plots. This suggests that both NSWE and Biobit could not effectively control the feeding activities of the borers.

4.13 Bud borer damage

Percentage of damaged buds recorded for all treatments also varied consistently with plant age (Fig 8) . Similar patterns were observed among plots treated with NSWE, Biobit and control (Fig 8). At each sampling period, percent bud damage was always higher on NSWE, Biobit and control plots compared to Karate-treated plots.

Fig 7. Effect of three insecticide on the activities of shoot borers of **garden eggs**

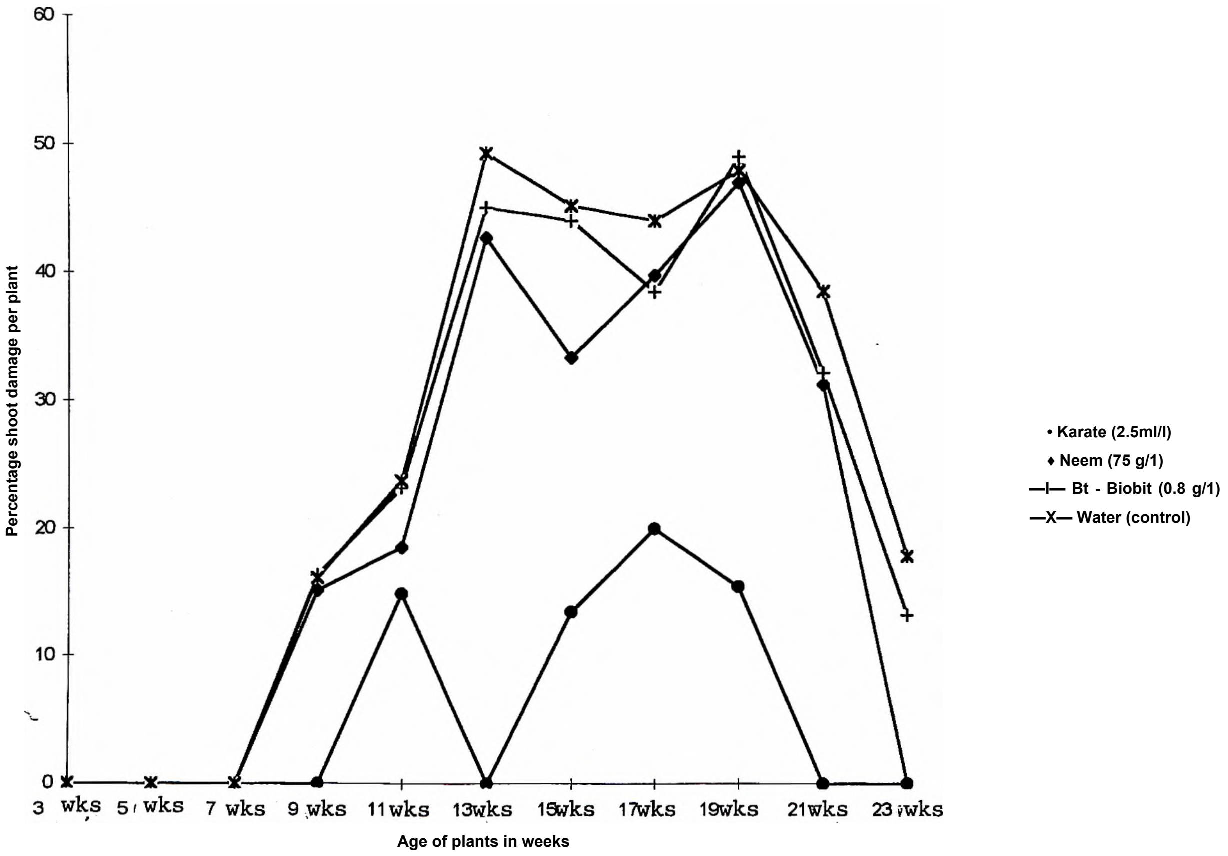
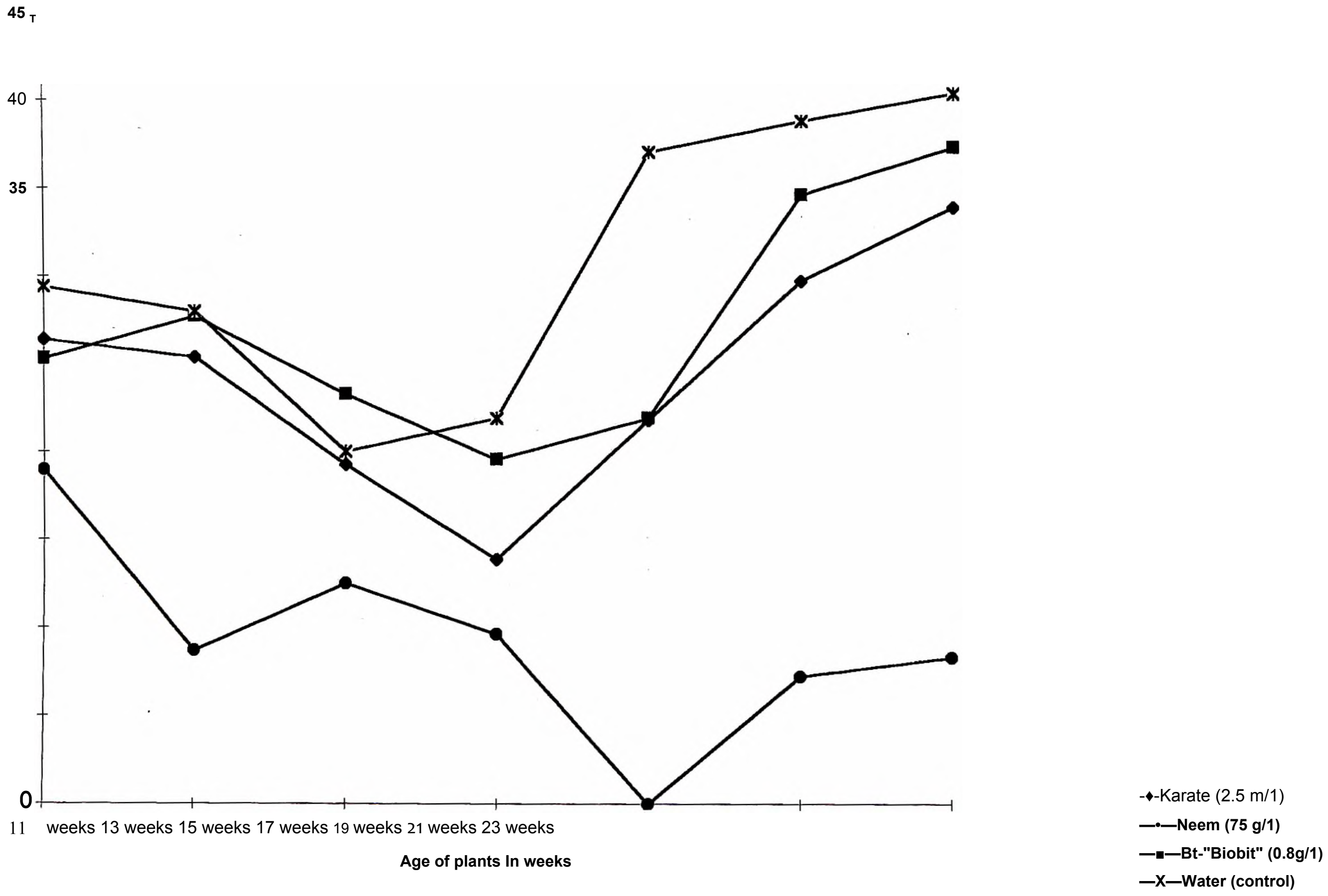


Fig.S. ^Effect of three protectants on damage caused by bud borers to garden eggs



vSt

4.14 Fruit yield analysis

Analysis of variance performed revealed significant ($P < 0.05$) treatment effects on the mean number of marketable fruits per plant. All the treatments produced greater number of fruits per plant than the control. Plants treated with Karate produced the highest number of fruits followed by NSWE and Biobit-treated plants in that order (Fpr = 0.03, df = 3,6, Table 8) . Plants treated with Karate produced about 4 marketable fruits more than NSWE and Biobit per plant, but about 7 fruits more than the control.

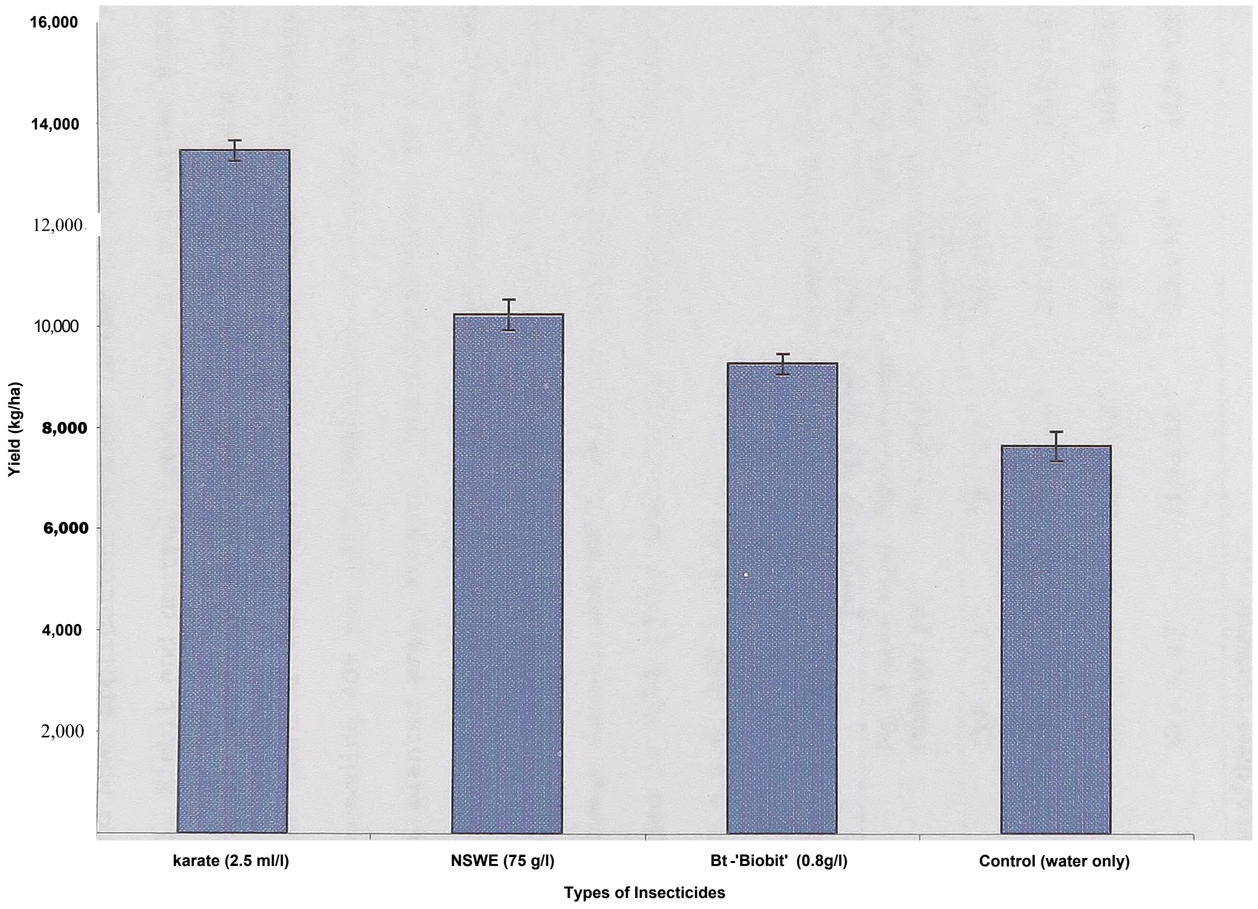
Fruit weight was significantly ($P < 0.05$) higher in plots treated with Karate, NSWE or Biobit than control plots (Fpr = 0.045, df =3,6). Karate-treated plants produced longer and bigger fruits than control, NSWE and Biobit-treated plots. The overall yield followed a similar trend, with Karate-treated plants producing the highest yield per hectare (Fig. 9)

Table 8. Effect of different treatments on the yield of garden egg

Treatments	Marketable fruits per plant	Single fruit Weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit yield per plant (g/m^2)
Karate (2.5 ml /I)	23.67±0.3 ^{a}	55.9±1.4 *	5.33±0.4 *	5.0±0.8 ^{a}	1346*
NSWE (75 g/I)	20.33±1.1 ^{b}	49.5±1.7 *	4.63±0.2 ^{b}	4.47±0.2 ^{b}	1022 ^{b}
Bt-Biobit (0.8 g/I)	19.33±0.8^{c}	48.6±1.2 *	4.57±0.3 ^{b}	4.57±0.3 ^{b}	926^{c}
Water only (control)	17.00±1.5 ^{d}	45.0±1.5 ^{b}	4.23±0.2 ^{b}	4,17±0.2 ^{b}	765 ^{d}

Means of three replicates ± S.E
Column means followed by the same letters are not significantly different at $P > 0.05$

Fig 9 Effect of three- insecticides on fruit yield (kg/ha) of garden eggs



SP
SS

4.15 Assessment of fruit damage

Within the period of experimentation, it was observed that, both Karate and NSWE applications reduced number of fruit borers per fruit (Table 9) . Biobit and control treatments did not differ significantly ($P > 0.05$) in levels of fruit borer infestation. Plots treated with Biobit and control were heavily infested, with percentage damaged fruits exceeding 40% per plot. Percentage of damaged fruits per meter square of planted area, however, was significantly ($P < 0.05$) low and did not exceed 14% and 26% for Karate and NSWE, respectively. Mean number of fruit larvae per fruit did not differ significantly ($P > 0.05$) between Karate and NSWE. However, greater percentage of fruits was damaged on NSWE plots than Karate-treated plots (Table 9) , (Fpr< 0.001, df = 3,6, LSD = 11.0).

Table 9. Effect of Karate, NSWE and Biobit on mean number of fruit borers (larvae) and percentage of damaged fruits

Treatments	No. of undamaged fruits per plot	No. of damaged fruit per plot	No. of fruit borers(larvae) per fruit	Percentage of damaged fruits per plot
Karate (2.5 ml/I)	43.0. ±. 3.2 *	7.0 ±3.2*	3.0 ±0.9“	14.0 ±6.4*
NSWE (75 g /1)	37.0. ±. 2.1^{b}	13.0 ± 2.1 ^{b}	3.0 ± 0.8 *	26.0 ± 4.2 ^{b}
Biobit (0.8 g / I)	30.0. ±. 0.8 ^{c}	20.0 ± 0.8 ^{c}	6.0 ± 1.5 ^{b}	40.3 ± 1.8^{c}
Water only (control)	29.0. ±. 3.5 ^{c}	21.0 ± 3.5^{c}	7.0 ± 1.5 ^{b}	42.0 ± 7.0^{c}

Mean values of three repricates

Column means followed by the same letter(s) are not significantly different at P> 0.05.

4.16. Assessment of economic benefit

Approximately, 11 applications provided better returns in cedis for the investment in each pesticide used. Total yield of marketable fruit was highest for Karate treated plots. This was followed by NSWE and then Biobit treated plots. Control plots had the least fruit yield. Karate was found to be most profitable with net profit of <211,029,884.00/ha. (Table 13). Despite the higher shoot borer damage on the NSWE treated plots (exceeding 40 % in September) , the net profit from NSWE was equally good (<28,226,180.00/ha) . Biobit on the other hand did better (<£6,283,852.00/ha) than control plots which yielded a net profit of <25,337,820.00 per hectare (Table 13).

Table 10. Fixed and variable costs for production of fresh-marketable local garden eggs

Fixed costs	(Z/plante^rea (945m^2)	<£ /ha.
Costs of seeds	6,000.00	63,500.00
Transplanting of seedlings [a]	32,000.00	338,624.00
Transportation [b]	440,000.00	440,000.00
Labour [c]	132,000.00	1,396,824.00
Miscellaneous	40,000.00	423,280.00
Variable costs		
Costs of Karate	48,000.00	507,936.00
Biobit	24,000.00	253,968.00
Neem seeds [d]	35,000.00	370,370.00

* Transplanting costs based on 10,000 seedlings per hectare.

[b] Transportation costs from ARS, Kade to Ekoso between May -October.

[c] Labour costs included cultivation of land, fertiliser application, weeding and general maintenance of experimental site.

[d] Neem seeds costs plus costs of transportation of seeds from Kodiabe to ARS, Kade.

Table 11. Total input costs for each pesticide-use programme

treatment	Ct/planted area (945m^2)	<t /ha.
Karate	698,000.00	3,170,164.00
Biobit	674,000.00	2,916,196.00
Neem seed	685,000.00	3,032,598.00
Control	650,000.00	2,662,228.00

Table 12. Total output returns for each pesticide-use programme

Treatment	Ct/planted area (945m^2)	<t /ha.
Karate	3,726,573.00	13,850,000.00
Biobit	2,026,366.00	9,200,000.00
Neem seed	2,687,447.00	11,410,000.00
Control	1,095,948.00	8,415,000.00

table 13. Net profit based on typical market transaction during major season.

Treatment	(2/plantedarea (945m^2)	0£ /ha.
Karate	3,028,573.00	11,187,772.00
Biobit	1,352,366.00	6,537,772.00
Neem seed	2,002,447.00	8,747,772.00
Control	445,948.00	5,752,772.00

4.17 Relative abundance of insect fauna

Within the period of experimentation, the traps collected.over 1851 insects belonging to seven orders namely Coleoptera, Orthoptera, Lepidoptera, Diptera, Odonata, Hymenoptera and Hemiptera.

Out of 1851 insects, more than 675 insects visited the control (untreated) plots. The number of insects that visited NSWE plots exceeded 525. Biobit and karate plots had 477 and 174 insects respectively (Tables 14-17). Trap catches for all insects orders varied consistently with treatment and"plant age.

Hymenopterans and Dipterans were higher on control plots with percentage relative abundance of 31.2% and 37.2%, repectively (Table 14) . Biobit-treated plots had higher numbers of Hymenoptera and Orthoptera groups with percentage relative abundance of 35.0% and 31.6%, respectively (Tabie 15). Catches of Dipterans and

Hymenopterans were very high on NSWE-treated plots. Neem seed water extract and control plots had 40.5% and 44.9% relative abundance respectively (Table 16). High numbers of Dipterans and Orthopterans visited karate-treated plots with percentage relative abundance of 32.2% and 25.9%, respectively (Table 17).

About 37 families of insects were identified from trap catches (Table 18). Only the collection of adults is reported here.

Table 14. Relative abundance of insect fauna recovered from untreated (water-control) garden egg field plots.

Taxon	Mean number of individual Insects observed	Percentage relative abundance
Coleoptera	51.0 ± 1.1	9.0
Lepidoptera	25.0 ± 0.5	4.4
Orthoptera	140.0± 1.9	24.8
Hemiptera	25.0 ± 0.6	4.4
Hymenoptera	251.0± 1.5	37.2
Odonata	8.0 ± 0.6	1.4
Diptera	175.0± 1.7	31.2

Total number of insects recovered was > 675

Mean values ± S.E (three replicates) of insect recovered during major growing season.

Table 15. Relative abundance of insect fauna captured from garden egg field plots treated with Bt-'Biobit'

Taxon	Mean number of individual insects observed	Percentage relative abundance
Coleoptera	53.0 ± 1.2	14.1
Lepidoptera	22.0 ± 0.4	5.8
Orthoptera	119.0± 1.5	31.6
Hemiptera	16.0 ± 0.6	4.2
Hymenoptera	167.0± 1.2	35.0
Odonata	3.0 ± 0.2	0.8
Diptera	97.0 ± 1.1	25.7

Total number of insects was > 477. Mean values ± S.E (three replicates) of insects captured during major growing season

Table 16. Effect of NSWE on relative abundance of insect fauna collected from garden egg field experiment

Taxon	Mean number of individual insect observed	Percentage relative abundance
Coleoptera	32.0 ± 0.8	7.5
Lepidoptera	11.0 ± 0.3	2.6
Orthoptera	55.0 ± 0.6	12.9
Hemiptera	10.0 ± 0.4	2.4
Hymenoptera	236.0± 1.8	44.9
Odonata	9.0 ± 0.3	2.1
Diptera	172.0± 1.7	40.5

Total number of insects collected was > 525

Mean values ± S.E (three replicates) of insects collected during major growing season.

Table 17. Relative abundance of insect fauna recovered from Karate treated garden egg field trials

Taxon	Mean number of individual Insects observed	Percentage Relative abundance
Coleoptera	24.0 ± 0.6	13.8
Lepidoptera	3.0 ± 0.2	1.7
Orthoptera	45.0 ± 0.7	25.9
Hemiptera	9.0 ± 0.2	5.2
Hymenoptera	28.0 ± 0.5	6.1
Odonata	4.0 ± 0.2	2.3
Diptera	56.0 ± 1.0	32.2

Total number of insects recovered was > 174

Mean values (three replicates) ± S.E recovered during major growing season

Table 18. List of some identified insect fauna recorded on garden egg in the field at Ekoso, (Asamankese District), Ghana.[1]

Name of species/ Common name	Order	Family	Pest status (visual assessment)
1. Pachnoda spp	Coleoptera	Scarabaeidae	Chews stem/shoot
2. Adoretus umbrosus F.	=do=	Rutelidae	Sap feeder
3. Lagria spp.	=do=	Lagriidae	-
4. Hyprops spp.	=do=	=do=	-
5. Coecinella spp.	=do=	Coccinellidae	Predator
6. Catescopus spp.	=do=	CidndeUidae	-
7. *Aspavia hastator* F.	Hemiptera (Heteroptera)	Pentatomidae	“
8. Halyomorpha annulicornis (Sign.)	=do=	=do=	-Adult / numph eat leaves and fruits
9. Stenocoris spp.	=do=	Leptocorisinae	-
lO.Dysdercus spp.	=do=	Pyrrhocoridae	Sap feeder
ll.Helopeltis spp.	=do=	Miridae	=do=
12. Tribelocephala spp.	=do=	Tribelocephalida £k	-
13. Locris maculata F.	Hemiptera (Homoptera)	Cercopidae	
14. Rtcania sp.	=do=	Ricaniidae	-
15. Crematogaster sp.	Hymenoptera	Formiddae	predator
16. Camponotus spp.	=do=	Formiddae	Predator
17. Apis spp.	=do=	Apidae	-
18. Precis sophia	Lepidoptera	Nymphalidae	-
19. Neptis morola	=do=	=do=	-
20Acraea peneleos-peneleos	=do=	Acraeidae	Defoliator (caterpillar)
2l.Leudnodes orbonalis	=do=	Pyralidae	Stem and fruit borer
22. Scrobipalpa blapsigona	=do=	=do=	Bud borer
23A. pharsalus pharsalus	=do=	=do=	Defoliator (caterpillar)
24. Precis terea	=do=	Nymphalidae	-
25. Zonocerus variegatus	Orthoptera	Acrididae	Defoliator
26. Eulioptera spp.	=do=	=do=	Defoliator
27. Phaneroptera nana	=do=	=do=	Defoliator
28. Morter spp.	Odonata	Myrmdeonidae	-
29. Colobata spp.	Diptera	Tipulidae	-

[1] Unidentified species include the following families; Muscidae, Tachinidae, Calliphonidae and Asilidae (Diptera); Blattidae (Diptyoptcra); Gryllidae, Mantidae, Catonopidae (Orthoptera); Satyridae, Lycaenidae and Arctiidae (Lepidoptera); Icbneiunonidae, Pompiloidae and Melittidae (Hymenoptera).

CHAPTER FIVE

5.0. DISCUSSION

5.1. Probit analysis and efficacy of the products

Probit analysis of dosage-mortality for the fruit borer larvae after 96 hrs of feeding (at 24.5 ± 1°C) gave LC_{50} value of 31.5% for NSWE. The chi-square value ($X^2 = 5.0883$ at $P > 0.05$) was not significant when calculated probits were compared with expected probits for any of the bioassays. This is an indication that the data fit the assumption of the probit model (Finney, 1971) . It also implies that when the 3rd instar fruit borer fed on fruit tissue treated with 31.50% concentration of neem seed water extract for four continuous days, 50% larval mortality resulted. The study also revealed that mortality increased, throughout the test period with increasing hours of exposure to NSWE and dosage. The efficacy of the NSWE was dosage-dependent and slow in activity since the larvae were exposed for 96 h before 93 % mortality was achieved. NSWE of 75% (75 g/1 of water, wt/vol.) was observed to be optimal, causing 70% and 96% mortality after 72 h and 96 h, respectively. The effect of NSWE was, however, gradual and delayed. This probably provides the evidence that contact toxicity of the NSWE did not contribute significantly to the death of the insects. Insects feeding on neem treatments probably starved to death due to the antifeedant property of NSWE or their growth was disrupted. The above observations are consistent with the findings of Arnason et a2. (1985), Koul and Isman (1991) and Schmutterer (1995). These researches have also reported that insects feeding on neem treated food media starved to death and their growth was disrupted due to the antifeedant property of NSWE. The 3rd instar larvae of the *L. orbonalls* were more susceptible to the Karate, resulting in 100% mortality after only 24 h of exposure.

Bacillus thuringiensis-'Biobit' treatment was generally less toxic to the 3rd instar fruit borer. The highest mortality recorded was 60% after 96 h. The low toxicity of the Biobit found in the present study confirms the findings of Bond et *al.* (1971), who tested the insecticidal activity of *Bacillus thuringiensis* against the larvae of *Galleria mellonella.* They reported that total (100%) larval mortality occurred after a period of 7-14 days and no observable morphological changes were detected in the larvae within the period of experimentation.

5.2. Vegetative growth

The vegetative phase of growth of. the garden egg generally lasted for about eleven weeks during the period of experimentation. With the exception of the biomass of flowers, which was not significantly (3? > 0.05) affected by NSWE, the two-weekly application of 75 g/1 of NSWE significantly ($P < 0.05$) gave greater dry biomass of whole plant and various parts of the garden egg than Karate, Biobit and control treatments plots. The NSWE remarkably increased mean values of growth-related parameters such as plant height, number of branches per plant and plant girth, all measured at flowering. This probably shows that NSWE has growth enhancing properties and thus confirms the evidence that NSWE has high nitrogen content. The probable reason why NSWE significantly ($P < 0.05$) affected number of branches per plant but could not appreciably influence the number of functional leaves per plant, compared to Karate is that unlike Karate, NSWE-treated plots experienced higher incidence of shoot borer infestation. The number of damaged shoots was comparatively higher on NSWE-treated plots, with most leaves losing their freshness. This could have accounted for the low number of functional leaves per plant recorded for NSWE treatment. Neem seed water extract significantly ($P < 0.05$) delayed flower initiation and the cause of this delay is not known. It is likely that the vegetative phase of plants treated with NSWE was prolonged due to the growth-promoting effects of the NSWE. This might have contributed to the relatively long days taken for plants under NSWE treatment to flower.

5.3. Leaf damage

The occurrence of higher percentage foliar damage recorded at the latter part of season was due to the seasonal outbreak of *Zonocerus variegatus.* The feeding activity of this pest could not be controlled effectively by Biobit treatment compared to Karate and

NSWE treatments. Applications of Karate and NSWE at the pre-flowering, fruiting and post-fruiting stages reduced foliar damage by 50% when compared with Biobit and control plots.

Percent defoliation and number of feeding punctures recorded on the NSWE- and Karate-treated plots never exceeded 20% and 17 punctures per plant throughout the period of experimentation. At the recommended field rate of 2.5 ml/1 and 75 g/1, both Karate and NSWE strongly reduced the activities of defoliators such as *Zonocerus rariegatus* and *Phaneroptera nana,* during the latter part of the season period. The sudden rise in percentage leaf damage observed on both Karate- and NSWE-treated plots between 7th and 9th week could be due to heavy rainfall which occurred three days after pesticide application. It is likely that the rains washed away the chemical from the leaves thereby reducing the residual activity and persistence of the active ingredient.

Reduction in defoliation observed on plots treated with NSWE supports the report that neem products are bitter and have antifeedant properties which indirectly affect centers that control feeding and act on the gut musculature to prevent ingestion and food metabolism (Barnby and Klocke, 1987; Mordue *et al.* 1985; Wartten, 1989).

5.4. Shoot and bud damage

The application of NSWE at 75 g/1 could not offer adequate protection of the crop against shoot borer compared to the synthetic insecticide treatment. Though translocation of Azadirachtin has been reported to occur in vegetable crops (Osman and Port, 1990), the results of this study indicate low or slow systemic action of NSWE against shoot borer of garden egg in field experiment. Ken et *al.* (1994) have indicated that azadirachtin may not remain in the trunk tissue long enough to affect all larvae before being carried far up the crop since it may be more rapidly broken down.

Inspite of the high population and infestation levels of the shoot borer on NSWE-treated plots, borer activity did not cause any noticeable adverse effect on vegetative growth of the crop. Probably, the damaged caused by the shoot borer was compensated for by the initiation of more offshoots and branches by plants treated with NSWE.

Bud damage was significantly ($P < 0.05$) lower in plots treated with Karate than the other treatments. Percentage of buds damaged by insect pests never exceeded 20% for Karate-treated plots throughout the period of experimentation. Symptoms typifying bud borer activity peaked in September to October (fruiting and harvesting periods), on NSWE, Biobit and control plots.

During the peak period of pest infestation in October, bud damage caused by pests exceeded 25%, 30% and 35% on plots treated with NSWE, Biobit and control respectively. On the other hand, Karate-treated plots had less than 10% bud damage in October. The activities of the pest significantly ($P < 0.05$) influenced flowering and fruit set. The pest caused severe injury to buds and prevented them from developing. This might have affected yield adversely on the NSWE, Biobit and control-treated plots.

5.5. Fruit damage and yield

After harvesting, it was observed that about 86%, 74%, 66% and 50% of the fruits were fully marketable for Karate, NSWE, Biobit and control-treated plots, respectively. Karate-treated plots produced significantly ($P < 0.05$) greater number of marketable fruits. Although marketable fruits from plots treated with NSWE did not differ significantly ($P > 0.05$) from Biobit-treated plots, the fruits of plants treated with NSWE were numerically greater than that of Biobit. Both Biobit and NSWE-treated plots produced better yields than control. The average number of fruits per plant recorded in this study was not consistent with the findings of Tindall (1968) who reported 8-14 fruits per plant. However, the range of the number of fruits recorded in this study (17-24) per plant confirms the findings of Torkpo (1994) . Variation in yield may be due to differences in soil fertility status, varietal effect, diseases and pest infestation levels, moisture content of the soil and other cultural practices. Gross fruit yield (kg/ha) for NSWE was comparable to that of the Karate.

5.6. Economic benefit

Higher yields and remarkable reduction in pest infestation in Karate-treated plots resulted in greater net profit. At (£1,000.00 per kilo of marketable fruits during the major season, the net profit from Karate was <211,029,884.00/ha. This is higher by <22,803,704.00/ha compared with NSWE. The net profit obtained from NSWE treatment, however, was better by <£1,902,328.00/ha than Biobit, which yielded a net profit of £6,283,852.00 per hectare. The benefits of the NSWE programme, however, extend beyond the short-term economic returns. With reduced frequency of chemical application, negligible disruption of natural enemies, the potential reduction in the development of insecticide resistance, NSWE has considerable long-term economic inplications.

The incidence of shoot and bud borer activities on NSWE-treated plots was observed to be relatively higher when compared with the Karate-treated plots. This might have affected fruit development and yield appreciably since their activity was one of the most important factors determining the yield of the garden egg.

5.7. Insect fauna on garden egg

Various taxa were generally low on Karate-treated plots. Hymenoptera group consisted of more beneficial insects (predators) which included ants such as *Crematogaster* sp. and *Camponotus brutus.*

These insects have been noted to be beneficial (Schmidt and Pesel, 1987). Black ants were the most abundant predators captured among the Hymenoptera group. They were observed to be most active during fruiting and harvesting where they were found preying on larvae of *Leucinodes orbonalls.*

In general, hymenopterans were the most abundant group of insects recorded during the study. Plots treated with NSWE harbored more hymenopterans (predators) with relative abundance exceeding 44.19%. This observation is consistent with those reported by Shukla (1992). Hymenopterans were estimated to be over 37.2%, 35% and 6.1% for control, Biobit and Karate-treated plots, respectively. There was about 38.8% reduction in the Hymenoptera populations on Karate-treated plots compared to NSWE-treated plots. NSWE treatments had little side effect on beneficial and other ecologically important non-target organisms than Karate, which probably had strong contact and neurotoxic mode of action. The information obtained from this study could be desirable to enable an assessment of the compatibility of neem products with the ecosystem.

Lepidoptera counts consisted mostly of defoliators (caterpillars) during the vegetative phase of crop growth. These insects were generally low in numbers. It was estimated to be 1.7% on Karate-treated plots. About 2.6% of the Lepidoptera counts was obtained for NSWE-treated plot. The control and Biobit-treated plots had relative abundance of 4.4% and 5.8%, repectively.

Few Orthopteran species such as *Z. varlega tus*, *Eulioptera. recticulata* and *Phaneroptera* nana were found to be defoliators- The Orthoptera group was proportionally greater in number on plots treated with water (control) and Biobit. This group of insects, however, was relatively low on NSWE and Karate-treated plots.

Dipterans were well represented throughout the period of experimentation. Percentage relative abundance was 31.2%, 25.7%. 40.5% and 32.2% for control, Biobit, NSWE and Karate, respectively. Families of Dipterans trapped included Muscidae, Tachinidae, Calliphonidae, Asilidae and Tipulidae.

Odonata was recorded as the lowest insect group captured through out the study. Coleoptera and Hemiptera were fairly moderate in abundance.

Five families belonging to Coleoptera group were identified. *Pachnoda* sp. (Scarabaeidae) was found to be more prevalent on control and Biobit-treated plots. They were, in most cases, found chewing and scraping young and fresh stem. This family has also been reported by Pe Pury (1968) to be leaf feeders, stem-borers and soil pests. According to De Pury (1968) , the larvae of this pest are known to live an immobile life in the soil and feed upon roots. The adults are inclined to eat foliage but the damage done by larvae is by far of greater importance. *Adoretus umbrosus* F. (Rutelidae) was found to be sap feeder of buds and leaves. *Lagria* sp. was observed on leaves and flowers but found to be harmless. Borror and White (1970) reported that Lagriidae usually occur on flowers, foliage and under the bark of plants. The larvae of this insect according to them, feed on decaying vegetation in rotten wood or under bark. *Coccinella.* sp. (Coccinellidae), commonly known as the ladybird beetles were mostly found on plots treated with NSWE, Biobit as well as control plots. They were observed to be harmless to the garden egg. According to De fury (1968) these beetles are of worldwide importance to agriculture because nearly all of them are carnivorous and the majority are predators of two major groups of plant pests, Aphididae and Coccoidae. Donald efc al. (1976) also reported that the ladybird beetles are important predators of aphids. The other family recorded among the Coleoptera is Cicinellidae. Available information obtained so far has not reported of *Adoretus vtmbrosus F., Hyprops* sp. and *Catescopus* sp. as among the insect fauna of the local garden egg. In all a total of twelve different species of Coleopterans were found during the study but not all had been identified.

Seven families were identified as Hemipterans. These include Pentatomidae, Leptocorisidae, Pyrrhocoridae, Miridae, Tribelocephalidae, Cercopidae and Fulgoroidae. *Helopeltis* sp. and *Dysdercus* sp. were sap feeders of leaves and young shoots of the garden egg. According to Klots and Klots (1969), most insects belonging to Miridae feed on plants. They feed on the sap of young green plant tissue, injecting saliva that causes a breakdown of the tissue. This results in pale brown dead patches or lessions on the leaves. De Pury (1968) has reported that if these lesions are found on a leaf before it is fully grown the leaf may appear plucked or rolled and the attacked areas may die and drop off finally. Forsyth (1966) also recorded *Helopeltis begrothi* Rent, as a pest of garden egg in Ghana. Among the list of insects of garden egg reported, *Aspavia hastator, Halyomorpha azmulicomis, Stenocoris spp, Tribelocephalia squamusa, Locris maculata* F. and *Ricania* sp. have not been recorded. A total of 17 different species were recorded for the Hemipteran. Six families belonging to the order Hymenoptera were identified. These consist of Formicidae, Apididae, Ichneumonidae, Pompiloidae, Melittidae and Myrmicidae. Most Ichneumon wasps are parasites of caterpillars (De Pury, 1968). Burton (1968) also reported that majority of the insects belonging to this family attack the larvae of butterflies and moth. *Crematogaster* sp. and *Camponotus bmtus.* (Formicidae) were found to be pr.edators of the fruit borer larvae. Pompiloidae, Melittidae have not been reported among insect fauna of garden egg. Twenty-three (23) different species were obtained for the order Hymenoptera.

Nymphalidae, Acraeidae, Pyralidae, Satyridae, Lycaenidae and Arctiidae were some of the lepidopterous familes recorded. With the exception of Pyralidae, the rest have not been reported among the list of insect fauna of garden egg. Among the major pest complex listed as lepidopterous pest of garden egg, *Acraea peneleos peneleos* and *A. pharsalus pharsalus* (Caterpillar), which were found to be defoliators in this study, have not yet been reported. Adults of *Precis sophia,* P. *terea* and *Neptis morola* collected from the garden egg field experiment were found on ripened garden eggs during harvesting. They have also not been reported as insects associated with garden egg.

Four families (Acrididae, Gryllidae, Mantidae and Catonopidae) in the order Orthoptera were observed. The preying mantid (Mantidae) according to Klots and Klots (1969) is the sole member of the order Orthoptera to have departed from the general plant-eating behaviour and adopted a predatory life. De Pury (1968) reports that as predators, preying mantid feeds on moths, caterpillars and flies thereby reducing their population. *Zonocerus variegatus* (Acrididae) were the most serious pests (defoliators) observed during the study. They were mostly found on Biobit and control plots. Their populations began to build up during the latter part of the season (September). Gryllidae and Catonopidae have not been reported among the insect fauna of garden egg. About thirty-one (31) different species of Orthoptera were recorded associated with garden egg in the study.

Other families such as Myrmeleonidae (Odonata), Tipulidae, Muscidae, Tachinidae, Calliphonidae and Asilidae (Diptera) were also observed in this study as unreported insect families of the garden egg. A total of twenty-six (26) different species were recorded among the Orthoptera.

5.8. Parasitic Nematodes

The presence of parasitic nematodes was also observed on garden egg from all plots treated with Karate, NSWE and Biobit as well as control plots. Species recorded were mainly *Meloidogyne* sp. (Nematoda: Heteroderoidea). Few of these insects were observed on Karate-treated plots. In other parts of West Africa such as Liberia and Niger, nematodes have also been reported on garden egg farms (Lambert, 1988).

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATIONS

Neem Seed Water Extract has great potential as an environmentally acceptable insecticidal product for managing pests of garden egg in Ghana. It has antifeedant and toxicity effects against a range of insects. Its potency is dosage-dependent, bioaccumulative and varied between species. However, Neem Seed Water Extract is not a panacea for the control of pests of local garden egg. There are likely to be certain pests for which NSWE cannot provide adequate control. In this study in particular, shoot and bud borers were difficult to control with Neem Seed Water Extract. Neem extracts alone therefore may be less suitable for crops with high quality demands because they are less efficient in killing target insect quickly than the synthetic chemical already in use.

Nevertheless, with proper timing and innovative methods of application, alternating the use of Neem Seed Water Extract with Karate or mixing with other suitable biopesticides can be promising. Such treatment may invariably show better performance than the Neem product alone.

A weekly application of the Neem Seed water extract could have provided good control of the garden egg pests. This is because, garden egg is a rapidly growing crop. In each week, during the mid season, significant new leaf area is added to the canopy. Such crops therefore need more frequent sprays to keep a high percentage of the leaves and shoots treated. The active ingredient, according to Schmutterer (1995) is easily degradable in sunlight. This limits its residual activity and hence may reduce its performance in the field.

As a cultural practice, picking of shoots showing signs of borer infestations could control shoot borers. On a large scale, this may require labour and family support.

Since NSWE could support vegetative growth, it is recommendable to use NSWE for leafy vegetable cultivation.

It is recommended that future research should include the investigation of percentage damage and crop loss attributable to the various key pests and diseases of the crop in the country.

REFERNCES

Akpabi, I.B.K. (1989). A guide to garden egg production in Ghana *In* Horticultural crops. A report by the commodity committee of NARP, CSIR, Accra, Ghana (1993) 3, 20-40.

Ampong, J.E. (1979) . Effect of chemical treatment on germination and seedling growth and the effect of spacing on fruit yield of garden egg *(Solanum integrifolium and S. melongena*). A Bachelor of Science Dissertation, Department of Crop Science, Faculty of Agric. Univ. of Ghana, Legon, 70 pp.

Angus, T.A. (1956). Association of toxicity with protein -crytalline inclusions of Bacillus sotto Ishiwata Can. *J. Microbiol. 2,* 122-131.

Arnason, J.T., Philogene, B.J.R., Oonskov, N., Hudon, M., Mcdougall, C., Fortier, G., Morand, P., Gardner, D., Lambert, J., Morris, C. and Nozzolillo, C. (1985). Antifeedant and insecticidal properties of azadirachtin to the European corn borer, *Ostrinia nubilalis. Entomol. Exp. Appl.* 38, 29-34.

Arnon, J. (1972) . Plant population and distribution patterns in crop production in dry regions, background and principles, *In* Ampong, J.E. (Ed). Effect of chemical treatment on germination and seedling growth and the effect of spacing on fruit yield of garden egg *(Solanum integrifolium and S. melongena).* A Bachelor of Science Dissertation, Department of Crop Science, Faculty of Agric. Univ. of Ghana, Legon, 68 pp.

Asante, A. K. (1992). A survey report by .Crop Research Institute, *In* Horticultural crops (July 1993), *NARP Commodity Committee*$_r$ (3) , 4 - 10.

Asari, P.A.R. and Nair, M.R.G.K., (1972). On the control of brinjal pests using deterrents, *Agric. Res. J. Karala* 10, 133-135.

Atwood, D.W., Young, S.Y. and Kring, T.J. (1997). Development of *Cotesia marginiventris* (Hymenoptera: Braconidae) in tobacco budworm (Lepidoptera: Noctuidae) larvae treated with *Bacillus thuringiensis* and Thiodicarb. *In J. of Econ. Entomol.* 90(3), 751 - 756.

Baha-Eldin, S.S., Blackhurst, H.T. and Perry, B.A. (1968). The inheritance of certain qualitative characters in eggplant. *Proc. Of American Soc. Hort. Sci.* 92, 480-497.

Balls, L.W. (1951) . The yields of a crop. *In* Ampong, J.E. (Ed) . Effect of chemical treatment on germination and seedling growth of garden eggs and the effect of spacing on fruit yield of garden eggs *(Solanum integrifolium* and *S. melongena).* A Bachelor of Science Dissertation, Department of Crop Science, Faculty of Agric. Univ. of Ghana, Legon, 70 pp.

Barnby, M.A. and Klocke, J.A (1987) . Effects of *aza* on the nutrition and development of the tobacco budworm, *{Heliothis virescens* Fabr: Noctuidea) J. *Insect Physiol.* 33, 69-75.

Bauer, L.S. (1995). Resistance: a threat to the insecticidal crystal protein of *Bacillus thuringiensis. Fla. Entomol.* 78, 414-443.

Berrie, G. K., Berrie, A. and Eze, J. M.O. (1987). Tropical Plant Science. Longman Scientific and Technical, U.K.103 pp.

Blay, E.T. (1986). Garden egg production in Ghana. *Legon Ext. Bull.* 18, 1-10.

Bond, R.P.M., Boyce, C.B.C., Rogoff, M.H. and Shieh, T.R. (1971). The thermostable exotoxin *of Bacillus thuringiensis. In* Microbial control of insects and mites. Burgen, H.D.and Hussey, N.W. (Eds). Academic Press, London. 623 pp.

Borror, D.J. and White, R.E. (1970). A field-guide to the Insects of America North of Mexico. Hughton Mifflin Company Boston, 404 pp.

Boswell, V.R. and Jones, H.A. (1941) . *In* Climate and vegetable crops yearbooks Agric. 1941. U.S. 395 pp.

irader, L. (1982). Recent trends in insect control in the tropics. *Entomol. Exp. et appl.* 31, 111 - 120.

Buchanan, R.E. and Gibbons, N.E. (1974). Berey's Manual of Determinative Bacteriology, [8th ed.] The Williams and Wilkins Company, Baltimore, U.S.A. 536 pp.

Burton, J. (1968). The Oxford book of insects. Oxford University Press. 208 pp.

Butani, D.K. and Varma, S. (1976) . Pests of vegetables and their control: Brinjal. *Pesticides India,* 10(2), 32 - 35.

Chakraborty, D.P., Ghosh, G.C. and Dhua, S.P. (1974). Studies on the compatibility and effectiveness of different urea-insecticide mixture. *Tecnology,* 11(2&3), 189-191.

Claus, D. and Berkeley, R.C. (1986). Genus *Bacillus* Cohin.1872, 174. In "Bergey's Manual of Systematic Bacteriology", Sneath, P.H.A. [ed] . Williams and Wilkins, Baltimore, 2, 1141 pp .

Cobbinah, J. R. and Osei-Owusu, K. (1988) . Effects of neem seed extracts on insect pests of okra and cowpea, *Insect Sci. Appl.* 9, 601-607.

Cobley, L. S. and Steele, W. M. (1956). An Introduction to the Botany of Tropical Crops. Longman, Green, London. 233 pp.

Coffie-Agblor, R. (1982). A review of insect pests of eggplant *(Solanum melongena)* and their control. A Bachelor of Science Dissertation, Department of Crop Science, Faculty of Agric., Univ. of Ghana, Legon. 72 pp.

De Barjac, H. (1978) . *Bacillus thuringiesis* serotype H-14. *In* Data Sheet of the biological Control Agent, WH0/VBC/79.750, 1 - 1 3 .

Dei-Tutu, J. (1973). Preservation of garden egg by dehydration. *Ghana J. Sci.* 13, 86-91.

De Pury, J.M.S. (1968) . Crop pests of East Africa. Oxford University press, 227 pp.

Dhandapani, N., Rajmohan, N.S. and Kareem, A. (1985). Plant products as antifeedants to control insects. *Pesti.* 19, 53-60.

Division of Agriculture, (1962). Crops other than cocoa and the disease and pests, which affect them. *In* Agriculture and Land Use in Ghana. (Ed. J.B. Wills). Oxford University Press. 393 pp.

Donald, C.M. (1963). Competition among crop and pasture plants. *Adv. in agronomy* 15, 1 - 118.

Donald, J., Borror, D., Whight, M.D. and Charles, A. T. (1976). An introduction to the study of insects. Holt, Rhinehart and Winston. USA. 617 pp.

Donovan, W.P., Dankoscik, C.C., Gilbert, M.P., Gruat, R.G., Gawron-Burke, M.C.and Carlton, R. C. (1988) . The p-Z protein of *Bacillus thuringiensis* varkurstaki. Nucleotide sequencing and entomocidal activity. *J. of Biol. Chem.* 263, 561-567.

Dreyer, M. (1987) . Field and laboratory trials with simple neem products as protectants against pests of vegetable and field crops in Togo. *Proc. 3rd Int. Neem Conf. (Nairobi, Kenya, 1986).* 431-447.

Dreyer, M. and Hellpap, C. (1991) . Neem a promising natural insecticides for small-scale vegetable production in tropical and subtropical countries. *Z. PflKrankh.* 98, 428-437.

Dulmage, H.T. (1981). Insecticidal activity of isolates of *Bacillus thuringiensis* and their potential for pest control. *In* Burges, H.D. [Ed.], Microbial control of plant pests and diseases, 1970 - 1980. Academic press, Lodnon. 222 pp.

DuRant, J.a. (1977) . Field efficacy by insecticides against the *Heliothis* species complex on cotton in South Carolina. J. *Ga. Entomol. Soc.* 12, *163-166.*

El-Sherif, s.I. (1971). Infestation rates and annual generations of *Euzophere asseatella* Triet. (Lepidoptera: Pyralidae) under field conditions in Alexandria area. *Zeitschrift fur Angewandte Entomol.* 69(1), 37-43.

Ermel, K. (1995) . Azadirachtin contents of neem seed kernels from different regions of the world. *In* Schmutterer [Ed]. The Neem Tree *Azadirachta indica* A. Juss. and Other Meliaceous Plants. VCH Publishers Inc. New York, NY (USA) . 692 pp.

Eyeson, K.K. and Ankrah, E.K. (1976). Food composition tables. Food Research Institute, C.S.I.R., Accra. 135 pp.

FAO (1988). Crop production bulletin 42, *In* Roderick G. McKinlay [Ed.] 1992. Vegetable crop pests. The Macmillan Press Ltd. 119 pp.

Finney, D.J. (1971). Probit analysis. Univ. Printing Press, Cambridge, UK. 267 pp.

Forsyth, J. (1966). Garden eggs production in Ghana. *Legon Ext. Bull.* 18, 1 - 10.

Goldberg, L. J. and Margalit, J. (1977) . A bacterial spore demonstrating rapid larvicidal activity against *Anopheles sergenti, Uranotaenia uguiculata, Culex univittus', Aedes aegypti and Culex pipiens. Mosq. News.* 37, 355-358.

Green, M.B., Harthy G.S. and West, F.T. [Eds]. (1987). Chemicals for crop improvement and pest management. 3rd ed. Pergamon Press, Oxford, 370 pp.

Hannay, C.L. (1953) . Crytalline inclusions in aerobic spore-forming bacteria. *Nature* 172, 1004-1006.

Hannay, c.L. and Fitz-James, P. (1955). The protein crystals of Bacillus thuringiensis Berl. *Can. J. Microbiol.* 1, 694-710.

Harper, J.D. (1974). Forest insects control with *Bacillus thuringiensis: a* survey of current knowledge. Auburn Univ. Agriculture Exp. Station Publication, Auburn, Ala. 438 pp.

Heimpel, A.M. (1967). A critical review of *Bacillus thungiensis* and other crystlaliferous bacteria. *Annu. Rev. Entomol.* 12, 287-322.

Herklot, G.A.C. (1972). Vegetable in SouthEast Asia. George Allen and Unwin Ltd. London, 484 pp.

Hernstadt, C.G., Soares, G., Wilcox, E.R. and Edwards, D. (1986). A new strain of *Bacillus thuringiensis* with activity against coleopteran insects. *Bio/Technology* 4, 305 - 308.

Hollingsworth, D.F. (1981). The place of potatoes and other vegetables in the diet *In* Vegetable productivity. Spedding, C.R.W. (Ed). Macmillan, London. 340 pp.

Husz, B. (1929). On the *Bacillus thuringiensis* in the fight against the corn borer. *Int. Corn Borer Invest. Sci. Rep.* 2, 99-110.

Irvine, F.R. (1969). Vegetables. West African Crops. Oxford University Press. 211 pp.

Jackai, L.E.N (1993). The use of neem in controlling cowpea pests. *International Institute of Tropical Agriculture Journal.* 7, 5-11.

Joshi, M.L. and Sharma, J.C. (1973) . Insecticides for the control of brinjal aphid (*Aphis gossypii)* Glov., Jassid (*Amarasca devastans)* Dist. and fruit borer (*Leucinodes orbonalis)* Guen. *In* Rajasthan, *India J. of Agric. Sci.* 43 (5), 436 - 438.

Katiyar, R. n. (1972). Termites in Indian agriculture and losses caused by them. In Larbi, M. (1978). Comparison of insects fauna on the three cultivars of eggpalnts *(Solanum* spp.). A Bachelor of Science Dissertation, Department of Crop Science, Faculty of Agric., Univ. of Ghana, 65 pp.

Ken, N., Leo, J.R., and Murray, B.I. (1994). Systemic action of neem seed extract on Mountain Pine Beetle (Coleoptera: Scotylidae) in Lodge Pole Pine. *J. Econ. Entomol.* 87, 1580-1584.

Kirkpatrick, T.W. (1957). Insect life in the tropics. Longmans Green and Co., London. 311 pp.

Kirsch, K. (1987) . Studies of the efficacy of neem extracts in controlling major insect pests in tobacco and cabbage. *Proc. 3rd Int. Neem Conf.* Nairobi, Kenya, 1986. 495-515.

Kiselev, E.V. (1975). The effect of biopreparations on insect parasites and predators. *Zash Rast.* 12, 23.

Klots, A.B. and Klots, E.B. (1969). Living insects of the World.
Hamish Hamilton Ltd., London. 304 pp.

Koul, O. and Isman, M.B. (1991) . Effects of azadirachtin on the dietary utilization and development of the variegated cutworm *Peridroms saucia. J. Insect Physiol.* 37, 591 -598.

Kreig, A. (1971). Is the potential pathogenicity of bacilli for insect related to production of alpha-exotoxin? *J. Invertebr. Pathol.* 18, 425-426.

Kreig, V.A., Huger, A.M., Langenbruch G.A. and Schnetter, W. (1983). *Bacillus thuringiensis* var Tenebrionis: a new pathotype effective against larvae of Coleoptera. *Z. Angew Entomol.* 96, 500-505.

Krishnaiah, K., Tandon, P.L. and Jagan, M.N. (1976). Control of shoot and fruit borer of brinjal *(Leucinodes orbonalis* Guen.) with new insecticides. *Pesticides*, 10(6), 41-42.

Kumaresan, D. and Baskaran, P. (1976). Persistence of certain systemics in brinjal (*Solanum melongena* L.) plants. *Pesticides India* 10(11), 45 - 47.

Lambert, F. (1988) . Parasitic nematodes. *In FAO Plant Protection Bulletin*, 36, 69-73.

Larbi, M. (1978.) Comparison of insects fauna on the three cultivars of eggpalnts (*Solanum* sp.). A Bachelor of Science Dissertation, Department of Crop Science, Faculty of Agric., Univ. of Ghana, Legon. 65 pp.

Luttrell, R.G., Roush, R.T., Ali A., Mink, J.S., Reid, ' M.R. and Snodgrass, G.L. (1987). Pyrethroid resistance in field populations of *Heliothis virescens* (Lepidoptera: Noctuidae) in Mississipi in 1986. *J. Econ. Entomol.* 80, 985-989.

Miller, J.C. (1990) . Field assessment of the effects of microbial pest control agents on non-target Lepidoptera. *Am. Entomol.* 36, 135-139.

Mohd-Salleh, M.B. and Lewis, L.C. (1982). Feeding deterrent response of corn insects to beta-exotoxin of *Bacillus thuringiensis. J. Invert. Pathol.* 39, 323-328.

Mordue Luntz, A.J., Coffee, P.K. and Evans, K.A. (1985). Azadirachtin, its effect on gut mobility, growth and moulting in Locusta. *Physiol. Entomol. 10,* 431-437.

Morris, O.N. (1982). Bacteria as pesticides: Forest applications. *In* Kurstak, E. (Ed). Microbial and viral pesticides. Marcel Dekker, New York. 387 pp.

Mohan, K., Gopalan, M., Balasubramanian, G. and Jayaraj, S. (1988). Studies of the use of botanicals for the management of sucking pests in brinjal by bare root dip method. Final workshop of IRR-ABD-EWC Project on botanical pest control in rice-base cropping systemms. IRRI, Los Banos, Philipines. 158 pp

NARS, (1998). Workshop on sustainable agricultural production in Ghana. Nov. 16-20, 1998, Accra International Conference Center.

Norman, J.C. (1974). Eggplant production in Ghana. *Ghana Farmer,* 18(2&1), 25-27.

Nsowah, G F. (1970). Effects of sowing date on flowering and yield in of eggplant. *Ghana J. of Agric. Sci.* 3, 99-108.

Ofosu-Budu, K. G. (1984). Evaluation of eggplant breeding-lines (S. *melongena)* . A Bachelor of Science Dissertation, Department of Crop Science, Faculty of Agric. Univ. of Ghana, Legon. 72 pp.

Ohba, M., Aizawa, K. and Sudo, S. (1984). Distribution of *Bacillus thuringiensis* in sericultural farms of Fukuoka Prefecture, Japan. *Proc. Assoc. Plant Prot. Kyushu* 30, 152-155.

Oscar, A. Lorenz and Donald, N. Marynard (1988). Knott's handbook for vegetable growers, 3rd ed. John Wiley and Sons, Inc. 327 pp.

Oomen, H.A.P.C. and Grubben, G. J.H. (197'8) . Tropical leaf vegetables in human nutrition. Royal Tropical Institute. Amsterdam and Orphan Publishing Company, Willemstad, Curcacao. 230 pp.

Osei, K.A. (1986). Effect of Perfekthion EL20 and NPK fertlizer on the yield and performance of garden egg, *Solanum integrifolium* (L). A Bachelor of Science Dissertation, Department of Crop Science, Faculty of Agric., Univ. of Ghana, Legon. 75 pp.

Osman, M.Z. and Port, G.R. (1990). Systemic action of neem seed substances against *Pieris brassicae. Entomol. Exp. Appl.* 54, 297-300.

Owusu, J. (1980). The effect of Gardona (Tetrachlorvinphos) on the insect fauna of eggplant, *Solanum melogena,* L. A Bachelor of Science Dissertation, Department of Crop Science, Faculty of Agric., Univ. of Ghana, Legon. 75 pp.

Padua, L.E. and Federici, B.A. (1990) . Development of mutants of the mosquitocidal bacterium *Bacillus thuringiensis* subspecies *morrisoni* (PG-14) toxic to lepidopterous and dipterous insects. *FEMS Microbiol. Lett.* 66, 257-262.

Pal, S.K. (1971). Relative efficacy of different insecticides on *Urentius echinus* Dist. and *Empoasca* species infesting brinjal crop in Mathania area of Western Rajsthan. *Madras Agric. J.* 58(4), 323 - 325.

Palevitch, D. (1969). Varietal and spacing effect on the yield of red pepper. *Capsicum annum* L. in single harvest. *Israel J. Agric. Res.* 19, 65-69.

Parmar, B.S. (1995). Results with commercial neem formulation produced in India. *In* Schmutterer (Ed). The Neem tree, source of unique natural products for integrated pest management, medicine, Industry and other purposes. VCH verlagsgeseltshaff MbH, D-69451 Weinheim. 1469 pp.

Patti, J.H. and Carner, G.R. (1974). *Bacillus thuringiensis* investigations for control of *Heliothis* sp. on cotton. *Econ. Entomol.* 67, 415-418.

PPMED/Statistics division (1991). Ministry of Agriculture. Xn Horticultural crops. *A report by the commodity committee of NARP* (1993) *3,* 41-52.

Randhawa, N.S. and Parmar, B.S. (Eds.) (1993). Neem research and development. *Society of Pesticides Science,* New Delhi, India. 39-45.

Rawat, R.R. and Modi, B. (1969). Biology and natural enemies of the brinjal mealybug *centrococcus insolitus* (Green) in Madhya Pradesh. *Indian J. Agric. Sci.* 39, 112 - 116.

Redknap, R.S. (1991) . The use of crushed neem berries in the control of some insect pests in Gambia. *Proc. 1st Int. Neem Conf.* Rottach-Egern, Germany, 1980, 123-214.

Reed, D.K. and Reed, G.I. (1985). Control of vegetable insects with neem seed extracts. *Proc. Indiana Acad. Sci.* 94, 335-339.

Rembold, H. (1995) . Biological effects of neem and their modes of action on growth and metamorphosis. *In* Schmutterer, H. (Ed) . (1995) . The Neem tree, source of unique natural products for integrated pest management, medicine, Industry and other purposes. VCH verlagsgeseltshaff MbH, D-69451 Weinheim. 1179 pp.

Rice, R. P., Rice, L. W. and Tindall, H. D. (1992). Fruit and vegetable production in warm climate. The MacMillan Press Ltd., London. 472 pp.

Rodgers, P. B. (1993). Potential of Biopesticides in Agriculture. *Pestic. Sci.* 39, 117 - 129.

Rosalind, R. J., Jeffrey, C. M. and Bruce, L. (1993). *Bacillus thuringiensis* var. Kurtsaki, affects a beneficial insect, the Cinibar moth (Lepidoptera: Arctiidae) *Econ. Entomol.* 86(2), 335-339.

Ruscoe, C.N.E (1972) . Growth disruption effects of an insect antifeedant. *Nature New Biol.* 236, 159-160.

Saddappaji, C. (1973). *Epilachna gagentica,* a new pest on brinjal. *Current Research,* 2(6), 43.

Sandhu, G.S., Ramzan, M. and Bhalla, J.S. (1973). Effectiveness of some new insecticides against hadda beetle. *Punjab Hort. J. 13*(2/3), 211-212.

Satpathy, J.M., Dash, P.K. and Misra, B. (1974). Insecticidal residues in some vegetables grown in treated soil. *Indian J. Agric. Sci.,* 44(2), 113-115.

Saxena, R.C. (1989). Insecticides from neem. *In* Arnason J.T. (Ed). Insecticides of plant origin. ACS Symposium Series No. 387. *American Chemical Society,* Washington, DC. 112-135.

Schmidt, G. and Pesel, E. (1987). Studies on the sterilizing effect of neem extracts in ants. *In* Schmutterer, H. and Aschar, K.R.S. (Eds). Natural pesticides from the Neem Tree and other Tropical plants. *Proc. 3rd Int. Neem Conf. Nairobi, Kenya, 1986.* 361-373.

Schmutterer, H. (1969). Pests of crops in Northeast and Central Africa. Gustav Fisher Verlag, Stuttgart, Portland, U.S.A. 275 pp.

Schmutterer, H. (1990). Properties and Potentials of natural pesticides from the neem tree. *Ann. Rev. of Entomol.* 35, 468-475.

Schmutterer, H. (1995). Vegtables and Grain Legumes. *In* The Neem tree, *Azadirachta indica* A.Juss. and Other Meliaceous Plants. Sourcesof unique natural products for integrated pest management, medicine, Industry and other purposes. VCH verlagsgeseltshaff MbH, D-69451 Weinheim. 1402 pp.

Schmutterer, H. and Hellpap, C. (1988). Effects of neem on pests of vegetables and fruit trees *In* The Neem Tree. Jacobson, M. (Ed). Boca Raton, FL: CRC Press. 286 pp.

Sebesta, K., Farkas, J., Horska, K. and Vankova, J. (1981). The beta-exotoxin of *Bacillus thuringiensis. In* Burges, H.D. (Ed). Microbial control of pest and plant diseases 1970-1980'. 281 pp.

Shukla, B.C. (1992). Evaluation of botanical pesticides against rice insect pests. Natl. Seminar on changing pest scenario in pest management in India. *Neem News L.* 9(1), 18-19.

Siddig, S.A. (1981) . Evaluation of neem (*Azadirachta indica* A. Juss) as protectant against some major pests in the Sudan. Annual Report, Entomology Unit, Shambat Res. Station, Sudan, 28pp.

Sidhu, A.S. and Singh, G. (1971) . Chemical control of the real vegetable mite, *Tetranychus curcubitae* (Rahman) on brinjal. *Punhab Hort. J.* 11(1/2), 95 - 97.

Sombatsiri, K. and Tigvattanont, S. (1984). Effects of neem extracts on some insect pests of economic importance in Thailand. *In* Preybyszewski, J. (1993). The use of neem seed and leaf extracts to control lepidopteran pests of cabbage in Kaedi, Mauritania, West Africa. *Trop. Sci.* 23, 212-225.

Steinhaus, E.A. (1960) . Insect pathology: Challenge, achievement and promise. *Bull. Entomol. Soc.* Amer. 6, 9-16.

Steinhaus, E.A. (1975). 'Disease in a minor chord'. Ohio State, Univ. Press, Columbus. 232 pp.

Tindall, H. D. (1968). Commercial vegetable growing. Oxford University Press. 156 pp.

Torkpo, B. (1994). Influence of time of planting and variety of intercropped cowpea on the growth and yield of eggplant *Solanum integrifolium.* A Bachelor of Science dissertation. Faculty of Science, Department of Crop Science, University of Ghana, Legon. 87 pp.

Trumble, J.T., William, G.C. and Kristina, R.W. (1994). Economic analysis of a *Bacillus thuringiensis* - based Integrated Pest Management Program in fresh-market tomatoes. *J. Econ. Entomol.* 87(6), 1463-1469.

Ulthamasamy, S., Gopalan, M. and Venkatanarayanan, D. (1973). Control of major sucking pests of eggplant (*Solanum melongena* L.) with systemic granular insecticides. *Pesti.* 7(2), 14 - 17.

Van Frankenhuyzen, K. and Fast P.G. (1989). Susceptibility of three Coniferophagous *Choristoneura* species (Lepidoptera: Tortricidae) to *Bacillus thuringiensis* var. Kurstaki. *J. Econ. Entomol.* 82, 193-196.

Warthen, J. D. Jr. (1989). Neem *(Azadirachta indica* A. Juss): Organisms affected and reference list update. *Proc. Entomol. Soc. Nash.* 91, 367-388.

Watts, R.L. and Watts, G.S. (1951). The vegetable growing business, Rev. Ed. New York, Orange Judd. 542 pp.

Wollam, J.D. and Yendol W.G. (1976). Evaluation of *Bacillus thuringiensis* and a parasitoid for suppression of the gypsy moth. *J: Econ. Entomol.* 69, 113-118.

Wood, T., Ruggero, W. and Welson R. (1995). Performance profile for the neem-based insecticide 'ALIGN' *In* Schmutterer, H. 1995 (Ed). The Neem tree, *Azadirachta indica* A.Juss. and Other Meliaceous Plants. Sourcesof unique natural products for integrated pest management, medicine, Industry and other purposes. VCH verlagsgeseltshaff MbH, D-69451 Weinheim. 1447 pp.

Yearian, W.C., Luttrell, R.G., Stacy, A.L and. Young, S.Y. (1980). Efficacy of *Bacillus thuringiensis* and *Barulovirus heliothis* - chlordimefora spray mixtures against *Heliothis* sp. on cotton. *J. Ga. Entomol. Soc.* 15, 260-271.

Yoshinori, Tanada and Harry, K. Kaya (1993). Insect Pathology. Academic Press Inc., California. 1113 pp.