EVALUATION OF *Jatropha curcas* L. (EUPHORBIACEAE) AS A BIOPESTICIDE IN THE CONTROL OF INSECT PESTS COMPLEX OF AUBERGINE (*Solanum melongena* L.)

BY

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Declaration

I hereby declare that except for references to other people's work, which have been duly cited, this work is as a result of my own original findings and has neither been presented in whole nor in part elsewhere for any degree.

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Abstract

The potentials of aqueous seed extract and seed oil of the coral plant, *Jatropha curcas* L. (Euphorbiaceae) were evaluated as a biopesticide compared with aqueous seed extract of neem (*Azadirachta. indica* A. Juss) and cymethoate, (a commercially used synthetic insecticide) in the control of insect pests complex of aubergine (black beauty), *Solanum melongena* L. (Solanaceae) both *in* the laboratory and in the field. Three major insect pests of aubergine namely, *Urentius hystericellus* Richter (Homoptera: Tingidae) *Aphis gossypii Glover* (Homoptera, Aphididae) and *Selepa docilis* Butler (Lepidoptera; Noctuidae) collected from an aubergine field at the University of Ghana Farm, Legon that had not received chemical treatment for eight months were used to determine the levels of jatropha seed oil and aqueous seed extract that could induce 50 % mortality. Choice assays as well as the ovicidal effects of neem and jatropha products on *S. docilis* were investigated

In the laboratory fifty percent mortality was induced in *S. docilis, A. gossypii* and *U. hystericellus* when they were exposed to aubergine leaves dipped for 3 sec in 1.5, 2.2 and 3.6 ml/l seed oil of jatropha, respectively. Also 28.4 and 22.3 g/l aqueous seed extract of jatropha induced 50 % mortality in *A. gossypii* and *S. docilis*, respectively. Higher concentrations of the extract (40-100 g/l) and oil (2-8 ml/l) on treated leaves inhibited feeding by the larvae of *S. docilis*, which died within 48 hrs. Ninety percent of *U. hystericellus* and 60 % of the larvae of *S. docilis* avoided leaf discs or filter paper treated with the seed oil or the aqueous seed extract of jatropha. Jatropha seed oil reduced hatchability by 21 % while aqueous seed extracts of neem and jatropha had no ovicidal effect on *S. docilis*.

In the field, aqueous extract of jatropha (40 g/l), jatropha seed oil (4 ml/l), neem (75 g/l) cymethoate (2 m/l) were sprayed on weekly basis four weeks after transplanting. Results obtained showed that control (non-treated) differed significantly ($P < 0.05$) from other treatments in number of holes in fruits, marketable fruit weight, number of fruits and number of thrips per plant. In addition, percentage fruits bored, marketable fruit weight per plant, percent leaf area defoliated by leaf feeders and yield in tonnes/ha differed significantly (P< 0.01) from the control. Plant height at flowering and number of flower buds bored showed no significant differences (P = 0.05). Jatropha seed oil treatment gave slightly higher yield indices even though not significantly different (P= 0.05) from the other plant products and cymethoate. A significant (P < 0.01) positive correlation was observed between number of marketable fruits and fruit yield expressed in tonnes/h. Based on this findings jatropha seed extracts are good candidate biopesticide in controlling insect pests of aubergine and should be integrated into an overall management of agricultural pests.

Dedication

'…Whatsoever things are true, whatsoever things are honest, whatsoever things are just, whatsoever things are pure, whatsoever things are lovely, whatsoever things are of good report: If there be any virtue and if there be any praise think on these things.'(Philippians 4, 8).

Dedicated to my beloved wife, Martha Kwarshie; my son, Vincent Eziah Jnr and my mother, Florencia Ama Anyangeh.

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May the Almighty God bless and keep all of you including those I have not been able to mention here. May he let his face to shine upon you and be gracious unto you. May he lift his countenance upon you and give you peace. Amen.

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1.	ai	Active ingredient.
2.	ha	Hectare
3.	mg	Milligramme
4.	g	Grammes
5.	Cal	Calorie
6.	Kg	Kilogramme
7.	Wt	Weight
8.	g/l	Grammes per litre
9.	cm	Centimeter
10.	t/ha	Tonnes per hectare
11.	h	Hours
12.	aq	Aqueous
13.	ml	Milliliter
14.	m	Metre
15.	LSD	Least Significant Difference
16.	ANOVA	Analysis of variance
17.	GMT	Greenwich Mean Time
18.	JSKE	Jatropha seed kernel extract
19.	JSO	Jatropha seed oil
20.	NSKE	Neem seed kernel extract
21.	CY	Cymethoate
22.	NS	No spray
23.	EC	Emulsifiable Concentrate

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Appendices.

1.0 GENERAL INTRODUTION

Aubergine (*Solanum melongena* L.) originated from East Indies where it is called brinjal and was introduced into Europe and other parts of the world including Africa (Norman, 1992). Several varieties exist and differ considerably in size, shape, colour and maturity period. The crop is very important for its nutritive values and even though it is primarily grown for local consumption, it is exported in Niger, Senegal, Cote d'Ivoire and Ghana to European countries (Norman, 1992). It is widely grown in Ghana especially in the Greater Accra region where it has a great potential to increase income levels and standard of living.

Factors such as availability of good seed, soil fertility, diseases and pest are constraints to the cultivation of the crop. Among these, insect pest problems are the most important. The major pests include leaf feeding caterpillars and beetles, stem and fruit borers, leafhoppers as well as mealybugs. Borah (1995) also listed *Aphis gossypii* and *Epilachna sp* as major pests of the crop in India. Damage by the fruit and shoot borer for instance, has been reported to range between 27 and 61 % in India (Grewal *et al.*, 1995). In States such as Punjab and Haryana, losses up to 63 % have been reported (Dhankhar *et al.*, 1977). The borer is not only limited to India but also Malaysia, South Africa and Congo (Dhankhar, 1988). In central Accra, Ghana, for example, as high as 100% yield loss on farmers' farms due to insect pest infestation is not uncommon (V. Y. Eziah Personal observation).

Control of these pests is mainly by the use of synthetic insecticides. Most farmers use very high doses and mixtures of synthetic insecticides indiscriminately to control pests of aubergine.

Synthetic pesticides while valued for their effectiveness and convenience, can pose problems when misused. Some of these are environmental pollution, development of resistant strains of insects, health hazards and toxicity to non-targeted organisms. In developing countries, additional problems include prohibitive cost, supply uncertainties and misuse. In Ghana, gross misuse of insecticides has led to the development of resistant strains of insect pests of some vegetables, and a call for national monitoring network to monitor insecticide use, and resistance development in all major insect pests (Owusu in press).

There is, therefore, the need to search for cost effective, agronomically sustainable and environmentally friendly methods of controlling pests of aubergines. Several plant species have been shown to have insecticidal properties (Irvine, 1961; Zanno, 1974; Schmutterer 1990). One such plant is the neem tree; *Azadirachta indica* A. Juss (Miliaceae), whose crude extract and oil have been used successfully in pest management programmes (Schmutterer, 1990). Additionally it possesses medicinal properties and it is available locally. It therefore provides a safe and relatively cheap source of control agent that is biodegradable and available to the resource poor farmers.

The seed extract of the coral plant *Jatropha gossypifolia* L. has been shown to have .insecticidal properties and several medicinal properties (Irvine, 1961). The most common species of the genus *Jatropha* in Ghana is *curcas* L. It is normally used for fencing and can easily be propagated by seeds and stem cuttings. Cobbinah and Appiah-Kwarteng. (1989) showed that the oil of *Jatropha curcas* confers effective protection on maize and cowpea against *Callosobruchus maculatus* F. and *Sitophilus zeamais* Motsch.. They also reported that the oil of jatropha emulsion significantly reduced the feeding activity of *Zonocerus variegates* L.

The oil has also been shown to be effective against cotton stem borers in The Philippines (Solsoloy, 1995). The phorbol extracts have also been shown to have insecticidal properties (Irvine, 1961) but little research has been done on these products to evaluate their potential for the control of field pests. It is therefore important to carry out further studies on the plant and evaluate its protectant potential for the control of insect pest complex of aubergine

This work was carried out with the following objectives.

a. To determine the insect fauna associated with aubergine.

b. To evaluate the efficacy of *Jatropha curcas* seed oil and aqueous seed extract against eggplant insect pests complex.

c. To investigate the effect of jatropha products on indigenous natural enemies.

d. To establish 50 % lethal dose (LD_{50}) of *J. curcas* for the major insect pests of aubergine if proved to be effective.

2.0 LITERATURE REVIEW

2.1 Origin and botany.

Eggplant, *Solanum melongena* L. belongs to the family Solanaceae. It is exotic to West Africa and thought to have first been cultivated in India and China where it is known as brinjal (Norman, 1992). From there, it was spread to Europe by Maorish invaders of Spain. They are perennial crops grown as annuals. Several cultivars such as Black beauty, Florida high bush, Black magic purple, Long green, Long purple are grown both in the wet and dry seasons (Town, 1964). These cultilvars also vary considerably in size, shape, and colour.

The stem and leaves are covered with umbrella shaped hairs. The flowers, with white, mauve, or purple corolla have yellow stamens, opening via a pore at the tip. Flowers are solitary but occasionally in twos. Fruits are entire with no cavity in which seeds are embedded. The calyx covering the upper part of the fruit can be smooth or spiny, green or purplish. The seeds are glabrous and in the sixth month after extraction, germination can be erratic. This can be enhanced by placing the seeds in the refrigerator at 4-6 °C for about 21 days.

2.2 Agroecological suitability.

The eggplant is a warm season crop; it prefers relatively high temperature for growth and development. The optimum day and night temperatures range from 25-35 °C and 20-27 °C, respectively. It does well in soils rich in organic matter and a pH range of 5.5-6.8 is desirable for successful production (Messiaeh, 1992).

2.3 Nutritive value and use.

The fruits contain 93.5 % moisture. The nutrient value per 100 g of fresh edible portion are energy, 20 cal; carbohydrate, 4 g; protein, 1.1 g; fat, 0.1 mg; fibre, 1g; calcium, 7 mg; phosphorus, 25 mg; iron, 0.4 mg; vitamin A, 70 I.U; thiamin, 0.09 mg; ascorbic acid, 15 mg; riboflavin, 0.2 mg nicotinamide, 0.6 mg and niacin, 0.6 mg (Norman, 1992). The fruits are cut into pieces and used in stews or boiled and ground for the preparation of soups. It is also sometimes fried or stuffed with minced meat and either fried or baked.

2.4 Yield.

Aubergine produces between five to ten fruits per plant and the more the fruits the smaller the size. An individual fruit may weigh between 0.1 – 1.5 kg depending on the cultivar. Akinlosotu (1979) reported yields up to 35.7 t/ha while Nsowah (1969) showed that fruit yield diminished with age of plant. In fact, 70% of total yield are produced during the first eight to nine weeks after transplanting. He also showed that fruit yield was higher in the main wet season than in the minor wet season in the forest zone of Ghana and that yields increase with early planting. Kogbe (1983) also reported that yield varies with spacing and recommended 90 x 60 cm, giving yields of up to 54.8 t/ha.

2.5 Insect pests.

A number of insect pests from six orders, namely, Coleoptera, Heteroptera, Homoptera, Isoptera, Lepidoptera, and Orthoptera attack egg plant (Chritchley, 1997) and may feed on young seedlings, leaves, flowers, flower buds and the fruit (Table 1). Messiaeh (1992) reported that probably the most serious insect pest that attacks the crop is *Thrips palmi* Karny (Thysanoptera; Thripidae). In French West Indies, it has ruined the production of eggplant for export. He also stated that *T. palmi* causes less damage in wetter areas where rainfall exceeds 2500 mm per annum.

Tommasini *et al.*, (1997) reported that other thrips especially *Frankliniella occidentalis* Pergande (Thysanoptera; Thripidae) (the most harmful one) and *Thrips tabaci* Lind. (Thysanoptera; Thripidae) also attack the crop. In a survey conducted in Homestead Florida by Castineiras *et, al.*, (1977) to determine the relative abundance of thrips on leaves, flowers and fruits, they showed that *T. palmi* was more abundant on leaves (x = 17. 97 ± 5.07) than on fruits (x = 3.22 ± 0.7) and flowers (x = 0.9 ± 0.3). They further stated that the population was low on the youngest leaf (x = 1.75 ± 0.28) and high on the oldest leaf (x =50.83 ± 11.64) and therefore recommended the fourth leaf from the terminal bud of a branch for population sampling studies. Of the twelve vegetable crops surveyed for infestation by *T. palmi* in Thailand, Malaysia and The Philippines, aubergine appeared to be the most frequently infested crop by thrips (Kajita *et al.*, 1996).

Kapoor *et al.*, (1997) reported that *Tetranychus cinnabarinus* Boisd. and phytoseiids are the main pests of aubergine in India; while Mishra and Mishra (1996) stated that

Leucinoides orbonalis Guen. (the shoot and fruit borer) can cause damage of between 30 and 50 % to the fruit. In a study conducted by Grewal *et, al.*, (1995) to screen 12 cultivars of aubergine to the fruit borer, infestation levels ranged from 27 to 61 %. Dhankar (1988) reported that the shoot and fruit borer is the major constraint to the production of eggplant not only in India subcontinent but also in South Africa, Congo, and Malaysia.

In India, Hampson (1896) first reported the occurrence of the fruit and shoot borer on eggplant. It remains active in India throughout the year because of successive cropping of eggplant, particularly in areas having moderate climate. The pest attacks eggplant from nursery to maturity. The caterpillars of the fruit and shoot borer bore into young shoots causing drooping and withering of growing tips. Later they bore into flower buds and fruits. The buds are shed whereas the fruits bear circular holes rendering them blemish and unmarketable. Yield losses vary with season and location, being maximum during the period of high temperature and relative humidity.

In India, the States in which very high losses have been reported are: Haryana 63 % (Dhankhar *et al.*, 1977), Punjab 61 % (Singh and Guram, 1967), Tamil Nadu 54 % (Srinivasan and Gowder, 1959), Bengal 50 % (Som Chaudhary, 1973), Orissa 43 % (Panda *et al.*, 1971). Vitamin C in affected fruits is reported to be reduced by 60 % (Hami, 1955).

The brinjal lace bug, *Urentius hystericellus* Richter, is another insect that attacks the leaves from the under surface, secreting toxic saliva that turns the leaves chlorotic and distort. Affected plants become stunted (Fimpong and Buahin, 1997). The moth, *Selepa docilis* Butler (the eggplant skeletonizer), causes severe defoliation of the leaves and can result in stunted and withered plants (Frimpong, 1981). *Eublema admota* Fldr. the leaf worm, also attacks the terminal buds of the plant boring through the apex and feeds inside rolled up leaves (Norman, 1974). They generally appear soon after transplanting, mainly in the dry season. The larvae of *Scrobipalpa blapsigona* Meyrick also bore into the buds, which later become spherical instead of cylindrical and are invariably shed. Heavy attack can result in heavy losses in yield.

Sapsuckers Such as *Anoplocnemis curvipes* Fab. (Heteroptera: Coreidae), *Helopeltis bergrothi* Reuter (Heteroptera: Miridae), *Empoasca* lybica de Berg. (Homptera: Cicadellidae) attack young fruits and shoots causing them to become distorted. *Aphis gossypii* Glover (Homoptera: Aphididae) and *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) feed by sucking sap from the under surface of the leaves, secreting honeydew on the upper surface that encourage growth of sooty mould. They also act as vectors of various viral diseases including leaf curl and mosaic. Coleopterans such as *Diabrotica sp,* (Coleoptera: Chrysomelidae) *Epitrix aethiopica* Wse. (Coleoptera: Chrysomelidae), *Ootheca mutabilis* Sahl. (Coleoptera: Chrysomelidae) and *Epilachna elaterii* Rossi (Coleoptera: Coccinelidae) cause considerable amount of damage to the leaves and sometimes fruits.

Table 1.Major insect pests of aubergine worlwide.

Scientific name	Plant part attacked
Leucinodes orbonalis Guen.(Lepidoptera: Noctuidae)	Shoot and fruit
Tetranychus urticea Koch.(Acarina: Tetranychidae)	Leaves and stems
Amrasca devastans Devastant (Homoptera:Ciccadellidae)	Leaves
Bemisia tabaci Gennadius (Homoptera: Aleyrodidae)	Leaves
Diabrotica sp (Coleoptera: Chrysomelidae)	Leaves
Epitrix aethiopica Wse. (Coleoptera: Chrysomelidae)	Leaves
Ootheca mutabilis Sahl (Coleoptera: Chrysomelidae)	Leaves
Epilachna elaterii Rossi (Coleoptera; Coccinelidae)	Leaves
Anoplocnemis curvipes Fab. (Heteroptera; Coreidae)	Young Shoots
Helopeltis bergrothi Reuter (Heteroptera; Miridae)	Shoot
Empoasca lybica de Berg. (Homopera; Cicadellidae)	Leaves
Eublema admota Fldr. (Lepidoptera; Noctuidae)	Terminal buds
Selepa docilis Butler (Lepidoptera; Noctuidae)	Leaves
Urentius hystericellus Richter (Heteroptera; Tingidae)	Leaves
Frankliniella occidentalis Pergande (Thysanoptera; Thripidae)	Leaves, fruit and flower
Thrips palmi Karny (Thysanoptera; Thripidae)	Leaves, fruit and flower
Aphis gossypii Glover (Homoptera, Aphididae)	Leaves and stem

Source: Chrichley (1997)

2.6 Control of insect pests of aubergine.

A number of insect pests attack aubergines in the field and, therefore, different control measures have been adopted at different places against these pests. In an integrated pest management programme in a greenhouse, the pirate bug, *Orius laevigatus* Fieber was able to control effectively the exotic thrips species *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) despite chemical insecticides sprayed against *Aphis gossypii.* The pirate bug releases, conducted as soon as thrips were detected, allowed an early interaction to be established between the prey and the predator at low level of density (Tommasini *et al.*, 1997).

In a glasshouse experiment at Howard David Farm, Jersey, British Isles, Bennison *et al.*,(1996) showed that *Trialeurodes vaporariorum* Westw. (Homoptera: Aloyrodidae) and *Thrips tabaci* were well controlled by *Encarsia formosa* Gahan (parasitoid) and *Amblyseius accumeris* Oudm., respectively. Also the use of *Therodiplosis sp* and *Phidoletes sp* as bioagents with one a spot treatment using fenbutin oxide effectively controlled *Tetranychus urticea* Koch.

Aphis sp were controlled by a combination of the parasite *Aphelinus abdominalis* Dalm., (Hymenoptera: Aphilinidae), *Aphidius colemani* Viereck and *Aphedoletes aphidimyza* Rond. (parasites) with only one spot treatment of nicotine to reduce damage by *Aulacorthum solani* Kalt (Homoptera : Aphididae).

Chemical control of thrips has also been investigated and out of 11 insecticides tested, high level of tolerance was observed (Cermeli *et al.*, 1993). It was, however found that Flufenoxuron, Imidacloprid Chlorfluazuron and Oxamyl were most promising insecticides, in order of effectiveness, when applied at five days interval. However, no insecticide was more than 80.5 % effective. Etienne *et al.*, (1990) showed that rainfall depresses the population of the pest and that increased use of insecticides increases the pest population. This is because the activities of predator are reduced in treated areas.

Kawai and Kitamura (1990) also stated that physical prevention of invasion, reduction of population density on seedlings and mass trapping using sticky traps were effective methods of controlling *Thrips palmi* attacking the eggplant in greenhouses.

Nagai *et al.*, (1988) demonstrated that Flufenoxuron inhibited the ecdysis of first instar nymphs and metamorphosis of second instar nymphs to pupae of *Thrips palmi* but did not affect the rate of development and fecundity of females. It has also been shown that carbaryl, quinalphos, endosulphan, cypermethrin, deltamethrin and fenvalerate are effective against the larvae and adults of *Epilachna vigintioctopunctata* Fab. while dimethoate and fenpropathrin were effective against the adult only (Nagai *et al.*, 1992).

Bacillus thuringiensis subspecies tenebrionis have been shown to markedly affect percentage egg hatchability and dispersal of larvae of the Colorado potato weevil, *Leptinotarsa decemlineata* Say (Coleoptera: Chrysomelidae) (Ghidiu *et al.*, 1994). An application of 7.02 l/ha in the field, for example, produced only 5 % dispersal of the larvae from the treated eggs. It has also been shown that the hymenopteran, *Edovum putteri* Grissell produced 67 % egg parasitism of the potato beetle (Schroder and Athanas, 1995).

The shoot and fruit borer, *Leucinodes orbonalis* has also been effectively controlled by the use of Carbofuran 3G at 30 kg/ha applied every 20 days after transplanting or Cypermethrin 10 EC at 1 ml/l water applied at first signs of infestation, followed by three subsequent sprayings at 30 day interval (Chowdhury *et al.*, 1993). The insect is also susceptible to Endosulfan (Verma *et al.*, 1993).

Extracts from seeds of *Thevetia nerifolia* L. roots of *Nerium oleander* L.and leaves of *Lantana camara* L. and *Ocimum sanctum* Wiild.at 1.0 % treatment of aubergine leaves caused 90 % mortality to the larvae of *Epilachna vigintioctopunctata* exposed to the treated leaves (Satpathi and Ghatak 1990). Petroleum extracts from the leaves of *Bougainvillea spectabilis* Willd. produced 100 % mortality in *Henosepilachna vigintioctopunctata* when exposed to aubergine leaves treated with 0.2 % and 0.5 % of the extracts. The same mortality was recorded for extracts of *Azadirachta indica* applied at 0.5% (Rao *et al.*, 1992).

2.7 Neem (*Azadirachta indica* A. Juss)

2.7.1 Botany

Neem, *Azadirachta indica* A. Juss (Miliaceae) is native to India and Burma which contains an estimated 18 million tress with most of them lining along the roadsides. It is a fast growing plant that usually reaches a height of 15-20 m and under favourable conditions; it can grow as high as 35-40 m tall. It is seldom leafless but under extreme circumstances such as an extended dry period, it may shed most or nearly all its leaves. The branches spread widely. The fairly dense crown is roundish or oval and may reach a diameter of 15-20 m in old, freestanding trees, (Schmutterer, 1995). The trunk is relatively short, straight with a girth of 1.5-3.5 m. The bark is hard, fissured or scaly and whitish-grey to reddish-brown. The root system consists of a strong taproot and well-developed lateral roots.

The unpaired pinnate leaves are 20-40 cm long and medium to dark green leaflets, which number up to 31, are approximately 3-8 cm long. Very young leaves are reddish to purplish in colour. The white fragrant flowers are arranged in axillary, more-less drooping panicles, which are up to 2 cm long. The inflorescences, which branch up to third degree, bear approximately 150 and occasionally up to 250 flowers (Gruber, 1991). The glabrous fruits are green when young and yellowish-green to yellow when matured. The exocarp of the fruit is thin and the mesocarp is yellowish white and very fibrous. The endocarp contains, in most cases only one seed surrounded by a brown testa (Schmutterer, 1995).

2.7.2 Ecology.

The tree is famous for its drought resistance. It thrives well in areas with annual rainfall between 400-1200 mm though it can also grow well in areas with annual rainfall below 400 mm. Neem does well in different types of soil, but it seems to develop best on welldrained, deep sandy soils. A soil pH between 6.2 and 7.0 seems to be best for the tree. Neem, as a typical tropical plant does best with temperatures ranging from 21-32 °C although it can tolerate high to very high temperatures. Temperatures below 4 °C and frost are unfavourable and may result in the shedding of leaves or even death of young plants (Schmutterer, 1995).

Exracts of neem fruits, seeds, seed kernels, twigs, stem bark, root bark have been shown to possess antifeedant, insecticidal, insect growth disrupting, nematicidal, fungicidal (Jacobson, 1989; Rand-Hawa and Parma, 1993; Schmutterer and Ascher 1984, Schummutterer, 1990) anti-inflammatory (Dhawan and Patnaik, 1993) and anti- tumor (Fujiwara *et al.*, 1982; 1984) and other activities. More than one hundred compounds have been isolated from various part of the tree and several reviews on constituents of neem (Champagne *et al.*, 1992; Koul *et al.*, 1990; Taylor, 1984) have been published to date.

2.7.3 Active ingredient.

Most of the active ingredients belong to the group of tetranorterpenoids, but biologically active diterpenoids, triterpenoids, pentaterpenoids and a smaller number of nonterpenoidal ingredients have also been isolated. The major biologically active component is azadirachtin whose highly complicated structure was first reported by Zanno (1974) and Nakanishi (1975). Neem compounds are systemic in some plants. Potato, for instance, does not take up azadirachtin whereas beans do (Schmutterer, 1990).

Azadirachtin has attracted considerable interest during the past two decades because of its dual forms of activity: as an insect growth inhibitor at lower concentration, and an insect antifeedant at high concentrations if applied by feeding or topically (Champagne *et al.*,. 1992; Jacobson, 1989; Rembold, 1989). Since its correct structure was established (Kraus *et al.*, 1985) a number of azadiractin derivatives and analogs with modified ester groups attached to carbon-1 and carbon-3 have been isolated from neem (Rembold *et al.*, 1987).

The content of azadirachtin has been shown to vary greatly among different ecological zones and countries (Ermel *et al.*, 1987). However, the factors that influence the quantity of the active ingredient concentration are not clearly understood. Nevertheless, edaphic, climatic, as well as pre and post harvest conditions could be contributory factors.

2.7.4 Neem as a pesticide.

Both purified and crude extracts of neem seed kernel have been used widely against insect pests both in the field and in storage. Topical application of neem oil on the nymph of grassshopper and *Schistocerca gregaria* Forsk. (Othoptera: Acrididae) showed a gradual destruction of the antenna (Nicol and Schmutterer, 1991). Heyde *et al.*, (1984) found in assays using three species of plant and leafhoppers on rice, that, settling by the brown plant hopper, *Nilaparvata lugens* Stal and the white back plant hopper, *Sogetella furcifera* Horv, (Homoptera: Cicadillidae) was progressively reduced by increasing concentrations of neem oil (1–50 %). Adults of the green leafhopper, *Nephottetix virescence* Dist. (Homoptera: Cicadellidae) were not or only slightly repelled even by application of 50% neem oil.

Oviposition is also reduced by the application of 4–5% neem seed kernel extract. Saxena and Basit (1982) showed that the egg laying of *Amrasca devastans* on cotton treated with neem oil was significantly reduced. Saxena *et al.*, (1981) demonstrated; in the laboratory that the rice leafhopper *Cnaphalocrocis medinalis* Gn. (Homoptera: Pyralidae) laid only one third the number of eggs on neem oil treated rice plants as on control plants. A strong antiovipositional effect of neem oil on bruchids has also been recorded. Yadav (1985) showed that when green gram seeds were treated with neem oil (2-50 mg per 100 g) *Callosobruchus maculatus* never oviposited on seeds treated with 50 mg oil per 100 g while *C. chinensis* L. and *C. analis* L. did not oviposit from 40 mg oil per 100 g upwards. In Taiwan, for some unknown reason, Klemm and Schmutterer (1993) cited by Schmutterer (1995) showed that *Plutella xylostella* L. (Lepidoptera: Yponomeutidae) preferred neem treated cabbage to the untreated as very high number of eggs were laid on the treated as against the untreated.

The brown planthopper, *N. Lugens* failed to produce the normal courtship signals after topical application of 2.5 or 5 μg neem oil per insect. This observation was also made when the insects were exposed to caged rice plant sprayed with 3 % neem oil (Saxena *et al.*, 1993).

Experiments in India have proved the repellent effect of aqueous neem seed extract (10 g/l) against *Empoasca lybica, Aphis gossypii* and *Epilachna* beetles on brinjal. Asari and Nair (1972) reported that neem performed better in post treatment counts showing immediate repellency. Damage by the flea beetle, *Epitrix fuscula* Croch and the corolado potato beetle *Leptinotarsa decemlineata*, was significantly reduced by weekly application of an ethanol extract of neem seeds, whereas the neem dust formulation was not effective in the field trial (Reed and Reed 1985).

It has also been shown that application of 5, 10 and 20 % neem oil to eggplants at the pre-flowering, fruiting and post fruiting stages effectively controlled *S. docilis* with the 10% formulation causing immediate mortality. The lace bug, *Urentius sp* and the grasshopper, *Zonocerus variegatus* were strongly repelled from treated plants. However, a concentration of 10 % and 20 % in the pre flowering application resulted in phytotoxicity effects (Cobbinah and Osei–Owusu, 1988).

When exposed to sunlight neem products degrade and lose their activity. Typically, the crude extract remains active for only eight days when exposed to the sun's ultra violet rays. The fact that neem products are natural does not mean they are environmentally benign. In a trial, both tadpoles and mosquito eating fish, gumbusia died when neem extracts were applied to the water in which they were (Jotwani and Srivastava, 1981). Also certain neem compounds can damage plants in green house and in the field. Cabbage treated with neem produced medium sized heads, whereas in tomato growth and yield were reduced (Jacobson, 1989).

In Ghana neem is traditionally used for the treatment of malaria (Abbiw, 1990). Research work done in different parts of Ghana showed that neem products are effective against a wide range of both field and storage pests of vegetables, legumes, cereals and plantation crops. The target species include the diamondback moth, fruit flies, mealy bugs, aphids, pod borers flower borers, and bud borers (Forjoe, 1995; Kottoh, 1997; Adzaho, 1997; Afreh-Nuamah *et al.*, 1998).). It has also been shown that an application of 50–75 g/l provided a good protection for garden egg pests and increasing dry matter content significantly (Owusu-Ansah *et al.*, 1998).

Aqueous extracts of neem seeds and leaf extracts has been reported to reduce the incidence of *Megalurothrips sp* infesting cowpeas and increase yields significantly in Northern Ghana (Tanzubil, 1991). Cobbinah and Osei-Owusu (1988) have demonstrated that various concentrations of neem emulsion reduced the incidence of the noctuid *Selepa docilis*, the tangid *Urentius sp*. and the acridid, *Zonocerus variegatus* on aubergine.

Neem products have also played a significant role in grain storage. It has been shown to provide an effective protection against grain weevils, grain beetles, grain borers, cowpea beetles and several species of storage moths (Cobbina and Appiah–Kwarteng, 1989; Owusu Akyaw, 1991; Baba Niber, 1994; Allotey and Dankwah, 1994; Obeng–Ofori, 1997). Maize kernels treated with neem oil or ash were reported to have been damaged less by *Sitophilus zeamais* than untreated kernels while derivatives of neem inhibited oviposition and/or deterred feeding (Cobbinah and Appiah-Kwarteng, 1989). Tanzubil *et al.*, (1987) showed that neem fruit dust at 10% by weight of seed protected stored cowpea for at least 4 months against *Callosobruchus maculatus* while the leaf dust (10%) seed weight were effective for 3 months. Forjoe, (1995) and Kottoh, (1997) also showed that some natural products such as garlic, (*Allium sativum* L.) and hot pepper (*Capsicum frutenscens* L.) provided a synergistic effect on neem products.

2.8 Physic nut (*Jatropha curcas* L.)

2.8.1 Botany and ecology.

The coral plant, *Jatropha curcas* (Euphorbiaceae) is a tropical crop and native to America and Central America but is widely cultivated in many Latin American, Asian and African countries as a hedge (Irvine, 1961). It has become of interest to various development agencies because it adapts well to semi-arid and marginal areas (Heller, 1996). The plant is a shrub or tree up to about 6 m high. It is easily propagated by seed and stem cuttings and can be trimmed to any height. It is often planted over graves and sometimes to mark the limits of fields (Visser, 1975). The stem is thick, grey, glabrous and often twisted. It is almost leafless in the dry season. The leaves are about 8 cm in diameter and generally 3–5 digitately lobed to beyond the middle. It has glandular fruits containing three seeds, which are rich in oil (Heller, 1996).

The plant has several English names such as physic nut, pignut, purging nut, Barbados nut etc. The plant is widely distributed in Ghana. In Ashanti it is called ‘Kaagya’, in Fante, ‘Aburokyiraba’ or ‘Akandedua’; in Ga, ‘Kpitikpitso’; in Ada, ‘Kitigbletso’ in Ewe, ‘Babatsi’, ‘Gbomagbotsi or 'Kporti.’ (Irvine, 1961). The plant is normally planted as a hedge to protect crops. It is usually used in the villages for fencing and the seeds are easily reached by hand (Irvine, 1961).

2.8.2 Medicinal and pesticidal properties.

The plant has a lot of medicinal properties. The juice of the leaves is used in Ghana for the treatment of sores in babies' tongues; the yellowish-brown substance in the pith of old stems is used for headaches, which induces the patient to sneeze (Irvine, 1961). It has been shown to be a very effective pesticide. Its leaves and fruits are poisonous to livestock. The plant is listed as a fish poison. The bark contains 37% tannin and the seed contains a taxalbumen whose chief poison is curcin, a phytotoxin, which remains in the cake rendering it unsuitable as cattle feed. (Watt and Breyer-Brandwijk, 1962). The oil content of the seed ranges between 50-58 % and semi-drying and is formed from esters of palmitic and stearic acid (10-17%), Oleic acid (45-62%), linoleic acid (18-45%). The minimum fatal dose of the seed is unknown but a purgative doze of 3-4 seeds has been reported (Bouquet, 1969; Dazeil, 1937; Watt and Breyer-Brandwijk, 1962).

Not much has been done in respect of its insecticidal properties. In Philippines, researchers at the Cotton Research and Development Institute used *J. curcas* seed oil to control bollworms. They also found that it successfully controls other pests such as weevils in stored grains. The seed powder is effective against snails that infest rice paddies (Solsoloy, 1995).

Two new tinglain-type diterpene esters were isolated from the oil and phorbol ester extracted exhibited insecticidal activity against the larvae of *Manduca sexta* L. (Lepidoptera: Sphingidae) (Sauerwein, 1993). The leaves are burnt in houses as fumigant against bed bugs while powdered leaves have been used as repellent against house flies (Watt and Breyer-Brandwijk, 1962).

In an experiment to determine the effect of *Jatropha curcas* oil on *Sitophilus* zeamais Motsch and *Callosobruchus maculatus* on stored maize and cowpea, respectively, Cobbinah and Appiah-Kwarteng (1991) showed that the oil of jatropha conferred similar level of protection to maize as neem, producing 36.5 % mortality in *S. zeamais* and mean percent grain damage of 2.17 as against 2.19 % by neem oil. He also showed that less than 1.0 % damage occurred in jatropha and neem treated beans; therefore, *C. maculatus* was highly susceptible to the oils.

Application of 5 % jatropha emulsion significantly reduced feeding activity by *Z. variegatus* by as much as 40 % within 24 hours after application. Treated insects were less mobile and were therefore more susceptible to predation (Cobbinah and Tuani, 1992).

3.0 MATERIALS AND METHODS.

3.1 Laboratory studies.

Prior to the commencement of the laboratory work, visits were made to eggplant-growing areas in parts of Central Accra, to ascertain which insect pests were the most serious ones. Preliminary results showed that from the visits the eggplant skeletonizer, *Selepa docilis*, the fruit borer, *Leucinodes orbonalis, Aphis gossypii*; the lace bug, *Urentius hystericellus* among others caused serious damage to the eggplant (In line with reports in literature). Depending on their availability, the lace bug, the aphid and the eggplant skeletonizer, were used in the laboratory studies.

Insects considered killed were the total number of insects apparently dead, moribund or so badly affected as to be unable to move a few steps when prodded. Normal or slightly affected insects were considered to have survived (Tattersfield *et al.*, 1925).

3.1.1 Extraction of jatropha seed oil.

The seeds of *J. curcas* were harvested from trees around Achimota in the Greater Accra Region of Ghana in August 1999. They were sun-dried for 7 days after which they were shelled and batches were ground for 1 minute each into a fine powder, using IKA Universalmuhle M20 hand milling machine. Five hundred and fifty grammes of the powder and 2.5 litres of petroleum ether (40–60°C) were used in the extraction of the oil by Soxhlets apparatus for 48 h. This yielded about 260 ml of clean yellow oil. The ether was recovered through a rotary evaporator.

3.1.2 Preparation of aqueous seed extract of jatropha.

Matured seeds were collected from jatropha trees around Achimota in the Greater Accra region of Ghana. They were sun-dried for 7 days aftter which they were shelled. The kernels were then pulverized into a fine powder using IKA Universalmuhle M20 hand milling machine. Five levels of the aqueous seed extract were prepared by weighing 2, 4, 6, 8, 10 grammes of the powder into conical flasks containing 100 ml each of water. These were shaken for two hours and left to stand for 48 h. They were then sieved and the resultant liquid used against the test insects.

3.1.3 Toxicity of jatropha aqueous seed extracts and oil to *Aphis gossypii*

Aphis gossypii were collected from an eggplant field, which had not been chemically sprayed for several months. The insects were starved for 2 hr and used for the study. Ten nymphs of aphids each were placed into six petri dishes (9 cm in diameter) containing one young leaf each of aubergine taken from the apical shoot region which had previously been dipped into each of the various solutions (0, 2, 4, 6, 8,and 10 g/100 ml of water) for three seconds. Each treatment was replicated three times in a Completely Randomized Design (CRD) with a water treated control. Mortality was recorded after 24h.

In a similar experiment, five levels of the seed oil of jatropha (0.1, 0.2, 0.3, 0.4, and 0.5 %) were prepared and 1 ml of 1 % soap solution (Teepol 610 S) was added as an emulsifier. Aphids were collected from the eggplant field as stated above (3.1.3) and were starved for 2 h. Ten nymphs each were placed into six petri dishes (9 cm in diameter) containing one young leaf each of aubergine taken from the apical shoot region, which had previously been dipped into the various solutions for 3 sec. There were three replications for each treatment arranged in a CRD. Mortality was recorded after 24 h.

3.1.4 Toxicity of jatropha aqueous seed extract and oil to larva of *Selepa docilis*.

An aqueous extract of the seed was prepared as described in 3.1.2. Third instar larvae of *S. docilis* were collected from an eggplant field, which has not received chemical treatment for months and starved for two hours. Due to limited number of test insects, seven insects were placed in separate petri dishes (9 cm in diameter) containing a leaf each of eggplant that has previously been dipped into each of the various treatments for three seconds. Each treatment was replicated three times in a CRD. Mortality and percent leaf area damaged were recorded after 24 h. Survivors were also observed after this period to determine the effect of the extracts on the development of the larvae.

Eight levels of the seed oil of jatropha (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, and 0.8, %) were also prepared and 1ml of 1 % soap (Teepol 610 S) solution was added to each treatment as emulsifier. The experiment was set up as described in 3.1.4 above. Five insects per treatment were used mortality was recorded after 24h. The leaf area fed on by the surviving insects was also recorded during the period.

3.1.5 Effect of jatropha seed oil on the brinjal lace bug, *Urentius hystericellus.*

Six levels of the seed oil of jatropha (0.1, 0.2, 0.3, 0.4, 0.5, and 0.6%) were prepared as described in 3.1.4 Young leaves of eggplant were dipped into the various treatments for three seconds and placed individually into petri dishes (9 cm in diameter). There were three replications for each treatment. Newly developed adult lace bugs were collected from an eggplant field and starved for two hours. Eight bugs each were introduced into the petri dishes (9 cm in diameter) and each treatment was replicated three times. Mortality was recorded after 24 h.

3.1.6 Choice Bioassay

Eggplant leaves (2 cm diameter) were dipped into an aqueous seed extract of jatropha (40 g/l) for three seconds. Each leaf was placed in a petri dish (9 cm in diameter) directly opposite a leaf previously dipped into water (control). This was replicated three times. There were two set-ups for two test insects; *Urentius hystericellus* and *Selepa docilis*. Ten adults of *U. hystericellus* and third instar *S. docilis* larvae were placed separately in the middle of each petri dish and their movement and settling was observed 15 minutes after their release. The numbers that settled on the treated and the untreated substrates as well as the percent leaf area damaged by *S. docilis* was recorded after 24 h. Mortality of test insects was also recorded over the period.

The above experiment was repeated for *U. hystericellus* using a filter paper. The paper was folded to give four equal sectors. Two opposite sides were impregnated with water whereas the other sides were treated with the aqueous seed extract. Ten adults of the test insects were released in the middle and the number that settled at each compartment after 24 h was recorded.

A similar experiment was carried out using the two test insects and 0.4 % seed oil. The leaf dip method was used and ten insects were used in each case. There were three replicates and the number of insects that settled on the treated and untreated leaves, as well as the damage caused to the leaves was recorded after 24 h.

3.1.7 Effect of jatropha seed and neem products on *S. docilis* eggs.

Neem aqueous seed extract was prepared after sun-drying the seeds for 7 days followed by shelling. The seeds were ground into a fine powder by the method described in 3.1.2. Seventy five grammes of the powder was added to 1 litre of water and left to stand for 24 h. Jatropha aqueous seed extract was also prepared by weighing 40 g of the powder into 1 litre of water and left to stand for 48 h. These were sieved and the resultant solutions used for the experiment.

Four leaves containing batches of *S. docilis* eggs were collected from the field and dipped into the seed extracts of jatropha and neem and placed separately in petri dishes (9 cm in diameter). The number of eggs that hatched and the survival of the neonate larvae on the treated food sources were recorded.

3.1.8 Effect of jatropha extract on the behaviour of *Aphis gosssypii*

Two eggplant leaf discs (2 cm in diameter) were treated with 40 g/l jatropha aqueous seed extract. Two others were dipped into water and placed alternately with jatropha-treated discs in a petri dish (9 cm in diameter). An adult aphid was released in the middle of the dish and its orientation to the leaves was monitored until it finally settled. The procedure was repeated four times.

3.2. Field studies.

3.2.1. Experimental site

The work was carried out at the University of Ghana Farm, Legon between September 1998 and January 1999. The seeds of Black beauty, a cultivar of eggplant obtained from the Department of Crop Science, University of Ghana, were nursed and transplanted five weeks later in a Randomized Complete Block Design (RCBD). Five treatments, namely, Jatropha aqueous seed extract (JSKE), Jatropha seed oil (JSO), Neem aqueous seed extract (NSKE), Cymethoate 25EC (CY) and Control (NS) were used.

There were four blocks (replicates) with each block containing each of the five treatments. The size of each plot in a block was 3 x 5 m and separated from each other by 1.5 m path. Each plot had three rows containing five plants spaced at 1 x 1 m. This gave a plant population of 10,000 per hectare. Routine cultural practices such as weeding, fertilizer application and irrigation were carried out when necessary.

Based on the results of laboratory experiments, 40 g/l and 4 ml/l of the aqueous extract and the seed oil of jatropha, respectively, were used. For neem and cymethoate, the recommended rates of 75 g/l (Owusu–Ansah *et al.*, 1998) and 2 ml/l, respectively, were applied using a CP 15 knapsack sprayer. Weekly application of these treatments began four weeks after transplanting, during which a spray liquid of 1 litre per plot was used for the next four weeks thereafter, 1.5 litres per plot was used to correspond with higher vegetative growth. All treatments were applied in the mornings.

3.2.2 Data Collection

The following data were collected.

-The number of days to first flowering,

-The number of days to first fruit maturity,

-The number of fruits per plant,

-Plant height at flowering,

-Fruit weight,

-The number of bored fruits,

-Insects associated with the treatments,

-% Leaf area damaged by leaf feeding insects,

-Fruit yield,

-Beneficial arthropods.

Sampling for insects started at the nursery. In the field, this was done a day before spraying, one day after spraying and 3 days thereafter between the hours of 0530 and

0730 GMT. Three plants were selected for each treatment, three leaves per plant were randomly examined, and all insects found were recorded. The immature stages were cultured in the Entomology laboratory of Crop Science Department until adult emergence. Harvested fruits were cut open to assess fruit borer attack. Fruit yield was calculated based on mean yield per plant, spacing and plot size.

3.2.3 Data analysis

All count data on the major insect pests and yield indices were transformed using the square root transformation, (($\sqrt{x}$) or ($\sqrt{x + 0.5}$)) where there were zeros, before analysis. statistically. Where significant differences were observed, means were separated using the Least Significant Difference (LSD). Correlation analysis was also carried out between yield of marketable fruits and number of fruits per plant. Probit analysis was used to determine the LD_{50} and LD_{90} of the plant products for the tests insects used in the laboratory bioassay.

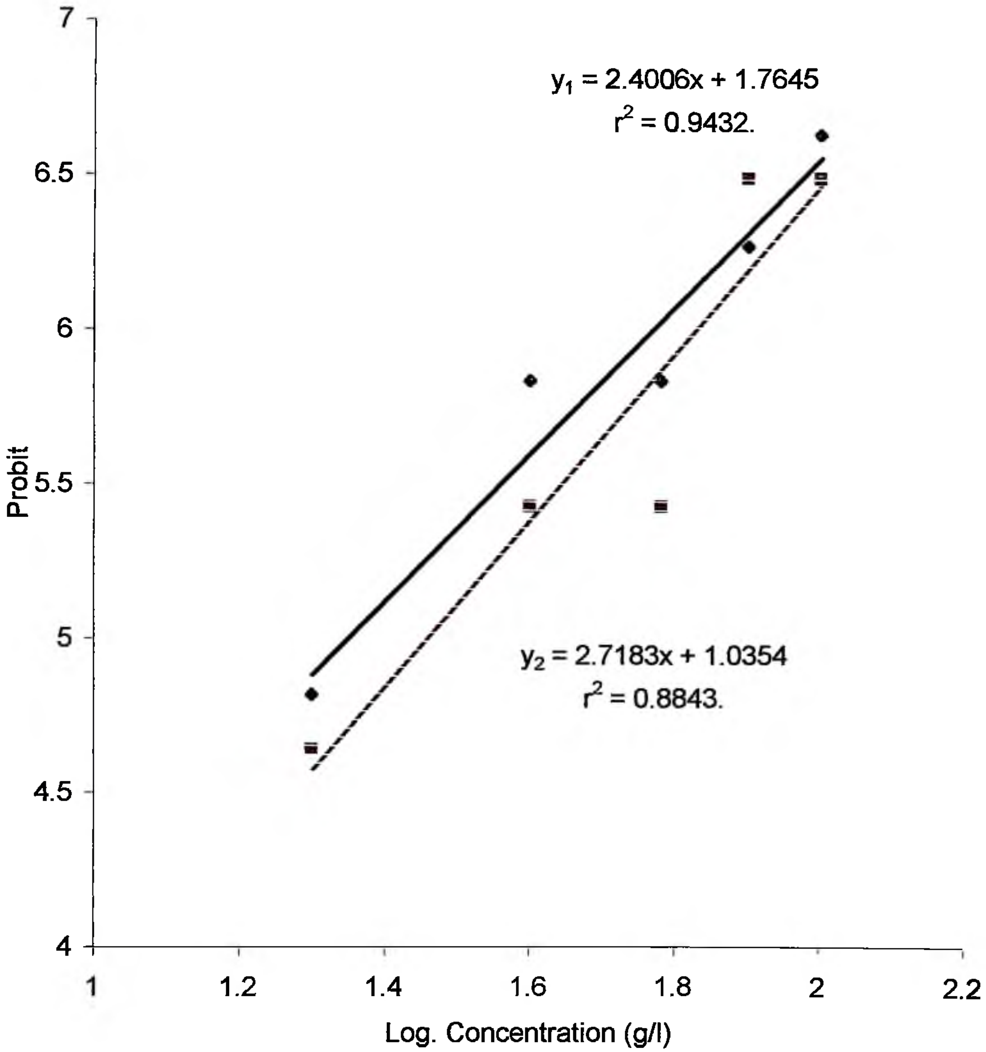

Fig. 1 Response of *S. docilis* (y_1) and *A. gossypii* (y_2) to varying levels of jatropha (aq) seed extract

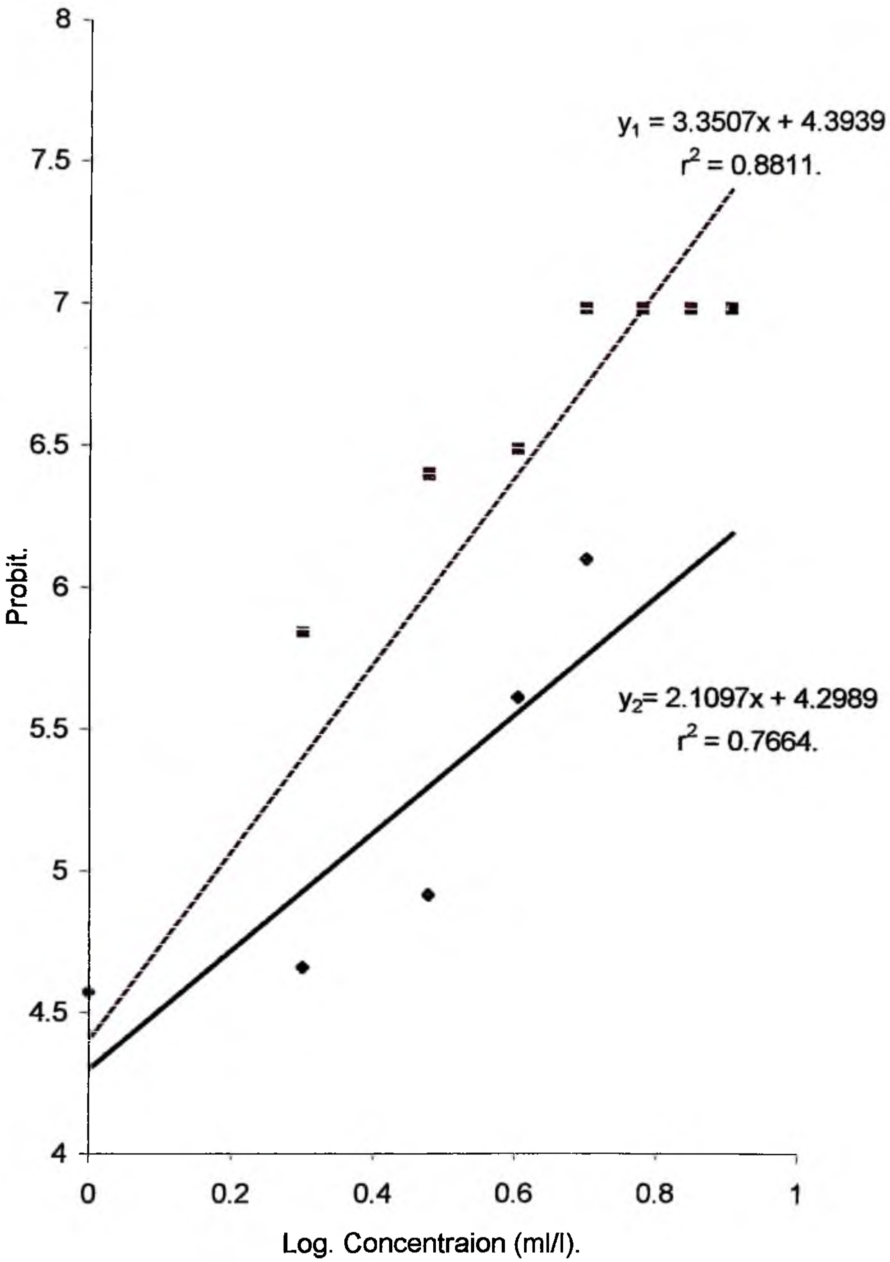

Fig. 2 Responses of *S. docilis* (y_1) and *A. gossypii* (y_2) to varying levels of jatropha seed oil.

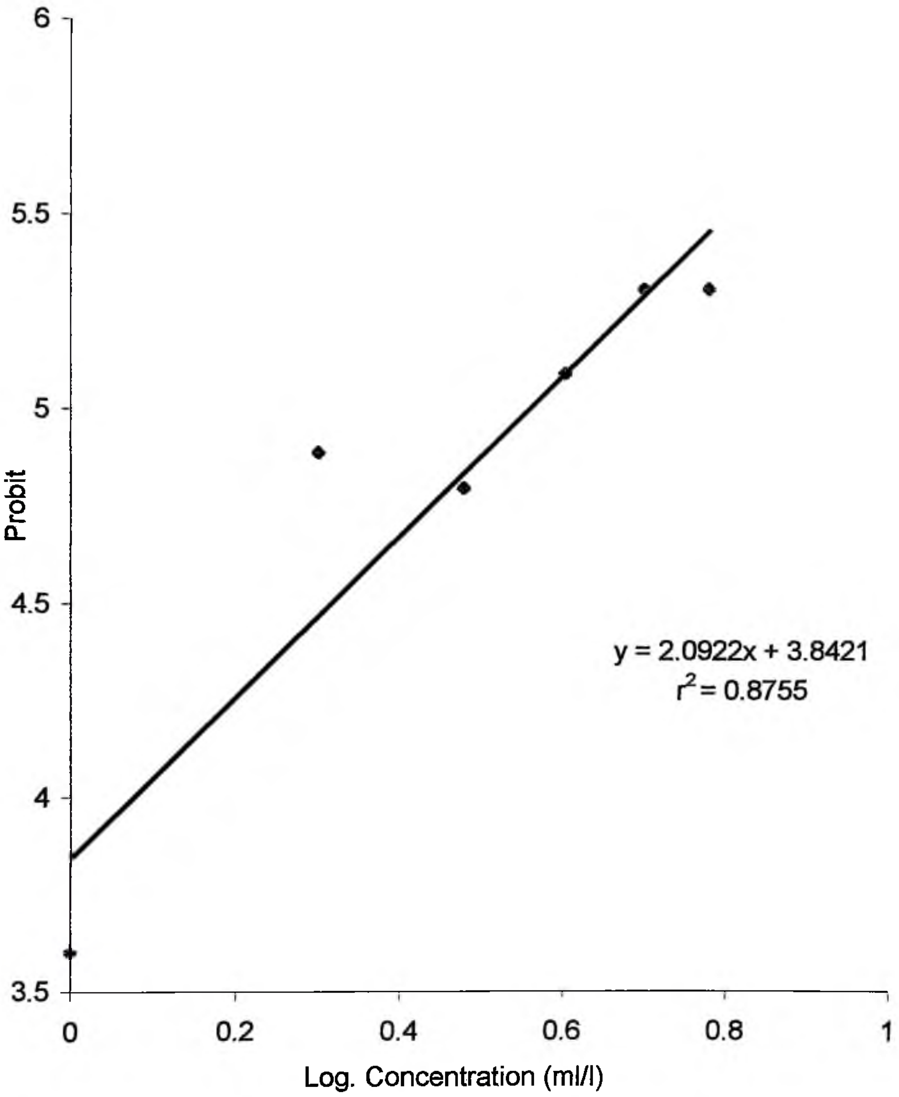

Fig.3 Respose of *U. hystericellus* to varying levels of jatropha seed oil.

Plate 1 shows percent leaf area consumed by the surviving larvae of *Selepa docilis* following treatment of the leaves with varying levels of the seed extract. The larvae consumed more than 90% of the leaf area within 24 hours in the control and just less than 1 % leaf area consumption in the 20 g/l seed extract treatment. Those in the other treatments did not feed at all. They were either dead or moribund within the period.

Plate 1. Feeding patterns of larvae *S. docilis* on aubergine leaves treated with seed extracts of jatropha after 24 h. Corresponding % leaf area consumed is as follows: 0 = 90-95, 20 = 0.5-1.0, 40, 60, 80, 100 = 0.

In the oil treatment, about 60% leaf area was consumed in the control within 24 hours and 100 % within 48 hours compared to between 10–20 % leaf area consumption at a concentration of 0.1%.oil within 24 h. There was no feeding at the concentrations of 2–8 ml/l within the period (Table 2). Some of these insects died after 24 hours of exposure but those alive after the period became moribund and died 48 h later.

Table 2. Feeding effect of jatropha seed oil on larvae of *S. docilis*

Treatment (m/l)	% leaf area damage
0	60-65
1	10-20
2	Nil
3	Nil
4	Nil
5	Nil
6	Nil
7	Nil
8	Nil

4.1.3 Effect of jatropha seed oil on the lace bug, *U. hystericellus*.

The effect of the oil on the insect is shown in Appendix 12. When the concentration was increased from 1 to 2 ml/l, mortality increased from 8.4 to approximately 42 % but as the concentration was increased from 5 to 6 ml/l, mortality remained constant at 62.5 %. Figure 3 shows the response of adult *U. hystericellus* to varying levels of jatropha seed oil. Fifty percent (LD_{50}) and 90 % (LD_{90}) mortalities corresponded to 0.55 and 1.17, respectively.

4.1.4 Choice bioassay

Plates 2, 3, and 4 show the results of the choice bioassay. Ninety percent of *U. hystericellus* settled on the untreated surface whereas 10 % settled on the treated surface, (Plate 2). In the case of *S. docilis*, 60 % settled on the untreated leaf causing about 30 % leaf area damage compared to 40 % settling on the treated leaf. About 50 % of the insects, which settled on treated surface died and caused less than 5 % leaf area damage (Plate 3). In the case of the oil, 40 % settled on the untreated and 60 % (all dead) settled on the treated. There was about 20 % leaf area damaged in the control as against no feeding in the treated leaf, (Plate 3). The feeding pattern of the larvae of *S. docilis* on aubergine leaves treated with jatropha seed extract, seed oil and water is shown in Plate 4.

Plate 2. Preference for treated (T) and untreated (UT) portions of filter paper by *U. hystericellus* (black spots). T. = One insect, UT. = Nine insects.

A B

Plate 3. Preference for treated (T) and untreated (UT) leaves; A, (aq); and B, (oil) of jatropha seed by *S. docilis* larvae. (aq), T = 4 and UT = 6 insects. (oil), T = 6 (all dead) and UT = 4 insects.

A B C

Plate 4. Comparison of the feeding patterns by the larvae of *S. docilis* on aubergine leaves treated with A, aqueous seed extract; B, water; and C, seed oil. after 24 h.

A B

Plate 3. Preference for treated (T) and untreated (UT) leaves; A, (aq); and B, (oil) of jatropha seed by *S. docilis* larvae. (aq), T = 4 and UT = 6 insects. (oil), T = 6 (all dead) and UT = 4 insects.

A B C

Plate 4. Comparison of the feeding patterns by the larvae of *S. docilis* on aubergine leaves treated with A, aqueous seed extract; B, water; and C, seed oil. after 24 h.

4.1.5 Effect of jatropha and neem products on *S. docilis* eggs.

Table 3 shows the effects of the various treatments on the oviposition of *S. docilis*. There was 100 % hatchability in all the treatments except in jatropha seed oil treatment where there was a reduction by 21 %. With the exception of the control in which there was 74 % survival of the neonate larvae, 100 % mortality was recorded in the other treatments after 48 h.

Table 3. Effect of jatropha seed extract, jatropha seed oil, and neem seed extract on *S. docilis* eggs.

Treatment	No. of eggs	No. hatching	No. alive after 24 h	No. alive after 48 h.
Water control	31	31	31	23
Jatropha seed extract (40 g/l)	14	14	14	0
Neem seed extract (75 g/l)	26	26	26	0
Jatropha seed Oil (0.4%)	38	30	30	0

4.1.6. Effect of jatropha extract on the behaviour of *Aphis gossypii*.

Plate 5 shows the orientation of *A. gossypii* to treated (40g/l seed extract of jatropha) and untreated leaf discs. The insect moved from the point of introduction to the untreated leaf disc, then back to the treated. It then turned round and moved to the point of introduction and settled finally on the untreated in 42 minutes.

Plate 5. Orientation of *A. gossypii* to treated (T) and untreated (UT) leaf discs

4.2 Field work.

A list of insects recorded during the sampling period and their relative abundance in the various treatments is given in Tables 4 and 5. These are leaf feeders flower bud and fruit borers, terminal bud and apical shoot feeders. The cotton jassid, *Empoasca lybica*; the eggplant skeletonizer, *Selepa docilis*; the brinjal lace bug, *Urentius hystericellus*; white flies, *Bemisia tabaci*; the fruit borer, *Leucinodes orbonalis*; *Thrips palmi*; and *Tetranychus sp* were recorded in high numbers. They caused varying degree of damage to the plants in the various treatments Plates (6 to 16).

Table 4. A list of insects recorded on eggplant (*Solanum melongena* L.) at the University Farm, Legon.

Scientific name	Order	Family	Part of plant found
Empoasca lybica de Berg.	Homoptera	Cicadellidae	Leaves
Selepa docilis Butler	Lepidoptera	Noctuidae	Leaves
Urentius hystericellus Richter	Heteroptera	Tingidae	Leaves
Bemisia tabaci Genn.	Homoptera	Aleyrodidae	Leaves
Aphis gossypii Glover	Homoptera	Aphididae	Leaves
Prodenia litura Koch	Lepidoptera	Noctuidae	Leaves
Eublema admota Fldr.	Lepidoptera	Noctuidae	Terminal leaf
Scrobipalpa blapsigona Meyrick	Lepidoptera	Gelechidae	Flower buds
Thrips palmi Karny	Thysanoptera	Thripidae	Leaves,flowers
Epilachna elaterii Rossi	Coleoptera	Coccinellidae	Leaves
Zonocerus variegates L.	Orthoptera	Pyrgomorphidae	Leaves
Leucinodes orbonalis Guen	Lepidoptera	Pyralidae	Fruit
Anoplocnemis curvipes Fab.	Heteroptera	Coreidae	Apical shoot
Dysdercus superstitiosus Fab.	Heteroptera	Pyrrhocoridae	Leaves
Coryna sp.	Coleoptera	Meloidae	Leaves
Tetranychus sp.	Acarina	Tetranychidae	Stem, leaves
Unidentified	Diptera		

Table 5. Relative abundance of insects collected from *S. melongena* under the various treatments at the University farm, Legon.

Scientific/Common name	JSKE	JSO	NSKE	CY	NS
Empoasca lybicus	213	355	108	118	602
Selepa docilis	25	117	35	1	174
Urentius hystericellus	2	174	2	26	1429
Bemisia tabaci	79	92	25	636	2351
Spider	4	4	4	3	1
Crematogaster sp	1	1	1	0	2
Aphis gossypii	27	8	3	0	35
Prodenia litura	0	8	0	0	3
Scrobipalpa blapsigona	34	71	59	32	96
Thrips palmi	29	48	51	223	40
Epilachna elaterii	0	0	0	2	2
Zonocerus variegatus	2	6	0	5	1
Anoplocnemis curvipes	12	5	0	0	27
Lagria cuprina	0	1	1	1	0
Eublema admota	0	5	0	0	2
Mantis mantis	2	5	8	2	2
Dysdercus superstitiosus	6	4	7	3	4
Tetranychus sp	240	109	1110	0	1746
Nezera viridula	1	3	4	5	14

Key

JSKE: Jatropha seed kernel extract

JSO: Jatropha seed oil.

NSKE: Neem seed kernel extract.

CY: Cymethoate

NS: No spray

Plate 6. Damage to plant caused by larvae of *S. docilis*

Plate 7. Adult *S. docilis*

Plate 8. Damage by larvae of *E. admota*

Plate 9. Adult *E. admota*

Plate 10. Chlorotic leaf surface caused by *Tetranychus sp.* infestation.

Plate 11. Leaf infestation by *U. hystericellus*.

Plate 12. Adult of fruit and shoot borer, *L. orbonalis*

Plate 13. Larvae of the fruit and shoot borer, *L. orbonalis*

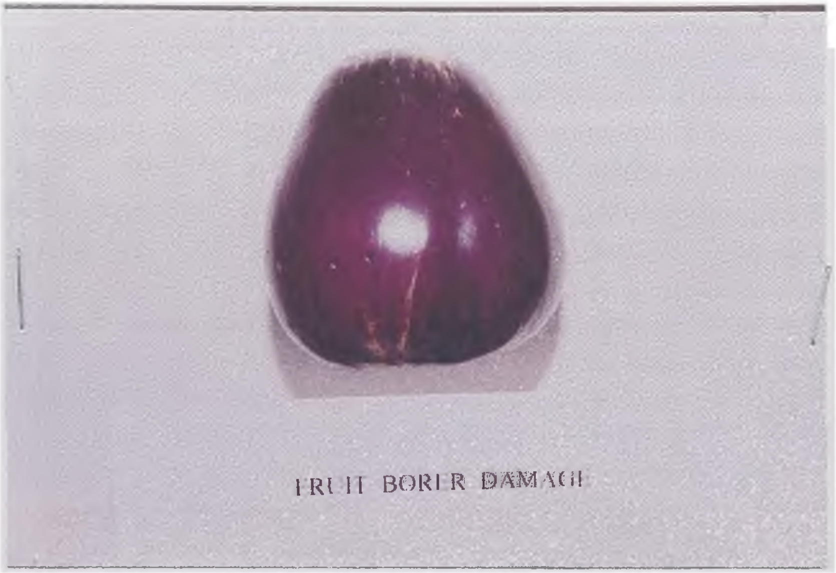

Plate 14. Tunnels created in the fruits by emerging larvae of *L. orbonalis*

Plate 15 Internal damage caused to the fruit by larvae of *L. orbonalis*

Plate 16. Unidentified parasitoid associated with the larvae of *S. docilis* showing the pupal case.

Figures. 4, 5 and 6 represent the population trends of *E. lybica*, *S. docilis* and *U. hystericellus*, respectively. There was generally a gradual build up of the insects' populations four weeks after sowing until a peak was attained around the sixth and the seventh week before declining to zero at the twelfth week. Cymethoate treatment generally performed better than the other treatments as lower number of these insects were collected from that plot. Figure 7 shows significant ($P < 0.01$) correlation between number of fruits and yield in tonnes/h.

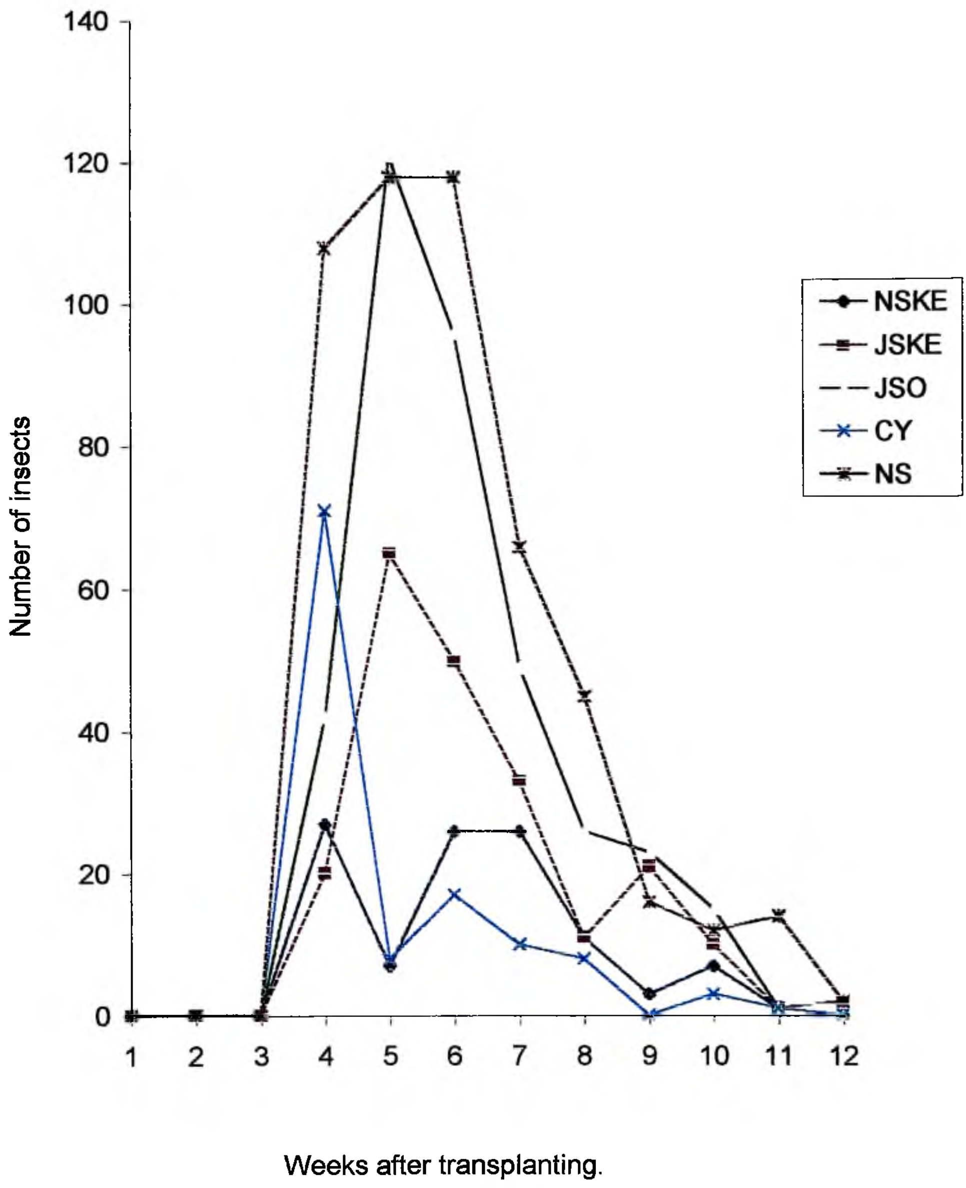

Fig. 4 Population trend of *E. Lybica* on treated eggplant

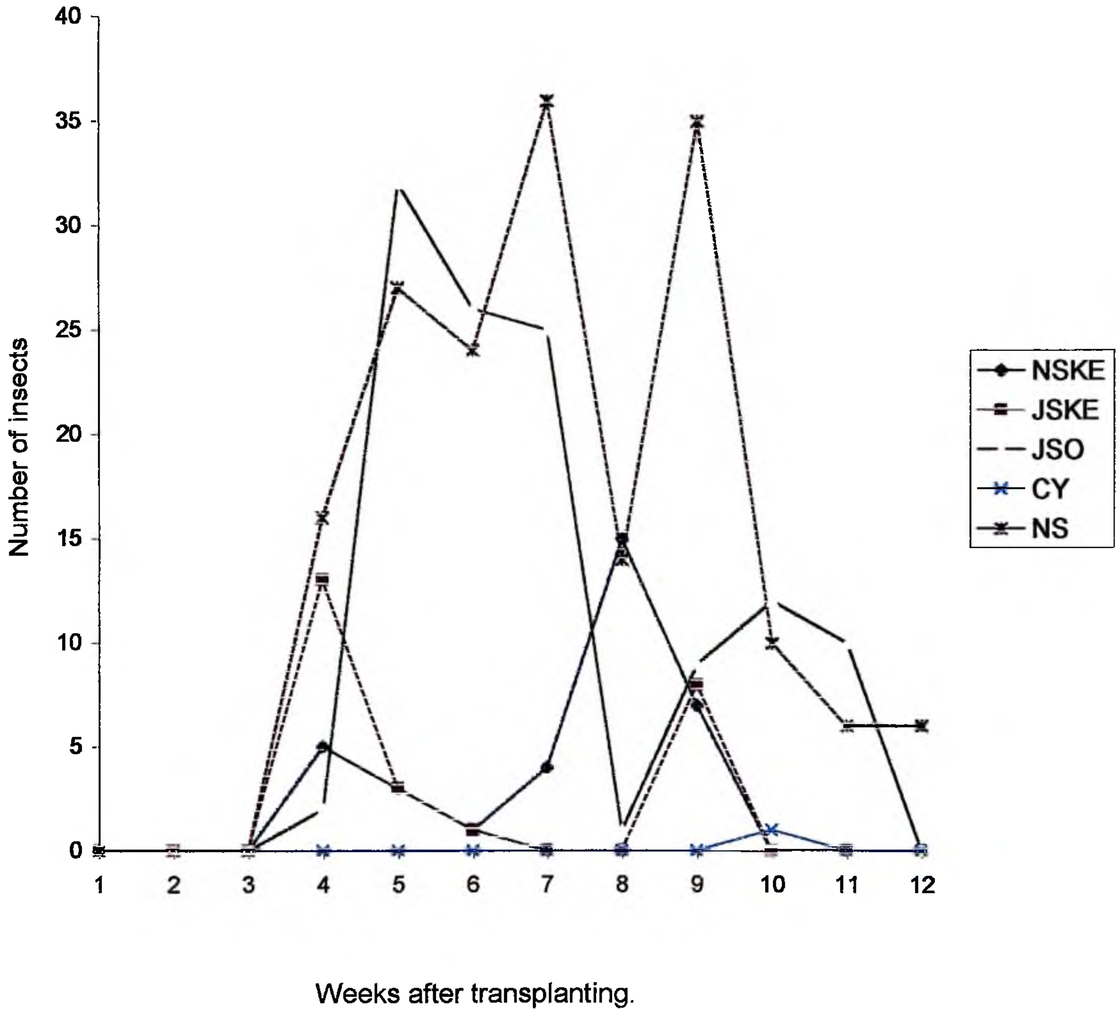

Fig. 5 Population trend of *S. docilis* on treated eggplants

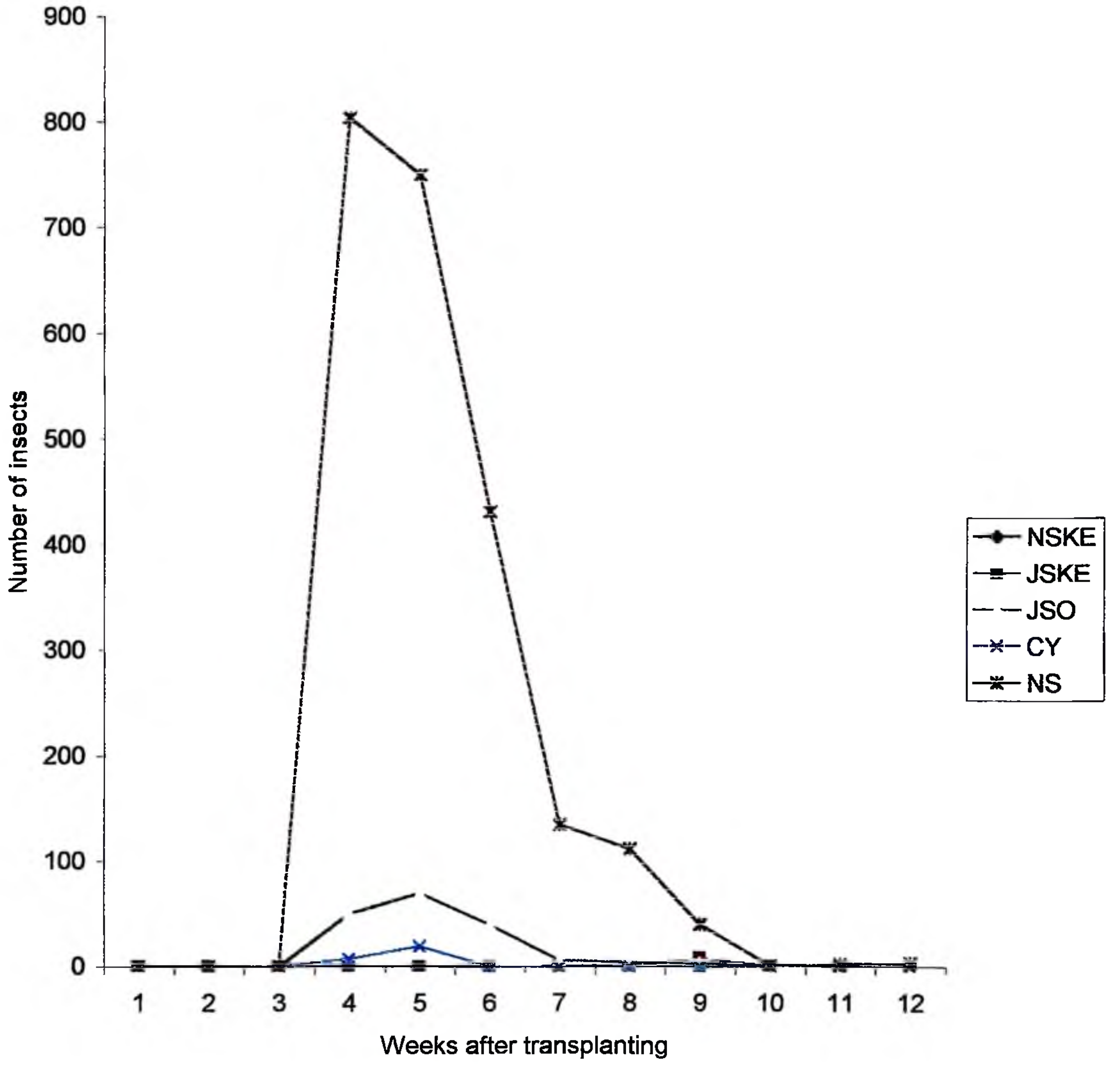

Fig.6 Population trend of *U. hystericellus* on treated eggplant

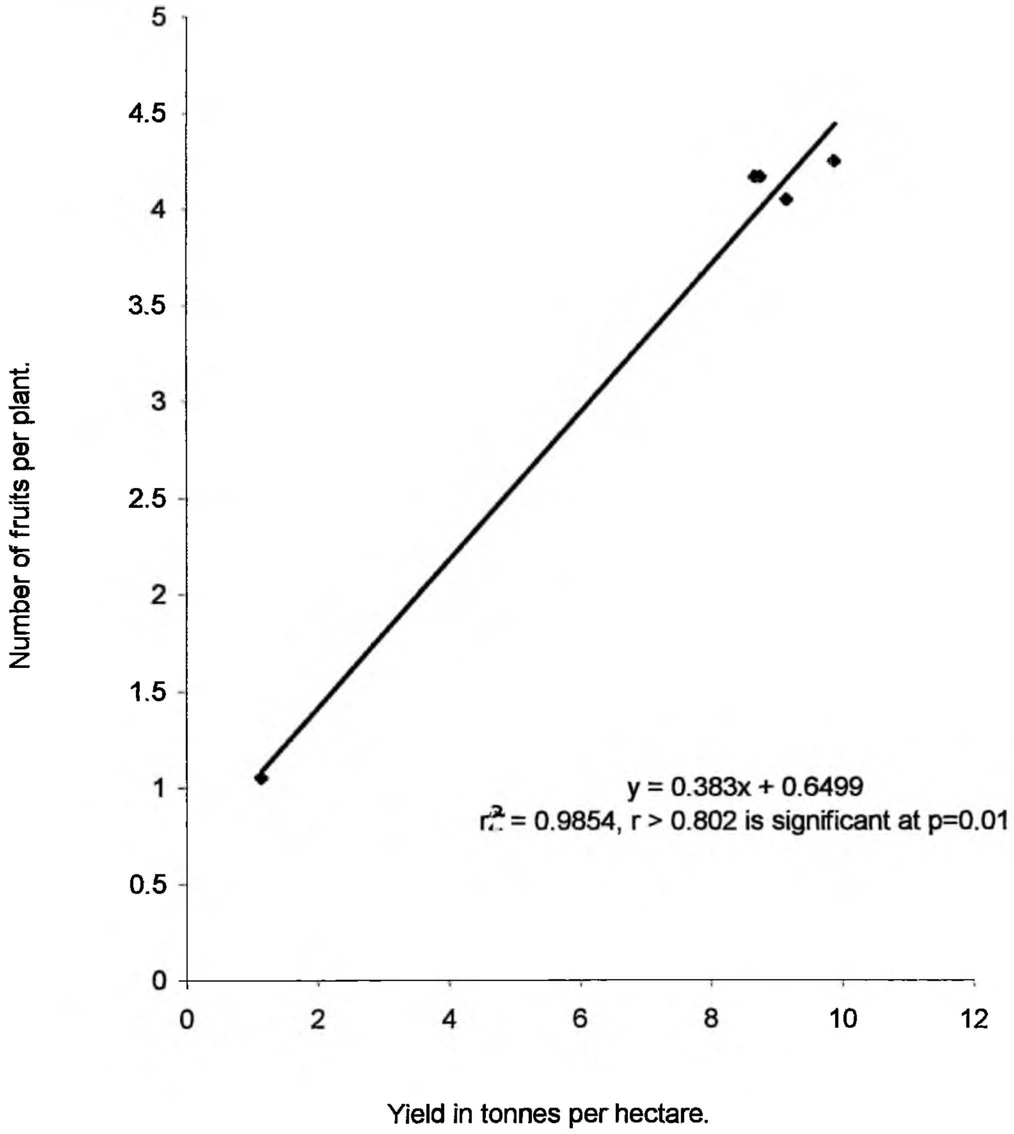

Fig. 7 Correlation between Yield in tonnes per hectare and No. of marketable fruits per plant.

Tables 6 shows the means of growth and yield indices as well as the effect of some of the insect pests on these indices. The number of bored buds ranged from a mean of 9.25 for cymethoate to 24.0 for control. There was no significant difference ($P=0.05$) between the treatments. The number of holes in fruits also ranged from 1.75 for cymethoate to 30.50 for control. The control plot differed significantly ($P < 0.05$) from the other treatments. The values for the plant products ranged from 3.25 for neem extract to 12.75 for jatropha oil. There were no significant differences ($P= 0.05$) among these treatments. The percentage of fruits bored also followed the same pattern with as high as 40 % recorded for control as against 4 % for cymethoate.

The damage in plants treated with neem and jatropha products ranged between 6-11 %. The control pot differed significantly ($P < 0.01$) from other treatments. Chlorosis of leaves was significantly ($P < 0.01$) higher for plants treated with Jatropha seed oil and control (25-29 %) compared to those treated cymethoate and neem extracts (0.3-7.5%). (Table 7) Damage by leaf feeders was significantly ($P < 0.05$) lower for plants that received chemical treatments (19-22%) than for control where as much as 30% leaf defoliation was recorded. (Table 8).

Plant height at flowering ranged from 31.7 cm. for plants treated with cymethoate to 41.8 cm for those treated with jatropha seed oil (Table 9). There were no significant differences ($P = 0.05$) between the treatments. The control plot recorded significantly ($P < 0.05$) lower figures in number of fruits per plant, marketable fruit weight, fruits weight per plant and yield in tonnes per hectare compared to the other treatments while plants treated with jatropha seed oil recorded highest values in all the indices (Table 10). Significantly ($P < 0.05$) higher number of thrips was recorded on cymethoate treated plot compared to the others. This ranged from 35 insects for cymethoate to 8 for jatropha aqueous seed extract treated plot (Table 11). Higher number of thrips (18) were collected at noon than other times of the day where the relative humidity and temperature were 55.2 % and 41.1 °C, respectively, (Table 12).

Table 6. Effect of treatments on damage caused to the fruits of *S. melongena*.

Treatment	No. of flower buds bored.	No. of holes in fruits.	% bored fruits
NSKE	14.00 ± 3.58 [a]	3.25 ± 1.65 [a]	6.26± 0.99 [a]
JSKE	13.75 ± 4.50 [a]	9.25 ± 5.94 [a]	11.86 ± 3.59 [a]
JSO	22.00 ± 4.30 [a]	12.75 ± 8.48 [ab]	9.60 ±1.09 [a]
CY	9.25 ± 3.33 [a]	1.75 ±1.11 [a]	4.28 ± 1.46 [a]
NS	24.00 ± 9.04 [a]	30.50 ± 10.41 [b]	40.14 ± 8.19 [b]

Means in a column followed by the same letters in a column do not differ significantly from one another at P = 0.05.

Key: JSKE, Jatropha seed kernel extract; JSO, Jatropha seed oil; NSKE, Neem seed kernel extract; CY, Cymethoate; NS, No spray.

Table 7 Effect of treatments on chlorotic leaf damage, % leaf defoliation and plant height.

Treatment	% leaf chlorosis. (X ± SE)	% defoliation. (X ± SE)	Plant height. (cm.) (X ± SE)
NSKE	7.50 ± 5.37 ab	20.30 ± 0.65 a	37.20 ± 6.52 a
JSKE	12.10 ± 4.42 bc	21.13 ± 1.32 a	34.30 ± 2.52 a
JSO	25.80 ± 8.06 cd	22.52 ± 2.25 a	41.80 ± 5.36 a
CY	0.30 ± 0.20 a	19.52 ± 0.25 a	31.70 ± 1.82 a
NS	29.60 ± 7.56 d	30.04 ± 4.86 b	37.50 ± 3.49 a

Means followed by the same letters do not differ significantly from one another at P = 0.05.

Table 8 Effect of treatments on yield of eggplant.

Treatment	Marketable fruit weight.	Marketable fruit wt./plant.	Fruit no. per plant.	Yield Tonnes/ha.
NSKE	240.38 ± 8.70 b	912.78 ± 135.61 b	4.03 ± 0.50b	9.13 ±1.35b
JSKE	227.23 ± 9.99 b	864.92 ± 102.47 b	4.15 ± 0.56b	8.65 ± 1.02b
JSO	266.20 ± 16.59 b	985.00 ± 40.85 b	4.23± 1.53b	9.85 ± 3.32b
CY	224.22 ± 10.06 b	873.01 ± 172.66 b	4.15 ± 0.97b	8.73 ± 1.73b
NS	187.45± 22.19 a	114.82 ± 25.16 a	1.05 ± 0.23a	1.14 ± 0.25a

Means in a column followed by the same letters in a column do not differ significantly from one another at P = 0.05

Key: JSKE, Jatropha seed kernel extract; JSO, Jatropha seed oil; NSKE, Neem seed kernel extract; CY, Cymethoate; NS, No spray.

Table 9.Effect of treatments on number of thrips.

Treatment	No. of thrips.
NSKE	8.75 ± 4.37 [a]
JSKE	8.00 ± 2.08 [a]
JSO	12.00 ± 3.00 [a]
CY	35.25 ± 10.59 [b]
NS	9.75 ± 0.85 [a]

Means followed by the same letters do not differ significantly from one another at P = 0.05.

Key: JSKE, Jatropha seed kernel extract; JSO, Jatropha seed oil; NSKE, Neem seed kernel extract; CY, Cymethoate; NS, No spray.

Table 10 Number of thrips recorded for NS at different times of the day.

Time (Hours)	Average no. of thrips	Relative humidity (%)	Average temperature (°C)
6.00-7.00	12	95.3	27.0
12.00-1.00	18	55.2	41.1
5.00-6.00	13	80.1	31.2

5.0 DISCUSSION

5. 1 Laboratory bioassays

The studies showed that 42.9 and 80 % mortalities were induced in *S. docilis* larvae when exposed to 20 and 60 g/l, respectively, of jatropha seed aqueous extract while 100 g/l induced a mortality of 95.7 %. When these same concentrations were administered to *A. gossypii*, 36.6, 66.6 and 93.3 % mortalities, respectively, were observed. Also fifty percent and ninety percent lethal doses (LD_{50}) and (LD_{90}) of 22.3 g/l and 76.0 g/l, respectively, were obtained for *S. docilis* while those of *A. gossypii* were 28.4 and 85.1 g/l, respectively. These showed that *S. docilis* larvae were more susceptible to the aqueous extracts than *A. gossypii*. A possible explanation to this is that the larvae being a herbivore is more likely to have ingested much of the extract which may lead to stomach poisoning compared to *A gossypii* which is a sap sucker and whose mortality depends on contact and/or systemic effect (which is yet to be established) of aqueous seed extract of jatropha.

The LD_{50} values are quite low compared to what is generally recommended for neem seed extract (50-75 g/l) for the control of insect pests in Ghana (Owusu-Ansah et al., 1998; Issahak, 1998). It is important to indicate that it is much easy to reach and collect the seeds of jatropha than those of neem and, therefore, makes the use of jatropha more economical in terms of labour compared to neem.

The feeding effect of *S. docilis* larvae on aubergine leaves treated with aqueous seed extract of jatropha showed that when leaves were treated with 20 g/l, a feeding deterrent of about

90 % was observed. About 57 % of the larvae died within 48 h. while 74 % died within 72 h. There was, however total feeding inhibition on leaves treated with higher concentration of 40-100 g/l. Butanol extract of *J. curcas* has been shown to have a high insecticidal and antifeedant activity against 3rd instar-larvae of *Atteva fabriciella*. Swed (Neelu *et al*., 1997). After the 24 h. of exposure, however, all the larvae became moribund. Under field conditions, therefore, they would be highly susceptible to predation. The larvae, however, died 48 h. after exposure to the treated leaves. Death of the larvae may be due to contact poisoning, starvation, or both. Methanol extract of jatropha has been shown to be a potent antifeedant against the teak skeletonizer, *Eutectona machaeralis* Walk. (Lepidoptera: Pyralidae) (Meshram *et al*., 1994). Cobbinah and Tuani (1992) showed a decrease in the activity of *Z. variegatus* when treated with 5 % emulsion of *Jatropha curcas*. Those on water-treated control consumed all the leaves within 48 and h. later developed into adults.

Jatropha seed oil treatment also showed similar responses. When *A. gossypii*, *S. docilis* and *U. hystericellus* were exposed to aubergine leaves treated with 1 ml/l seed oil, 33.3, 12.0 and 8.4 % mortalities, respectively, were observed but mortalities increased to 46.7, 92.5,and 46.9 % when 3 ml/l was applied. At 5 ml/l, however, 86.7, 100 and 62.5 % mortalities were observed in the test insects. These figures indicate that at low concentrations, *S. docilis* and *U. hystericellus* appeared to be least affected by the oil but as concentration increased, *S. docilis* became more susceptible to the oil while *U. hystericellus* does not seem to be very much affected. This could be due the sap sucking nature of *U hystericellus*, which may not have picked up enough of the ai compared to S. *docilis*, which is a herbivore.

The slopes of the response curves are in the increasing order of *U. hystericellus* (2. 08) < *A. gossypii* (2.11) < *S. docilis* (3.15). The LD_{50} for *S. docilis, A. gossypii* and *U. hstericellus* were 1.5, 2.2 and 3.6 ml/l, respectively, while their respective LD_{90} values were 3.7, 8.7 and 14.7 ml/l. These figures show that to produce 50 % mortality, the oil was 2.4 times and 1.5 times more toxic to *S. docilis* than to *U. hystericellus* and *A. gossypii*, respectively, while at 90 % mortality, these figures increased to approximately 4 times and 2 times, respectively. Among the three insects tested, *S. docilis* was most susceptible to the seed oil while *U. hystericellus* was least susceptible. This may partly explain the reason why about 10-20 % leaf defoliation was observed in *S. docilis* larvae placed on aubergine leaves treated with 0.1 % oil as compared to over 60 % leaf area consumption in the control (Table 2).

Those that fed on leaves treated with 0.1 % oil failed to reach the adult stage. This suggests that the oil may have led to stomach poisoning and/or interfered with the production of hormones involved in metamorphosis. Deyer *et al.*, (1986) reported that neem kenel powder and cake inhibits the development of 3rd instar larvae of *S. docilis*. Also, concentrations of 0.2-0.8 % deterred feeding by *S. docilis* larvae by 100 %. They appeared slow in activity and are, therefore, likely to be predisposed to predators under field conditions. They all died within 48 h. probably due to starvation or contact poisoning or both.

In the choice bioassay, approximately the same number of *U. hystericellus* (10 %) settled on leaves or filter paper treated with jatropha seed extract as against 90 % on water-treated control This suggests that the seed extract is more effective to *U. hystericellus* as a strong repellant than as a toxicant. *Selepa docilis* larvae also showed similar responses to leaves treated with the aqueous extract and oil. Though a higher number settled on treated leaves, feeding inhibition and death of insects occurred during the exposure time. The insect is, therefore, more likely to avoid plants treated with the extracts in the field.

With regards to leaves treated with the aqueous seed extract, a greater number of the insects (60 %) preferred the untreated leaves compared to treated ones suggesting the repellency effect of the aqueous extract. Feeding deterrence was also observed in insects that settled on the treated leaves. Aqueous seed products of neem and jatropha did not affect hatchability of eggs of *S. docilis* but there was 21 % reduction in hatchability when the eggs were treated with 4 m/l seed oil. All the neonate larvae that hatched out could not survive on the treated leaves but died within 48 h indicating that the plant products have a strong larvicidal effect on the first instar larvae of of *S. docilis*.

The response of *A. gossypii* to treated and untreated aubergine leaf discs, (Plate 5), shows random movements of the insect in the petri dish containing the leaf discs. The insect however, after moving round for about 42 minutes, settled on the untreated leaf disc. Though there was orientation towards both types of leaf discs, its final settlement on the untreated disc suggests that jatropha extracts could serve as a good repellent to the insect.

Application of jatropha aqueous seed extract and seed oil in the field could protect a growing crop in two ways. First, the crop would be protected via a primary gustatory repellent action of the products, which the insects ingest in an attempt to feed on the foliage. Secondly, the insect picking up residues on sprayed foliage or through foraging behavior can suffer feeding inhibition and high mortality, which may result in reduced crop damage.

During insect pests outbreaks, farmers are often helpless and have to rely on Governments to organize and effect control, which are usually late. The availability and the exploitation of jatropha under such conditions could enable the farmer to reduce spread and damage to crops. Arguably, control may not be achieved through the use of jatropha alone, but reasonable level of protecting the crop could be ensured.

5.2 Field work

5. 2. 1 Insect pests encountered in the nursery.

The first insect to be encountered in the nursery was the cotton jassid; *Empoasca lybica.* This was found a week after the seedlings emerged. They were widespread and sucked sap from the plants. Also observed were *Aphis gossypii* and *Selepa docilis.* The aphids were found on the stems of plants while *S. docilis* were found causing slight defoliation of the leaves. Their egg masses were deposited on the edges of leaves. A week after transplanting, however, all these insects disappeared. This may be due to the transplanting stress as the weather was so dry at the time.

5.2.2 Insect pests encountered in the field

Table 4 shows a list of insects encountered in the field. They belong to six orders, twelve families and eighteen genera. Three weeks after transplanting, it was observed that the cotton jassid, *Empoasca lybica* (Homoptera: Cicadellidae); the eggplant skeletonizer, *Selepa docilis* (Lepidoptera: Noctuidae); the brinjal lace bug, *Urentius hysterycellus* (Homoptera: Tingidae); white flies, *Bemisia tabaci* (Homoptera: Aleyrodidae); ants and spiders were randomly distributed in all the treatments

The population trend of *E. lybica* on the various treatments is shown in Fig. 4. There was a gradual increase in numbers from the fourth week up to about the seventh week after sowing before falling to zero in the twelfth week. Both the nymphs and the adults were found on the upper and the lower surfaces of leaves. They are known to suck sap from the under surfaces of maturing leaves and secreting toxic saliva which causes the leaves to turn yellow and brown and die (Chritchley, 1997). Severe infestation reduces yield as chlorosis of the leaf reduces the amount of chlorophyll necessary for photosynthesis.

Even though no statistical analysis was done on their relative abundance in the various treatments, highest numbers were observed in the control plot; an average of 42 insects per visit while the lowest number was observed with the cymethoate and NSKE treatment with an average of 9 insects per visit. The low numbers associated with neem might be due to its repellency effects (Schmutterer, 1990). Also Heyde *et al.*, (1984) showed that settling by the brown planthopper, *Nilaparvata lugens* and the *Sogatella furcifera* was progressively reduced by increasing concentration of neem oil from (1 to 50%). *Nilaparvata. lugens* failed to produce the courtship signals after topical application of 30% neem oil (Saxena *et* *al*., 1993). Asari and Nair (1972) demonstrated the repellent effect of a ten–day interval spraying of NSKE (10 g/l) on brinjal against *Empoasca spp*. Cymethoate on the other hand has both systemic and contact properties, hence the relatively low number of jassids found on eggplants treated with the insecticide

The egg masses of *Selepa docilis* were found to be deposited at the edges of leaf surfaces of plants in all the treatments. The larvae that hatched out caused serious defoliation of the leaves especially in the control plot (Plate 6). Though there were no significant differences ($P=0.05$) between the botanicals and cymethoate, the control differed significantly ($P < 0.01$) from other treatments, (Table 7). Frimpong (1981) stated that the insect causes serious defoliation of the leaves and its attack could result in stunted and withered plants.

Fig. 5 shows the population trend of *S. docilis* over the period of sampling. The population peaked between the fifth and the ninth week after transplanting. This was just around the flowering period. *Selepa. docilis* were probably attracted to the colour of eggplant flowers (Southwood, 1978). It was observed, however, that as the plant ages, the insect population declined considerably even with the control. The decline in the population around the 12^{th} week could be due to the fact that the plants had used most of the stored food substances in the reproductive phase and were not able to adequately supply the needs of the insects' population. Nsowah (1969) showed that 70% of total yield in brinjal are produced during the first eight to nine weeks after transplanting. This might be partly responsible for the high numbers of the insect encountered between 5 and 10 weeks after planting. Veeravel and

Baskaren (1995) showed that maximum pest population occurred in brinjal during the flowering and bearing stages of the plants. However, during the senescence stage, pest population was lowest.

High numbers were found on the control plot, whereas very low numbers were observed especially in the cymethoate and jatropha aqueous seed extract treatments. The low numbers of the insect associated with the aqueous extracts of jatropha treatment confirms the results obtained in the laboratory bioassays which showed that eggplant leaves treated with 40 g/l and 0.2 % seed extracts and oil, respectively, inhibited feeding by the larvae of *S. dicilis*. Cobbinah and Tuani (1992) showed that application of 5 % emulsion of jatropha to eggplants reduced the feeding activity of *Z. variegatus* by 40 % within 24 hrs. Neem oil applied to eggplants at 5–20 % effectively controlled *S. docilis* with the 10 % concentration causing instant mortality (Cobbinah and Osei–Owusu, 1988)

Even though there were high deposits of egg masses in all plots most of the larvae that hatched out could not survive on the treated plants compared to the control, (Plate 6). This observation confirms the result of laboratory studies carried out to determine the ovicidal effect of the plant products on the insect.

The brinjal lace bug (*Urentius hystericellus*) recorded the second highest in numbers after the red spider mite *Tetranychus sp*. There was heavy infestation in the control plots while relatively low numbers were encountered in jatropha extracts, neem extract and cymethoate treatments (Fig. 6). With age of the plants, however, their numbers declined. Cobbinah and Osei–Owusu (1988) showed that application of 5–20 % neem oil on brinjal strongly repelled *Urentius sp* from treated plants. The laboratory bioassays showed that about 90 % of the insects preferred untreated plants to those treated with 40 g/l of jatropha aqueous seed extract. Also 0.36 % oil produced about 50 % mortality in the insects (Fig. 3). Both the nymphs and the adults were found in clusters at the under surfaces of the leaves although occasionally the adults were found on the upper surfaces as well.

Leaves attacked by *U. hystericellus* showed chlorotic symptoms which latter turned brown and dropped off (Plate 11). This insect has also been reported to be a very serious pest of local garden egg *Solanum integrifolium* L (Brempong-Yeboah and Okoampa, 1989) but is effectively controlled using Dimethoate 20 EC at 80 g /ha.

Attack by the bud borer, *Scrobipalpa blapsigona* (Lepidoptera: Noctuidae) was manifested in the buds infested by the larvae, which showed slight differences even though there were no significant differences among the treatments (Table 6). It could, however, be observed that the lowest numbers occurred on the cymethoate treated plants. This may be due to its systemic effect. The buds, once infested, were aborted.

Attack by, *L. orbonalis* was observed in all the treatments. There were significant differences ($P < 0.05$) and ($P < 0.01$) among treatments in the number of holes in the fruits and percent bored fruits, respectively, (Table 6). Jatropha seed oil is effective against cotton bollworms (Solsoloy, 1995). Neem extracts have been used successfully to control major insects attacking vegetables (Owusu-Ansah *et al*., 1998). Both the neem and cymethoate differed significantly (P < 0.05) from the control in terms of number of holes bored into the fruits but there were no significant differences (P=0.05) between jatropha aquoeus seed extract and the oil from the control.

The mature larvae of *L. orbonalis* emerging from the fruits to pupate created the holes observed in the fruits. Therefore, the systemic effects of neem (Jacobson, 1989) and cymethoate might have affected their survival and development. Only a few of them were, therefore, able to emerge from the fruits to pupate hence fewer numbers of holes recorded for these treatments. This means that with time fewer and fewer number of the adults will be present in the system below the economic threshold. Chowdhury *et al*., (1993) showed that cypermethrin 10 EC is very effective against the fruit borer. Jaropha extracts and the oil on the other hand might not have conferred this systemic property on the plant and therefore the relatively high number of holes that were recorded in those treatments. This implied that majority of the larvae were likely to complete their life cycle leading to increased number of the insect in the system.

The botanicals compared favourably with the synthetic insecticide in protecting the fruits against damage by the borer (Table 6). The neem seed extract, jatropha seed extract and jatropha seed oil provided 85, 70 and 77.5 % protection, respectively, against the fruit and shoot borer (Table 6). The 40 % damage on the untreated plants fell within the range of 30-

50 % reported by Mishra and Mishra (1996).

The leafworm, *Eublema admota* (Lepidoptera: Noctuidae) fed on young leaves especially soon after transplanting. It also webbed together young leaves (Plate 8). This activity could greatly affect the photosynthetic activity of the young growing plant and therefore the ultimate yield. Its incidence was quite high soon after transplanting but as the plant puts on more vegetation, their numbers fell drastically to insignificant levels. According to Norman (1974), these insects are generally not present in high numbers to be considered as serious pests. Hence hand picking of the larvae could serve as an effective control measure.

Thrips palmi (Thysanoptera: Thripidae) was first observed in the cymethoate treated plants which also recorded the highest number of the insect while lowest numbers were collected from the plants treated with NSKE probably due to its repellency effect. (Table 5). There were significant differences ($P < 0.05$) between the treatments (Table 9). This shows that the insect may be developing some form of resistance to the synthetic insecticide. Cermeli *et al*., (1993) showed that out of eleven insecticides tested in an experiment, high tolerance to the chemicals was observed. Etienne *et al*., (1990) also found that synthetic insecticides used in controlling insect pests of aubergine led to the reduction of the activity of predators thus leading to higher population of *T. palmi* in treated areas than untreated ones. It was also observed that the insect was more commonly found during hot afternoons with average temperatures and relative humidity of 41.1 °C and 55.5 %, respectively, on surfaces of leaves than other times of the day (Table 10). This may be one of the reasons they are a problem in green houses.

Whiteflies, *Bemisia tabaci* (Homoptera: Aleyrodidae) were also observed in very high numbers in the control while lower numbers were associated with plants treated with jatropha and neem extracts (Table 5). They were normally found in clusters on the lower surfaces of older leaves. They sucked sap from the underside and secreted honey due that led to the growth of sooty mold on the upper surfaces of leaves. Most of the plants on which the insects were found were observed to develop symptoms associated with viral infection. The insect is a vector of leaf curl and mosaic viral diseases (Chritchley, 1997).

The red spider mite, *Tetranychus sp* first appeared in high numbers in the neem treatment and the control plots in the eleventh week after sowing and a week later to other treatments except cymethoate where the insect was not found (Table 5). The high infestation led to serious chlorosis of affected leaves (Plates 10).

Even though there were differences among treatments in terms of numbers, it could be observed that none of the botanicals was effective against the mite. Its high incidence, however, had little effect on the yield as its infestation occurred rather late in the experiment.

Other insects such as *Anoplocnemis curvipes* (Heteroptera: Coreidae); *Zonocerus variegatus*

(Orthoptera, Pyrgomorphidae); *Prodenia litura* (Lepidoptera: Noctuidae); *Aphis gossypii* (Homoptera: Aphididae) among others were also encountered but may not be considered very important based on the numbers observed, (Table 5). Neem and jatropha extracts have been shown to strongly repel *Z. variegatus*, and *A. gossypii*. (Cobbinah and Osei-Owusu, 1988).

5.2.3 Beneficial arthropods

Members in this group were not found in high numbers. Those encountered included spiders, ants, *Crematogaster sp* (Hymenoptera: Formicidae); the lady beetle, *Epilachna elaterii* (Coleoptera: Coccinelidae) *Mantis mantis* (Dictyoptera: Mantidae) and some unidentified dipterans (Plate 16).

The dipteran was found associated with the larvae of *S. docilis*. One special feature about it is that the pupa develops in a thick white cocoon, and this might provide a good protection against insecticides. Most of the cocoons collected from the field gave rise to adult insects (Plate 16).

The spiders were observed in all the treatments. *Crematogaster sp* and mantids were found in all the treatments except cymethoate. This suggests that the botanicals had little effect on these natural enemies but the synthetic insecticide probably killed them.

5.2.4 Effect of the treatments and pests on growth and yield indices.

There were no significant differences in plant height at flowering even though there were slight differences with jatropha seed oil giving the mean highest of 41.8 cm and cymethoate the lowest of 31.7 cm (Table 7). This means that the treatments had no effect on growth of plants in terms of height up to flowering.

Highly significant differences ($P < 0.01$) were observed in percent leaf area showing chlorotic symptoms (Table 7). Cymethoate treatment gave the least percent leaf area showing this symptom and differed significantly ($P < 0.01$) from other treatments while neem seed and jatropha seed kernel extracts differed significantly ($P < 0.05$) from jatropha seed oil and control plants. This may be due to the relatively high numbers of leafhoppers, *U. hystericellus* and other leaf miners that were recorded on plants treated with these protectants (Table 5). Significant differences ($P < 0.05$) were also observed in percentage leaf area defoliated by leaf feeders (Table 7), but there were no significant differences ($P=0.05$) between the botanicals and the cymethoate-treated plants. This meant that the insecticides gave adequate control of the leaf feeders.

In terms of marketable fruits, significant differences ($P < 0.05$) were observed for fruit weight/plant, fruit weight, number of fruits per plant and total yield in tonnes/ha (Table 8). In all the four parameters, the control plot gave the lowest values. This stems from the fact that there was heavy infestation of *E. lybicus*, *U. hystericellus*, *B. tabaci* and *S. docilis* whose activities led to distortion of leaves, chlorosis and reduction in leaf surface area necessary for photosynthesis. Also fewer number of fruits were produced in the control plots. This might be due to the fact that the bud borer, *S. balpsigona* among others destroyed a greater number of their flower buds (Table 6). In addition to this, *L. orbonalis*, rendered most of the fruits unmarketable as a result of high infestation.

Among the botanicals and the synthetic insecticide, however, there were no significant differences (P=0.05) in all the four parameters though; jatropha seed oil treatment gave slightly higher values (Tables 8).

A positive significant (P = <0.01) correlation (r=0.985) was observed between yield in tonnes per hectare and number of marketable fruits (Fig 7). This confirms the findings of Srivastava and Sachan (1973) that the most important factor in brinjal production was the number of fruits per plant.

6.0 SUMMARY AND CONCLUSION.

The effects of extracts of *J. curcas* were compared with those of *A. indica* on insect pests complex of aubergine, (*S. melongena*) in the laboratory and also in the field. The ovicidal effects of these extracts on *S. docilis* as well as the levels of *J. curcas* that would produce 50 % mortality in the populations of some of the major insect pests were also studied. Yield and yield components were also compared for the various treatments used in the fieldwork. The results obtained are summarized as follows:

1. Approximately 28 g/l of the aqueous extract and 2.2 m/l oil of jatropha produced 50 % mortality in *A. gossypii.*
2. Aubergine leaves treated with 1.5 and 3.6 ml/l jatropha seed oil produced 50 % mortality in *S. docilis* and *U. hystericellus,* respectively, while those treated with about 22.3 g/l of jatropha extracts produced the same mortality in *S. docilis*
3. *Selepa docilis* was more susceptible to the extracts of jatropha compared to *A. gossypii U. hystericellus* (least susceptible).
4. Higher concentrations of jatropha (40–100 g/l) and seed oil (2–10 ml/l) on treated leaves inhibited the feeding ability of the larvae of *S. docilis*. Such larvae became moribund 24 hrs after exposure to the leaves and died 48 hours later. Death might be due to contact poisoning, or starvation or both.
5. Ninety percent and 60 % of *U. hystericellus* and *S. docilis* respectively preferred untreated substrates to those treated with aqueous seed extracts of jatropha.
6. Aqueous seed extract of neem and jatropha had no ovicidal effect on *S. docilis* but

jatropha seed oil had some effect on hatchability. Neonate larvae however, failed to develop on the treated leaves.

7. The insects encountered in the field were made up of 6 orders, 12 genera and 18 families.
8. Majority of the insects was collected at the early flowering stages (6–9 weeks after planting)
9. *Empoasca lybica, Urentius hystericellus, Bemisia tabaci, Selepa docilis, Leucinodes orbonalis* and *Tetranychus sp*. were regarded as major insect pests by virtue of their numbers and the damage they caused.
10. The beneficial arthropods encountered include; *Crematogaster sp*. Spiders, *Epilachna elaterii, Mantis mantis* and an unidentified parasitoid. The plant products had little effect on these insects compared to the synthetic insecticide.
11. Both the neem and jatropha products were effective in controlling most of the important insect pests and compared favourably with Cymethoate.
12. There were no significant differences (P. = 0.05) among treatments in number of flower buds bored and plant height at flowering.
13. Significant differences were observed for number of holes in fruits, % fruits bored, % upper leaf area showing chlorotic symptoms and mean leaf area defoliated by leaf feeders.
14. Significant differences were also observed for marketable fruit weight, fruit weight per plant, fruit number per plant and fruit yield in tonnes per hectare. Plants treated with jatropha seed oil had slightly higher values on all the indices while lowest

values were recorded in the econtrol plots.

15. A positive significant ($P < 0.01$) correlation was observed for yield in tonnes per hectare and number of marketable fruits per plant.
16. Phytotoxicity was observed for higher levels of aqueous seed extracts of jatropha in a preliminary trials as the application of 60 g/l resulted in leaf scorch

Therefore, it is evident that jatropha seed extracts, when carefully integrated into pest management programmes, would to a large extent reduce some, if not all the problems associated with the misuse of synthetic insecticides. Resource poor farmers in Third world countries would be greatly relieved with the problems of supply uncertainty and cost associated with use of synthetic insecticides as the plant is used widely as fencing material in many towns and villages in Ghana.

However, it is important to carry out further research into the phytotoxicity, persistence in foods and environmental hazards that might be associated with the use of jatropha extracts. Furthermore, the mode of action of the seed oil and the aqueous seed extracts of jatropha, its active principles and pests spectrum need further investigation. Also it is important to carry out further research into plants that might act synergistically with neem and jatropha. Finally, traditional methods of extracting the seed oil of jatropha as well as large-scale cultivation of these plants require further studies.

REFERENCES

Abbiw, D. K (1990). Useful plants of Ghana. West African uses of wild and cultivated plants. Intermediate Technology Publications and The Royal Botanic Gaderns, Kew, UK, 337 pp.

Adzaho, K. D (1997). The potency of fresh neem extracts compared to Karate (synthetic chemical) in the control of the diamondback moth *(Plutella xylostella) on* cabbage plant *(Brassica oleracea var. capitata).* Bachelor of Science dissertation, Department of Crop Science, University of Cape Coast, Ghana. 55 p

Afreh-Nuamah, K; C. Akotsen; D. Obeng–Ofori and G. K Ofosu-Budu (1998). Laboratory evaluation of the effect of neem seed water extract on oviposition and developmental stages of fruitfly, *Ceratitis capitata* Weidemann (Diptera: Tephritidae). Paper presented at the First Biennial Agricultural research Systems (NARS) Workshop, Accra International Conference Centre, Ghana.16–20 th Nov. 1998.

Akinlosotu, T. A (1979). Screeming of Solanum fruit vegetables for resistance to *Sceliodes laisalis* wlk. (Lepidoptera: artiidae) attack, Proceedings. 9th Annual Conference. Nigerian Society of Crop Improvement in Ghana. University of Ghana. 52-71.

Allotey, J. K; J. Dankwah (1994). Some aspects of the biology and control of the cowpea weevil, *Callosobruchus maculatus* F. on cowpea and bambara groundnuts. *Insect Science and its Application.* **16** (2): 233-228.

Asari, P. A. R; M. R. G. K Nair (1972). On the control of brinjal pests using deterrents. *Agricultural Research Journal.* Kerela. **10**: 133 – 135.

Baba Niber, T. (1994). The ability of powders and slurries from ten plant species to protect stored grains from attack by *Prostephanus truncatus* Horn (Coleoptera: Bostrichidae) and *Sitophilus oryzae* L. (Coleoptera: Curculionidae). *Journal of Stored Product Research*. **30** (4): 297-301.

Bennison, J. A; C. Samposn; A. Vautier; P. F Challinor and Lenteren- J. C–Van (1996). Proceedings of the meeting; Integrated control in glasshouses. Vienna, Austria, 20-25 May Bulletin-OILB-SROP **19** (1): 7-10.

Borah, R. K (1995) Insect pest complex in brinjal (*Solanum melongena* L.) *Annals of Agricultural Research*. **16** (1): 93-94.

Brempong-Yeboah C. Y and N. D. Okoampah (1989). Afield experiment on the effect of some insectcides on the pests of garden eggs (*Solanum integrifolim*) at Legon. *Applied Entomology and Zoology*. **24** (4): 343-348.

Castineiras.A; R. M Baranowski; H. Glenn (1997) Distribution of *Neoseiulus cucumeris* (Acarina: Phytoseidea) and its prey, *Thrips palmi* (thysanoptera: Thripidae) within eggplants in Florida. *Florida Entomolgist*. **80** (2): 211-217.

Cermeli, M; A. Montagne and F. Goday (1993). Preliminary results on the chemical control of *Thrips palmi* Karny (Thysanoptera: Thripidae) on beans (*Phaseolus vulgaris* L.).*Boletin- de- Entomologia- Venezuelana* **8** (1): 63-73.

Champagne, D. E; M. B.Isman, G. H. N Towers, O. Koul, G. G. L Scudder (1992). Biological activities of limonoids from Rutales. *Phytochemistry*. **31**: 377–394.

Chatterjee, A; B. Das, N. Adityachaudhury; S. Debkirtaniya (1980). Note on the insecticidal properties of the seeds of *Jatropha gossypifolia* Linn. *Indian Jounal of*

Agricultural Science. **50** (8): 637-638.

Chowdhury, A. B. M. N. U; N. Islam; M. A Karim (1993). Efficacy of some pesticides against the brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen.(Lepidoptera: Noctuidae). *Bangladesh Journal of Zoology*.**21** (2): 133–139.

Chritchley B. R (1997). Pest of vegetables. NRI 282 pp.

Cobbinah, J. R and J. Appiah-Kwarteng (1989). Effect of neem products on stored maize weevil, *Sitophilus zeamais* Motsch. *Insect Science and its Application*. **10** (1): 89-92.

Cobbinah, J. R and J. Appiah-Kwarteng (1991). Pesticidal action of some local plants. *Forest Research Intitute of Ghana Technology Bulletin*. **10** (11): 18

Cobbinah, J. R, and G. K Tuani (1992). Antifeedant effect of *Jatropha curcas* L. seed oil and extracts on the variegated grasshopper *Zonocerus variegatus* L (Orthoptera: Acrididae). *Journal, University Science and Technology* **12:** 136-139.

Cobbinah, J. R; K. Osei Owusu (1988). Effects of neem seed extracts on insect pests of eggplant, okra and cowpea. *Insect Science and its Application*. **9**: 601 – 607.

Deyer, M., R. Schmutterer (ed.) ans K. R. S (1986). Field and laboratory trials with simple neem products as protestants against pests of vegetables and field crops in Togo. Natural pesticides from the neem tree (A. indica A. juss) and other tropical plants. Proceedings of the 3rd International Neem Conference, Nairobi, Kenya, 10-15 July. 431-447.

Dhankhar B.S (1988). Progress in resistance studies in the eggplant (*Solanum melongena* L.) against shoot and fruit borer (*L. orbonalis* Guen.) infestation. *Tropical Pest Management*. **34** (3): 343-345.

Dhankhar, B.S; V.P Gupta; and R. Singh (1997). Screening and variablility studies for relative susceptibility to shoot and fruit borer (*L. orbonalis* Guen) in normal and ratoon crop of (*Solanum melongena* L.). *Haryana Journal of Horticultural Sciences.* **6** (1-2): 50-58.

Dhawan, B.N; G.K Patnaik (1993). Pharmacological studies for the therapeutic potential. In Randwan, N.S, B.S Parma (Eds). *Neem Research and Development.* Society *of Pesticide Science*, New Delhi, India, 242-249. pp.

Ermel, K; E. Pahlich; and H. Schmutterer (1987). Azadirachtin content of Neem kernels from different geographic locations, and its dependence on temperature, relative humidity and light. In Schmutterer, H.; K. R. S Ascher [Eds.] Natural pesticides from neem tree and other tropical plants. Proceedings 3rd International Neem Conference. (Nairobi, Kenya, 1986) p. 171-184.

Etienne, J; J. Guyot; Waetermeulen-X-Van; Van-Waetermeulen-X (1990). Effect of insecticides, predation and precipitation on populatipons of *Thrips palmi* on aubergine (eggplant) in Guadeloupe. *Florida Entomologist* **73** (2): 339.

Forjoe, C.G (1995). Efficacy of aqueous neem leaf extracts in the control of the diamondback moth, *Plutella xylostella* L. on cabbage, (*Brassica oleracea* var. capitata) and the tomato bug (*Nesidiococris tennis* Reui). Bachelor of Science Dissertation, Department of Crop Science, University of Cape Coast, Ghana. 157 pp.

Frimpong, E (1981). The biology of *Selepa docilis* Butler (Lepidoptera: Noctuidae) an eggplant defoliator in Ghana. *Bulletin de l'I F. A. N.*, 43 ser, a, No.1, 1-2, 174-186.

Frimpong, E and G.K A Buahin (1997). Studies on the insect pests of eggplant, *Solanum* *melongena* L., in Ghana. *Bulletin de l'l F. A. N.,* 39 ser A, No.3 627-641.

Fujiwara, T; E. Y Sishita; T. Takeda; Y. Ogihara, M.. Shimizu; T. Nomura; and Y. Tomita (1984). Further studies on the structure of polysacharides from the bark of *Melia azadirachta. Chemical Pharmacology Bulletin.* **32**: 1385-1391.

Fujiwara, T; T. Takeda; Y. Ogihara; M. Shimizu; T. Nomura; and Y. Tomita (1982). Studies on the structure of polysaccharides from the bark of *Melia azadirachta. Chemical Pharmacology Bulletin.* **30**: 4025–4030.

Ghidiu, G. M; G. C Hamilton; and G. W Kirtman (1994). *Bacillus thuringiensis* ssp. tenebrionis sprays effect on hatching of Colorado Potato Beetle, *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae) eggs and subsequent larval dispersal. *Journal of Economic Entomology* **87** (5): 1298-1301.

Grewal, R. S; Dilbagh Singh; and D Singh (1995). Fruit characters of brinjal in relation to the infestation by *Leucinodes orbonalis* Guen. *Indian journal of Entomology*. **57** (4): 336-343.

Gruber, A. K (1991). Wachstum, Fruchtertrag und Azadirachtingehalt der Samen von *Azadirachta indica* A. Juss auf Verschiedenen atandorten in Nicaragua. Doctor. Thesis. Technology University of Berlin, Germany.

Hami, M. A. (1955). Effect of borer attack on the vitamin C content of brinjals. *Pakistan Journal of Health*. **4** (4): 223-224.

Hampson, G.F (1896) Moths: The fauna of British India including Ceylon and Burma **5**: 370-371.

Heller,J (1996). Physic nut *Jatropha curcas* L. International Plant Genetic Resources

Institute. (IBPGR) Rome; Italy.

Heyde, V. D. L; R. C Saxena; and H. Schmutterer (1984). Neem oil and neem extracts as potential insecticides for control hemipterous rice pests. In Schmutterer, H and K. R. S Ascher [Eds]. Natural Pesticides from Neem and other Tropical plants. Proceedings 2nd International Neem Conference. (Rauischholzhaussen, Germany 1983). P. 377–390.

Irvine F. R (1961). Woody plants of Ghana. Oxford University Press. 68 pp.

Issahak, A. S (1999). The efficacy of neem (*A. indica* A. Juss) seed extract against inset pests of cowpea (*Vigna onguiculata* L.). A B.Sc. Dissertation submitted to the Department of Crop Science, University of Ghana, Legon.46 pp.

Jacobson, M. (Ed) (1989) 1988. Focus on phytochemical pesticides. Vol. 1.The Neem tree CRC press, Boca Raton FL.

Jotwani, M. C and K. P Srivastava (1981). Neem: Insecticide of the future 111. Chemistry, tixicology and future strategies. *Pesticide* **15**: 1-2.

Kajita, H; Y. Hirose; M. Takagi; S. Okajima; B. Napopeth; and S. Buranapanichpan (1996). Host plants and abundance of *Thrips palmi* Karny. (Thysanoptera: Thripidae). *Applied Entomology and Zoology*. **31** (1): 87-94.

Kapoor,V. C; M. Paul; Jyotika-Kapur; and J. Kapur (1997). Seasonal incidence of mite species infesting okra (*Hibiscus esculentus*) and brinjal (*Solanum melongena*) in Punjab. *Indian Journal of Agricultual Sciences*. **67** (7): 325-326.

Kawai, A and C. Kitamura (1990). Studies on population ecology of *Thrips palmi* Karny. Evaluation of effectiveness of control methods of thrips on eggplant and sweet pepper using a simulation model. *Applied Entomology and Zoology*.**25** (2): 161-175.

Klemm, U and H. Schmutterer (1993). Wirkungen von Niempraparaten auf die Kohlmotte *Plutella xylostella* L. und ihre naturlichen Feinde der Gattung Trichogramma Z. PflKrankh Pflschutz 100, 113-128, LA English.

Kogbe, J.O.S (1983). Effects of spacing on the yield of local and exotic eggplant, *Solanum spp. Acta Hortic*. **123**: 291-297.

Kottoh, H (1997). Evaluation of some management methods for the control of fruit drop in hot pepper (*Capsicum frutenscens*). Bachelor of Science Dissertation, Department of Crop Science, University of Cape coast, Ghana, 66pp.

Koul, O; M. B Isman and C M Ketkar (1990). Properties and uses of neem. *Azadirachta indica. Canadian Journal of Botany*. **68**: 1 –11.

Kraus, W; M. Bokel; A. Klenk; and H. Pohnl (1985). The structure of Azadirachtin and 2,2, 2,3–dihydro–2,3β-methoxyazadirachtin. Tetrahedron letters. **26**: 6435–6438.

Meshram, P. B., Kulkarni N.and Joshi K. C (1994). Antifeedant activity of certain plant products against teak skeletonizer, *Euctona machaeralis* Walk. (Lepidoptera; Pyralidae). *Annals of Entomology* **12** (2): 53-56.

Messiaeh, C. M (1992). The tropical vegetable garden. Macmillan Press Int. 514pp.

Mishra N. C; and S.N Mishra (1996). Performance of brinjal varieties against the fruit and shoot borer, (*Leucenodes orbornalis* Guen.) and wilt, *Fusarium oxysporum* in the North–Eastern Ghat zone of Orissa. *Indian Journal of Plant Protection* **24** (1-2): 3336 pp.

Nagai, D. K; S. Kumar, P. Sharma, R. P Meena, M. L Saini and S. C Goel (1992). Laboratory evaluation of insecticides for the control of *Henosepilachna vigintioctopunctata* Fab. (Coleoptera: Coccinelidae) on brinjal (*Solanum melongena* L). Bioecology and control of insect pests: Proceedings of the National Symposium on Growth, Development and Control Technology of Insect Pests. Utter Pradesh Zoological Society. Muzaffarnagar, India. p. 188-191.

Nagai, D. K; T. Harimatsu and T. Henmi (1988). The effect of Flufenoxuron (benzyl phenylurea) on *Thrips palmi* Karny (Thysanoptera: Thripidae). *Japanese Journal of Entomology and Zoology*. **32** (4): 297-299.

Nakanishi, K (1975). Structure of the insect antifeedant in azadirachtin. *Recent Advances in Phytochemicals*. **9** :283–298.

Nicol, C. M and Schmutterer, M (1991). Kontatwirkungen des samenols des Niembaumes *Azadirachta indica* A. Juss bei gregaren der Wustenhueschrecke *Schistocerca gregaria* Forskal. *Journal of Applied Entomology* **111**: 197-205.

Neelu, S., B. Alka, N. Singh and Bhargawa, A. (1997). Bioefficacy of jatropha curcas against Ailanthus execelsa defoliator *Ateva fabriciella*. Swed. *World weeds*. **4** (1-2): 25-27.

Norman J. C (1992). Tropical Vegetable Crops. Arthur H. Stockwell Ltd. Elms Court 11 Fracombe Deven. 252pp.

Norman, J. C (1974). Eggplant production in Ghana. *The Ghana Farmer*. **17**: 25-27.

Nsowah G. K (1969). Genetic Variation in local and exotic varieties of garden egg (eggplant). Variation in morphological and physiological characters. *Ghana. Journal* *of Scince*. 9: 61-73.

Obeng-Ofori, D. (1997). Survey of indigenous plant as sources of repellents, toxicants, feeding deterrents and protections in storage against stored products pests. NARP report, CSIR, Accra, Ghana. 6pp.

Owusu E. O. (in press). Preliminary biochemical evidence of insectcide resistance development in Ghanaian populations of cotton aphid (Homoptera: Aphididae). *Ghana Journal of Science.*

Owusu-Akyaw, M. (1991). Evaluation of some plant products for the control of cowpea and maize storage insects. Proceedings: International SAFGRAD Research Network Workshop, Niamey, Niger. 8-11.

Owusu-Ansah, F., K. Afreh-Nuamah, D. Obeng- Ofori and G. K Ofosu-Budu (1998). Managing infestation levels of major pest complex of local garden eggs (*Solanum integrifolium*) with neem extracts. Paper presented at the First Biennial Agricultural Research Systems (NARS) Workshop, Accra International Conference Centre, Ghana. 16-20 th November, 1998.

Panda, N; A Mahapatra; and M. Sahoo (1971). Field evaluation of some brinjal varieties for resistance to shoot and fruit borer (*Leucinodes orbonalis* Guen). *Indian Journal of Agricultural Science* 4, 597-601.

Rand-Hawa, N. S and B .S Parma (1993). Neem Research and Development. Society of Pesticide Science, New Delhi, India.

Rao, S. J; K. C. Chitra; P. K Rao and K. S Reddy (1992). Antifeedant and insecticidal properties of certain plant extracts against the brijal spotted leaf beetle, *Henosepilachna vigintioctopunctata*. *Journal of insect science*. **5** (2): 163 – 164.

Reed, D. K. and G. I Reed (1985). Control of vegetable insects with neem seed extracts. *Proceedings. Indiana Academy of. Sciences*. **94**: 335-339.

Rembold, H (1989). Isomeric Azadirachtin and their mode of action. In Arnason, J. T; B. J. R Philogene; P. Morand [Eds] Insecticides of plant origin. ACS Symp. Ser. 387, American Chemistry Society, Washington, DC, p. 150-163 pp.

Rembold, H; H. Forster; C. H. Czoppeth (1987). Structure and bological activity of azadirachtins A and B. In Schmutterer, H; Ascher K. R. S [Eds] Natural Pesticides from the Neem Tree and other tropical plants. Proceedings. 3rd International Neem. Conference. Nairobi, Kenya, (1986). P. 149–160.

Satpathi C. R. and S.S Ghatak (1990). Evaluation of the efficacy of some indigenous plant extracts against *Henosepilachna vigintioctopunctata*. *Environment and Ecology*. **8** (4): 1293–1295.

Sauerwein, M; F. Sporer and M. Wink (1993). Insect-toxicity of phorbol esters from Jatropha curcas seed oil. 41st Annual Congress on medicinal plant research, Dusseldorf, Germany, 31 August-4 September. *Planta-Medica* **59** (7): A686.

Saxena, R. C and A. Basit (1982). Inhibition of oviposition by volatiles of certain plants and chemicals in the leafhopper, A. devatans (Distant.). *Journal of Chemical Ecology*. **8**: 329-338.

Saxena, R. C; G.P. Waldbauer, N. J. Liquido and B. C. Puma (1981). Effect of neem seed oil on the rice leaf folder, *Cnaphalocrocis medinalis*. In Schmutterer, H; K. R. S Ascher; H. Rembold [Eds.]. Natural Pesticides from the Neem Tree (a. indica

Juss). Proceedings. 1st International Neem Conference. (Rottch-Egerm, Germany, 1980) p. 189-204.

Saxena, R. C; Z. T. Zhang and M.E. M. Bonconim (1993). Neem oil effects on courtship signals and mating behavior of brown plant hopper, *Nilaparvata lugens* (Stal) (Homoptera: Delphacidae) females. *Journal Applied Entomology*. **116**: 127–132.

Schmutterer, H. (1990). Properties and potentials of natural pesticides from the neem tree, *Azadirachta indica*. *Annual Review of Entomology*.**35**: 271-297.

Schmutterer, H. (1995). The Neem Tree. Source of Unique Natural Products for Integrated Pest Management, Medicine, Industry and other purposes. VCH Publishers Inc. New York NY (USA) 696 pp.

Schmutterer, H. and K. R. S Ascher [Eds.] (1984). Natural Pesticides fro the Neem Tree and Other Tropical Plants. Proceedings. 2nd International Neem Conference. (Rauischholzhausen, Germany, 1983).

Schroder, R. F. W. and M. M. Athanas (1995). Egg parasitism of Colorado Potato beetle, *Leptinotarsa decelineata* (Say) by *Edovum putteri* Grissel (Hymenoptera: Eulophidae) infesting tomato and eggplant in Maryland. *Pest management in Horticultural Ecosystems*. **1** (1): 1–7.

Singh, Sardar; and M. S. Guram (1967). Trials for the control of brinjal fruit and shoot borer. *Plant Protection Bulletin*. New Delhi. **3**: 13-17.

Solsoloy, A. D. (1995). Pesticidal efficacy of the formulated Physic nut , *Jatropha curcas* L. oil on pests of selected field crops . *Philippine Journal of Science*. **124** (1): 59-67

Som Chaudhary, A.K. (1973). Comparative studies on the effectiveness of two modern insecticides in the control of brinjal shoot and fruit borer. *Pesticides*. 7 (8): 45-46.

Southwood, T. R. E. (1978). Ecological Methods with particular reference to the study of insect populations. Chapman and Hall, Methuen Inc. 733 3rd Avenue, New York, NY 10017. 524pp.

Srinivasan, P.M.; and R.B. Gowder (1959). A note on the control of brinjal fruit and shoot borer *(Leucinodes orbonalis* Guen.). *Indian Journal of Agriculture Sciences*. **29**: 71-73.Srivastavan, L. S and S. C. P and Sachan (1973). Correlation coefficient and path analysis in brijal. *Indian Journal of Agricultural Research*. **43**: 673-675.

Srivastava, L. S. and S. C. P Sachan (1973). Correlation coefficient and path analysis in brijal. *Indian Journal of Agricultural Research*.**43**: 673-675.

Tanzubil, P. B (1991). Control of some insect pests of cowpea (Vigna unguiculata) with neem (*Azadirachta indica* A. Juss) in Northern Ghana. *Tropical Pest Management*. **37** (3): 216-217.

Tanzubil, P. B; H. Schmutterer and K. R. S Ascher (1987). The use of neem products in controlling the cowpea weevil, *Callosobruchus maculatus*. Natural pesticides from the neem tree (*Azadirachta indica* A Juss) and other tropical plants. Proceedings. 3 rd International Neem Conference. Nairobi, Kenya, 10-15 July 1987 p.517-523.

Tattersfield, F., C. T. Gimiham and H. M. Morris (1925). Studies on contact insecticides. Introduction and Methods. *Annals of Applied Biology*. **12**: 60-65.

Taylor, D. A. H.(1984). The chemistry of limonoids from meliaceae. In Zechmeister, L; W. Hertz, H. Greisebach, G. W Kerby [Eds]. Progress in the Chemistry of Natural Products. 45, pp. 1–102, Springer - Verlag, New York NY.

Tommasini, M. A., S .Maini and G. Nicol (1997). Advances in integrated pest management in protected eggplant crops by seasonal inovative releases of *Orius laevigiatus*. *Advances in horticultural science*. **11** (4): 182-188.

Town, P.A. (1964). A summary of vegetable variety trials, Kumasi University of Science and Technology, Faculty of Agriculture, Department of Horticulture Mimeos.

Veeveral, R. P. Baskaram (1995). Succession of insect pests of brinjal (*Solanum melongena*) under unsprayed conditions. *Bulletin of Entomology*. New Delhi. **36** (1-2): 49-56.

Verma,S; B. G. Naik and K.G. Phadke (1993). Occurrence of pest in relation to degradation of insecticides in brinjal crop during summer and Kharif seasons. *Pesticide Research Journal*. **5** (1): 94-103.

Yadav, T. V (1985). Antiovipositional and ovicidal toxicity of neem (*A. indica* Juss) oil against three species of *Callosobruchus. Neem* News letter. **2** (1): 5-6.

Zanno, P. R (1974). The structure of Azadirachtin, a potent insect phagorepellent and systemic growth disruptor from *Azadirachta indica*, studies on ontheridiogens, fern sex hormones, the structure of itesmol, a photosterol from *Thelocactus bicolor*. Ph D. Thesis, Colunbia Univ., New York, NY.

APPENDICES

Appendix 1. ANOVA. No. of holes in fruits

Sources of variation.	Degrees of freedom.	Sums of Squares.	Mean Squares.	F.cal.	F critical.	
					5. %	1 %
Total	19	76.73				
Block	3	3.07				
Treatment	4	40.20	10.50	3.604*	3.26	5.24
Error	12	33.46	2.78			

* Significant at 5 %

Appendix 2. ANOVA. % Bored fruits

Sources of variation.	Degrees of Freedom.	Sums of Squares.	Mean Squares.	F.cal	F critical.	
					5 %	1 %
Total	19	4459.63				
Block	3	70.83				
Treatment	4	3439.87	859.95	10.88* *	3.26	5.14
Error	12	948.93	79.07			

* * Significant at 1 %

Appendix 3. ANOVA. Number of flower buds bored

Sources of variation	Degrees of freedom	Sums of Squares	Mean Squares	F cal	F critical.	
					5 %	1 %
Total	19	32.657				
Block	3	11.338				
Treatment	4	8.798	2.20	2.11ns	3.26	5.14
Error	12	12.521	1.04			

ns Not significant.

Appendix 4. ANOVA. % upper leaf area showing chlorotic symptoms.

Sources of variation	Degrees of freedom	Sums of Squares.	Mean Squares	F cal	F critical.	
					5 %	1 %
Total	19	1.443				
Block	3	0.454				
Treatment	4	0.744	0.186	8.92**	3.26	5.14
Error	12	0.250	0.020			

** Significant at 1 %

Appendix 5. ANOVA. % leaf area defoliated by leaf feeders.

Sources of variation.	Degrees of freedom.	Sums of Squares.	Mean Squares.	F cal.	F critical.	
					5 %	1 %
Total	19	480.33				
Block	3	60.73				
Treatment	4	275.52	68.88	5.74**	3.26	5.14
Error	12	144.03	12			

** Significant at 1 %

Appendix 6. ANOVA. Plant height at flowering

Sources of variation	Degrees of freedom	Sums of Squares	Mean Squares	F cal.	F critical.	
					5 %	1 %
Total	19	1347.66				
Block	3	153.00				
Treatment	4	229.81	57.45	0.71ns	3.26	5.14
Error	12	964.84	80.40			

ns Not significant.

Appendix 7. ANOVA. Marketable fruit wt. (g) per plant.

Sources of variation	Degrees of freedom	Sums of Squares	Mean Squares.	F cal.	F critical	
					5 %	1 %
Total	19	4085994.64				
Block	3	1071270.73				
Treatment	4	2054068.26	513517.07	6.41**	3.26	5.14
Error	12	960655.66	80054.64			

** Significant at 1 %

Appendix 8. ANOVA. Marketable fruit weight (g).

Sources of variation	Degrees of freedom	Sums of Squares	Mean Squares	F cal	F. critical	
					5 %	1 %
Total	19	25592.36				
Block	3	1455.60				
Treatment	4	13060.38	3265.00	3.54*	3.26	5.14
Error	12	11076.38	923.03			

* Significant at 5 %

Appendix 9. ANOVA. Number of fruits per plant.

Sources of variation	Degrees of freedom	Sums of Squares	Mean Squares	F cal	F. critical	
					5 %	1 %
Total	19	77.422				
Block	3	19.78				
Treatment	4	30.587	7.65	3.43*	3.26	5.14
Error	12	26.853	2.23			

* Significant at 5 %

Appendix 10. ANOVA. Yield in tonnes per hectare.

Sources of variation	Degrees of freedom	Sums of Squares	Mean Squares.	F.cal.	F. critical	
					5 %	1 %
Total	19	408.61				
Block	3	107.09				
Treatment	4	205.42	51.36	6.41**	3.26	5.14
Error	12	96.01	8.00			

** Significant at 1 %

Appendix 11. ANOVA. Number of thrips per treatment.

Sources of variation	Degrees of freedom	Sums of Squares	Mean Squares	F cal	F. critical	
					5 %	1 %
Total	19	46.607				
Block	3	2.200				
Treatment	4	26.747	6.687	4.54*	3.26	5.14
Error	12	17.660	1.472			

* Significant at 5 %

Appendix 12. Effect of jatropha aqueous seed extract and oil on *A. gossypii, S. dicilis* and *U. hystericellus*

Concentration	No. of insects	Mean ± SE no. dead	% Mortality
A.gossypii (oil ml/l)			
0	10	0	0
1	10	3.3± 0.12	33.3
2	10	3.7 ± 0.11	36.7
3	10	4.7 ± 0.78	46.7
4	10	7.3 ± 0.25	73.3
5	10	8.7 ± 0.11	86.7
A.gossypii (aq extract g/l)			
0	10	0	0
20	10	3.7 ± 0.77	36.7
40	10	6.7 ± 1.00	66.7
60	10	6.7 ± 0.77	66.7
80	10	9.3 ± 0.44	93.3
100	10	9.3 ± 0.11	93.3
S. docilis (oil ml/l)			
0	5	0	0
1	5	0.6± 0.13	12
2	5	4 0 ± 0.12	80
3	5	4.6 ± 0.25	92
4	5	5.0 ±0.11	100
5	5	5.0 ± 0.00	100
6	5	5.0 ± 0.00	100
7	5	5.0 ± 0.00	100
8	5	5.0 ± 0.00	100
S. docilis (aq.extract g/l)			
0	0	0	0
20	7	3 0± 0.30	42.7
40	7	5.6 ± 0.41	80.0
60	7	5.6 ± 0.10	80.0
80	7	6.3 ± 0.22	90.0
100	7	6.7 ± 0.15	95.7
U. hystericellus (oil ml/l)			
0	8	0	0
1	8	0.7 ± 0.11	8.4
2	8	2.3 ± 0.44	42.1
3	8	3.7 ± 1.44	46.9
4	8	4.3 ± 0.11	54.1
5	8	5.0 ± 0.35	62.5
6	8	5.0 ± 0.33	62.5