FIELD EVALUATION OF NEEM SEED EXTRACTS FOR THE CONTROL OF MAJOR COWPEA PESTS IN NORTHERN GHANA

BY

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Declaration

I hereby declare that this work is entirely the result of my own research and has not been presented elsewhere for the award of a degree. References to other people's works have been duly cited.

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Dedication

This work was dedicated to

My dear parents, *Mr. and Mrs Badii,*

My dear brother, *Mr. Issac Badii,*

And

My beloved wife, *Mrs Rose B. Radii*

For innumerable reasons.

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List of Abbreviations

ANSE: Aqueous Neem Seed Extract

ANOVA: Analysis of Variance

AZ: Azadirachtin

DAE: Days After plant Emergence

DMRT: Duncan's Multiple Range Test

EC: Emulsifiable Concentrates

IGR: Insect Growth Regulators

IITA: International Institute of Tropical Agriculture

IPM: Integrated Pest Management

NSKE: Neem Seed Kernel Extract

PBIs: Plant-Based Insecticides

PSBs: Pod-Sucking Bugs

RCBD: Randomized Complete Block Design

RVE: Rapid Visual Examination

SARI: Savanna Agricultural Research Institute

WP: Wettable Powders

Abstract

Field studies were conducted at the Experimental Farms of the CSIR-Savanna Agricultural Research Institute (SARI), Nyankpala, Northern Ghana, during the 2004 cropping season, to evaluate the effect of aqueous neem (*Azadirachta indica* A. Juss) seed extracts at 5%, 10%, 15% and20% on major insect pests namely; *Aphis craccivora* Koch., *Megalurothrips sjostedtri* Tyrb., *Maruca vitrata* Fab., and a complex of pod- and seed sucking bus and their effect on grain quality and fodder yield of copea (*Vigna unguiculata* L. Walpers). The incidence and abundance of all the target insect pests were significantly affected in a dose-dependent manner by the neem seed extract treatments. Cowpea grain y8ield was significantly higher in all neem-treated plots than the control plot. The 15% neem seed extract treatement proved as effective as that of the 20% in increasing the grain yield of the cowpea crop. However, none of the neem seeed extract treatements was comparable to the synthetic inseciticide (Karate) in terms of copwera grain yield. Grain quality obtained from the 15% or the 20% neem extract treatements was however as high as that obtained from the Karate insecticicde treatment. Cowpea fodder yield was found to decrease with incraing concentration of the extract, with the 5% extract treatment recording the highest fodder yield. Cost-benefit analysis from the grain and fodder yields indicated that the 15% extract treatment recording the highest fodder yield. Cost-benefit analysis from the grain yields indicated that the 15% and 5% neem extract treatments respectively, gave the best cost-benefit ratio. This seemed to suggest that 5% and the 15% neem seed extract treatments were the most profitable for use in controlling the mjor field pest of the cowpea crop for maximum economic returns in cowpea as fodder and grain, respectively, in the stud area.The Savanna Agricultural Institute (SARI) has made it and objective to develop a more comprehensive Integrated Pest Management (IPM) strategy for cowpea farmers in the savnna ecology of Ghana, using low-cost and residue-freee natural insecticides. The use of aques oextracts fro, neem seeds is thus, a possible innovation in this direction. The implication attempt to further contribute to knowledge in the use of neem se detracts in the control of cowpea pest in Ghana.

CHAPTER ONE

INTRODUCTION

Cowpea, *Vigna unguiculata* (L. Walpers), is one of the most important grain legumes widely cultivated in the tropics for human consumption, as livestock feed and for soil nitrogen enrichment (Singh and van Emden, 1979). One major constraint to the increased and sustainable production of cowpea in most of its geographical distribution is damage caused by insect pests (Singh *et al.*, 1990). Among the most serious field insect pest species that infest cowpea in the savanna ecology include the black cowpea aphid, *Aphis craccivora* Koch (Homoptera: Aphididae); the cowpea flower thrips, *Megalurothrips sjostedti* Tryb. (Thysanoptera: Thripidae); the legume pod borer, *Maruca (testulalis) vitrata* Fab. (Lepidoptera: Pyralidae); and a complex of pod-and seed-sucking bugs such as *Riptortus dentipes* Fab. (Heteroptera: Alydidae), *Clavigralla tomentosicollis* Stal., *Anaplocnemis curvipes* Fab., *Mirperus jaculus* Fab. (Heteroptera: Coreidae), and *Nezara viridula* L. (Heteroptera: Pentatomidae) (Jackai and Daoust, 1986).

The use of synthetic pesticides in the control of these pests has often generated more problems than provided solutions. Apart from their high cost and unavailability in local markets (Karungi *et al.*, 2000), their indiscriminate use has often resulted in mammalian poisoning, elimination of beneficial organisms, environmental pollution and the resurgence of more pests due to the development of resistance (Ascher, 1993). Although sources of resistance to some insect pests of cowpea have been identified, improved cultivars resistant to some cowpea pests are not yet widely available to growers (Saxena and Kidiavai, 1997). Alghali (1992) reported that the use of cowpea varieties resistant to insect pests did not contribute to any significant reduction in yield loss, which reached as much as 75% when thrips attacked cowpea during the flower bud and flower stages. Other biointensive strategies, such as biological control and habitat management by the use of mixed cropping (intercropping) systems, or the establishment of trap crops have been proposed, but their effectiveness seems to be site-, season-, crop- or pest-specific (Matteson, 1982; Mensah, 1988; Kyamanywa *et al.*, 1993; Ampong-Nyarko *et al.*, 1994; Ezueh and Taylor, 1994). Because of these concerns, there has been the need to develop more locally available, environmentally friendly and socio-economically sustainable pesticides, especially, those of plant or botanical origin.

Among the numerous plant ingredients studied over the years, seed extracts from the neem tree, *Azadirachta indica* A. Juss (Meliaceae), have attracted the special interest of entomologists and phytochemists throughout the world (Schmutterer, 1990). Several studies have demonstrated that neem seed products are effective in suppressing insect pest damage in grain legumes, especially, in cowpea. Aqueous extracts from neem seed have effectively controlled pod-sucking bugs (Jackai *et al.*, 1992; Tanzubil, 2000), the legume pod borer, *M vitrata* (Bottenberg and Singh, 1996), the cowpea flower thrips, *M. sjostedti* (Saxena and Kidiavai, 1997), the vegetable green bug, *N. viridula* (Abdulai *et al.*, 2002), and the black cowpea aphid, *A. craccivora* (Lowery *et al.*, 1993).

Results from numerous field trials have shown that the intensity of the effect of neem products on these pests is dependent on the concentration (w/v) of the extract as well as the species of insect tested (Schmutterer, 1990; Ivbijaro, 1990). Available results have own that different authorities have recommended different concentrations of the extracts as effective against the major field pests of cowpea. However, no comprehensive research has been conducted to standardize the concentration of aqueous extracts from the neem seed so as to achieve the most effective a4d economic control of the field pest-complex of cowpea in both the forest and the savanna ecologies of Africa in general and Ghana in particular. For instance, it has been demOnstrated in Eastern Nigeria that both 5% and 10% concentrations of the seed extracts significantly reduced pod damage by insect pests, (Emosairue and Ubana, 1998). Inspite of that, at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, the 10% solution has been considered as the recommended concentration for most field trials on cowpea pests (Jackai *et al.,* 1992). Also, Tanzubil (2000) evaluated the extract at 5% and 10% and reported that the 10% solution was more efficacious against flower thrips, pod borers and pod-sucking bugs in Ghana, but no economic analysis was performed. However, Schmutterer (1990) reported that 10% concentration does not provide satisfactory control of the major cowpea pests owing to their differences in susceptibility and time of occurrence. Cobbinnah and Osei-Owusu (1988) however, observed some level of phytotoxicity and high mortality of beneficial insects from the 20% seed extrct treatment on cowpea and garden eggs.

Current cowpea pests control at the CSIR-Savanna Agricultural Research Institute (SARI), Nyankpala, has been based on the 5% solution, and this has been recommended reported cases of unsatisfactory results from the use of the 5% seed extract (Asante, Personal Communication). Since the different species of cowpea pests are capable of occurring at different times of the season and at different growth stages of the crop, with varying levels of susceptibility, it is not known whether one concentration of the extract would be economically effective against all these pests or different concentrations would be required for the different pest species under field conditions. This has called for the need to standardize the concentration of aqueous extracts from the neem seed for the control of the major field pests of cowpea in the savanna ecology of Ghana.

The current studies have therefore been designed to find out the most appropriate or standard concentration of aqueous neem seed extracts that can be used to achieve effective control of the major field pests of cowpea for maximum economic returns in the northern guinea savanna agroecological zone of Ghana. This would help to make better recommendations to farmers on the use of neem products in controlling cowpea insect pests so as to help increase and sustain its production in the area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Economic Importance of Cowpea

Cowpea is of great importance to the livelihoods of millions of relatively low-income groups in the less developed countries of the tropics. Farm families derive food, animal feed, income and spillover benefits from its production. The fresh young leaves and immature pods are used as vegetables. Several snacks and main meal dishes are also prepared from the grain. All the plant parts are nutritious sources of food, providing protein (23-25% in grain), carbohydrates (50-67% in grain), some vitamins and minerals (Singh and Rachie, 1985). Petty trading of the fresh leaves and pods, grains and processed produce provides income for both rural and urban communities. Farmers also harvest and store cowpea haulms for subsequent sale as animal fodder, for income especially at the peak of the dry season. Grain and fodder yields of 2-4t/ha and 0.5-4 t/ha, respectively are common in Africa (Singh *et al.*, 1997).

Cowpea has also been known as the pivot of sustainable farming throughout Africa. In West and Central Africa, farming is generally dependent on rainfall. Agricultural lands are characterized by systems of farming that make use of limited purchased inputs, and the soils are relatively poor textured with low inherent fertility. Intercropping cereals with cowpea is widely practiced under such conditions. The cowpea crop provides ground cover, smothers the weeds and protects the soil against erosion. Some cowpea varieties also cause suicidal germination of the seeds of *Striga hermonthica,* a devastating parasitic weed that occurs in most cereal farms in Africa (Singh *et al.*, 1997). After harvesting the grain, the above ground parts as well as the roots may be allowed to decay *in situ* and this helps to increase the organic matter and nutrient content of the soil (Duke, 1990). Cowpea is also rotated with cereal crops in different seasons to enable the cereal crop to derive maximum benefit from the improved soil conditions resulting from the cowpea crop (Singh and Rachie, 1985).

Another important feature of cowpea is its symbiotic fixation of atmospheric nitrogen with the root nodule bacteria, *Bradyrhizobuim* spp. Many experimental findings indicate that soil nitrogen levels increase following cowpea cultivation. A contribution of 40-80kg N/ha is commonly obtained while the total amount of nitrogen fixation is 70-350kg/ha (Singh *et al.*, 1997). Cowpea therefore serves as the fulcrum for sustaining crop and animal production and enhancing household food security in Africa, and there is no evidence that the presence and importance of this crop in our farming systems and economic life will diminish in the foreseeable future (Jackai and Adalla, 1997).

2.2 Field Insect Pests of Cowpea

Cowpea, despite its economic importance in the tropical world, is among the many crops that suffer serious pest infestation, stretching from germination till harvesting and during storage. It is common knowledge that field pests attack usually leads to total crop failure if no appropriate control measure is affected. The pest-complex of cowpea ranges from two to more than four key pests, often including as many as four minor or sporadic pest species. Different pest guilds specialize on every part of the plant, and in the worst cases these pests overlap in their incidence and damage. It is therefore not uncommon to find four or more different pest species on the crop at the same time under the same growth stage and condition (Jackal and Adalla, 1997) (see Figure 1).

Figure 1: Cowpea growth stages and pest incidence at each stage.

Growth Stage	Days After Planting (DAP)	Insect Pests
Foliage	■■■■■■■■	Leaf aphids, leafhoppers, grasshoppers, foliage beetles
Flower bud initiation	■■■■■■■■	Flower thrips
Flowering	■■■■■■■	Flower thrips, pod borers
Early Podding	■■■■■■■	Pod borers, pod-sucking bugs
Late Podding	■■■■■■	*Apion* spp., *Callosobruchus* spp.
Spraying by Growth Stage	• • • •	

20 30 40 50 60 70 80 DAP

Source: Jackai and Adalla, 1997.

The most damaging of all field pests usually encountered in most cowpea farms in tropical Africa are those that occur during the seedling, flowering and pod bearing stages. They include the black cowpea aphid, *Aphis craccivora* Koch. (Homoptera: Aphididae); the bean flower thrips dominated by *Megalurothrips sjostedti* Tryb. (Thysanoptera: Thripidae); the legume pod borer, *Maruca (testulalis) vitrata* Fab. (Lepidoptera: Pyralidae) and a complex of pod-and seed-sucking bugs in which *Riptortus dentipes* Fab. (Heteroptera: Alydidae), *Clavigralla tomentosicollis* Stal. *Anaplocnemis curvipes* Fab.*Mirperus jaculus* Fab. (Heteroptera: Coreidae) *and Nezara viridula* L. (Hemiptera: Pentatomidae) are the dominant species (Tanzubil, 2000). Other pests of minor importance include the cowpea curculio, *Chalcodermus* spp. (Coleoptera: Curculionidae) and the beanfly, *Ophiomyia* spp. (Diptera: Agromizidae) (Singh *et al.*, 1997). It is also not uncommon to find specialized, location-specific pests species such as *Amsacta moore* Butler (Lepidoptera: Arctiidae) (Ndoye, 1980); *Apion* spp. (Coleoptera: Apionidae) and *Akidoles leucocephlus* Erichson (Coleoptera: Curculionidae) (Nonveiller, 1984) (see Table 1).

Table 1: Major insect pest species found on cowpea in Africa.

Pest Species (Order: Family)	Goegraphical Distribution	Plant Parts Attacked	Importance
Aphis craccivora Koch (Homoptera: Aphididae)	Cosmopolitan	Leaves, stems	Major
Empoasca dolichi Paoli (Homoptera: Cicadelidae)	West Africa	Leaves	Minor
Empoasca kraemri Ross and Moore (Homoptera: Cicadelidae)	South Africa	Leaves	Major
Ophiomyia phaseoli Tryb. (Diptera: Agromyzidae)	Asia, Africa	Leaves, Stems	Major (Asia); Minor
Amsacta moorei Butler (Lepidoptera: Arctiidae)	Africa (Senegal)	Leaves	Minor
Megalurothrips sjostedti Tryb. (Thysanoptera: Thripidae)	Africa, Asia, Americas	Floral Structures	Minor (Asia, America);
Maruca vitrata Fab. (Lepidoptera: Pyralidae)	Cosmopolitan	Flowers, Pods	Major
Clavigralla tomentosicollis Stal. (Heteroptera: Coreidae)	Africa, Asia, South America	Pods	Minor (Asia, America);
Nezara viridula Linnaeus (Heteroptera: Pentatomidae)	USA, Africa, Asia	Pods	Major
Chalcodermus spp (Coleoptera: Curculionidae)	South America, USA, Africa (rare)	Pods	Major
Callosobruchus spp (Coleoptera: Curculionidae)	Africa, Asia	Pods, Grains in storage	Major

Source: Jackai and Adallah, 1997.

The pest problem of cowpea is clearly more severe in Africa than elsewhere, probably because many of the pests are considered indigenous and / or have had ample time to co-evolve with the crop in their centres of origin and domestication (Ng and Marechal, 1985).

2.3 Field Pest Management Strategies for Cowpea

The management strategies for cowpea pests in the field now involve a biointensive Integrated Pest Management (IPM) system in which the most logical combination of different compatible control tactics are utilized (Jackai and Adalla, 1997). The major components include: chemical control, host-plant resistance, biological control, environmental management practices and the use of bio-pesticides.

2.3.1 Chemical Control

Chemical control using insecticides is the most widely known form of pest control on cowpea in Africa. Seed treatment and foliar sprays are the most common forms of chemical pests control on cowpea in the field (Booker, 1965).

Seed treatment: Damage by beetles, leafhoppers and birds, is usually avoided by treating cowpea seeds with an insecticide dust or slurry before planting (Breniere, 1967). Detailed studies conducted with Carbosulfan show that as little as 10g/kg of seed is required to protect cowpea seedlings from aphids, foliage beetles and tunneling herbivores such as beanflies for 3 weeks in the greenhouse and for longer periods under field conditions (Jackai *et al.,* 1988). More recently, another seed dressing, Apron®, was evaluated using two cowpea cultivars, one susceptible (Vita 7) and the other resistant (1T8452246) to *A. craccivora* (Adalla, 1994). The combination of varietal seed treatment was found to be additive, which extends over considerable periods (Ansari, 1984). Other seed dressings that were popular in the past, such as Fernasan-D® and Aldrex-T®, are no longer recommended because of their organochloride contents. Liquid seed dressings are usually more toxic than dusts, and require special devices for mixing. Dust formulations such as Carbosulfan can be applied to seed in small quantities (> 1 kg), using paper bags or covered cans. An additional advantage of seed dressing is that it has minimal impact on parasitoids and predators and it can therefore be used in conjunction with biological control practices. Proper use of seed dressing ensures good initial plant stands, which are critical to successful farming. Its major setback is the potential dangers posed to people who consume cowpea leaves especially at the pre-flowering stages (Jackai and Adalla, 1997).

Foliar Sprays: Many insecticides used on cowpea are foliar sprays, either as Emulsifiable Concentrates (EC) or Wettable Powders (WP). Several of these chemicals are effective against most cowpea pests, although there is greater specificity, in some cases, among specific groups; a distinction related to the feeding behaviour of the different pests. The most commonly used insecticides include Endosulfan, Lambda-cyhalothrin (Karate), Cypermethrin, Permethrin and Dimethoate (Table 2). Despite their differential efficacy, most of these chemicals will increase cowpea yield by tenfolds with 2-4 applications (Afun *et al.*, 1991). The more versatile and less expensive low-volume knapsack sprayer has remained the dominant sprayer for use in the drier savannas where most cowpea is cultivated.

Table 2: Some commonly used insecticides for pest control on cowpea

Common Name (Chemical Group)	Trade Name	Target Pest
Lambda-cyhalothrin (synthetic	Karate	Foliage beetles, flower thrips, pod borers, pod bugs
Cypermethrin (synthetic pyrethroid)	Cymbus, Serpa	Flower thrips, pod borers, pod bugs
Deltamethrin (synthetic pyrethroid)	Decis	Flower thrips, pod borers, pod bugs
Cypermethrin + Dimethoate (synthetic pyrethroid +organophosphate)	Serpa +Cymbus Serpa	All cowpea pests
Monocrotophos (organophosphate)	Azodrin, Nuvacron	Beanflies, leafhopper, aphids (in Asia), flower thrips, pod bugs
Endosulphan (organochlorine)	Thiodan, Perfekthion	Pod borers, pod bugs, beetles, leafhoppers
Carbofuran (Carbamate)	Furadan	Flower thrips, leafhoppers, aphids, beetles, beanflies
Carbosulfan (Carbamate)	Marshal	Flower thrips, leafhoppers, aphids, beanflies, beetles
Carbaryl (carbamate)	Sevin	Pod borers, other lepidopteran pests
Aluminum phosphide (fumigant)	Phostoxin, Detia, Gastoxin	Storage pests
Permethrin (synthetic pyrethroid)	Coopex	Storage pests
Pirimiphos-methyl +Permethrin (organophosphate+ synthetic pyrethroid)	Actellic, Actellic super	Storage pests
Deltamethrin (synthetic pyrethroid)	K-othrin	Storage pests

Source: Singh *et al.*, 1997

Insecticide use in cowpea will always be an element of controversy, but its use will never be completely eliminated without a substitute that gives comparable results; as of now, there is none. In the end, it is perhaps, those farmers that can afford the cost of chemical control who will influence the future of pesticide use on cowpea. Their influence creates a market for chemicals, thereby making insecticide use by others inevitable. There is therefore the need to make the use of the chemicals less attractive by providing more viable and realistic alternatives of pest control on cowpea (Jackai and Adalla, 1997)

Many authors have however acknowledged the fact that the use of synthetic pesticides in the control of cowpea pests sometimes generates more problems than provides solutions. Apart from their high cost and unavailability in local markets (Karungi *et al.*, 2000), their indiscriminate use has often resulted in mammalian poisoning, elimination of beneficial organisms, environmental pollution and resurgence of more pests due to the development of resistance (Ascher, 1993). This has called for the need to develop more locally available, environmentally friendly and socioeconomically sustainable pesticides especially those of plant or botanical origin (Jackai, 1993).

2.3.2 Host - plant Resistance

Resistance to seedling pests was first reported after evaluating a few hundred germplasm accessions from the gene bank at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Resistance to aphids has been identified in the Tvu nos. 36, 408, 801 and 3000 cowpea cultivars (Singh, 1980). According to Ansari (1984), resistance to these accessions is due to antibiosis. Most aphid resistant cowpea cultivars were developed from crosses involving either Tvu 3000 or Tvu 36. The potential weakness in the cultivars is the narrow resistance base, since it is controlled by a single dominant gene (Singh and Ntare, 1985). Cowpea seedlings resistant to the beanfly have also been studied in Philippines and Taiwan (IITA, 1986).

Plant resistance, however, does not provide adequate protection against post-flowering pests of cowpea because many insects that attack the crop at the reproductive stage are either oligophagous or sternophagous in their host range, with a few being narrowly polyphagous, and the development of resistant varieties against the pests has eluded efforts over the years (Jackai and Adalla, 1997). With the emphasis on the wild relatives of cowpea, intensive and systematic screening has resulted in the identification of good levels of resistance among the wild *Vigna* spp. Those that can be easily crossed to cultivated cowpea, have already been used in hybridization programmes that seek to pyramid the genes for partial resistance, both in the cultivated group, on one hand, and in the uncultivated group in the *V. unguiculata* subspecies *dekintiana*, on the other (Singh *et al.*, 1997).

2.3.4 Use of Biological control

Natural pest control agents have played an important part in ensuring that field cowpea pests are contained as much as possible. However, not much has been studied about these agents and their impact on cowpea pests. Bottenberg *et al.*, (1997) observed that more attention is being directed towards this important subject. Given the status quo, there is no known case where biocontrol agents, either arthropods or pathogens have been deliberately introduced for the control of cowpea pests. However, Tamo *et al.* (1997) reported that the future landscape of pest control on cowpea would include the introduction, conservation and augmentation of natural enemies. This implies that the overall equation of pest control on cowpea will also change and thus, promote biodiversity and sustain environmental quality (Singh *et al.*, 1997).

2.3.5 Environmental Management Practices

Pest control tactics for cowpea that involve manipulating the insect's environment are well known among traditional cowpea growers who have practiced these for ages, usually for different reasons, than those proposed by scientists (Richards, 1985). Several of these agronomic or cultural interventions are used in different parts of the tropics but the greatest diversity is in the African sub-tropics (Okigbo and Greenland, 1976).

One of the most commonly used methods of environmental management in cowpea farms is intercropping (Singh *et al.*, 1997). The scientific basis for intercropping as a tactic in the management of cowpea pests is that with an increase in vegetal diversity in the agroecosystem, there is usually a corresponding decrease in pest population density which generally leads to stability of the system (Jackai and Adalla, 1997). Even though plant species diversity results in a reduction of pest population (Ballidawa, 1985); not all intercropping with cowpea may confer entomological advantage. Blister beetles and seed suckers, for example, increase in population when cereals and cowpea were intercropped in Nigeria (Matteson, 1982). In a study in Kenya, insect pest populations, including those of thrips, were reported to be lower in sorghum/cowpea/maize intercrops than in pure cowpea stands (Dissemond and Hindorf, 1990), but in another study, no significant reduction in thrips activity and population density was observed in cowpea/maize mixed crops during the colonization phase (Ampong-Nyarko *et al.*, 1994). In Nigeria, the pest control potential of intercropping was found to be variable and highly dependent on environmental factors (Matteson, 1982). Simultaneous planting of maize and cowpea tended to increase cowpea infestation by the legume pod borer, *M. vitrata*, and the flower thrips, *M. sjostedti,* while interplanting of cowpea several weeks after maize had been planted also markedly increased the thrips incidence in the intercrop (Ezueh and Taylor, 1994).

Other agronomic practices have also been adopted, because they help reduce damage caused by pests, sometimes due to increase in natural enemy activity (Letourneau, 1990). Such control interventions, which could appropriately be referred to as cultural control methods, vary from one ethnic group to another and are truly culture-dependent. These include date of sowing, tillage, mulching, crop residue management and trap cropping (Litsinger and Ruhendi, 1984). Generally, these interventions have no adverse effect on the environment or their user. Their efficacy is quite variable, but they should work well in combination with resistant cultivars (Jackai and Adalla, 1997).

2.3.6 Use of Biopesticides

The problem posed by conventional insecticides has shifted research interest to the use of plant-derived insecticides in controlling cowpea pests in Africa. Neem is one of the many plants in the African landscape that has been investigated as a source of pest control on several food crops (Schmutterer, 1990). Although most research work on this aspect of plant protection has dwelled on protection of cowpea grain (Ivbijaro, 1983) and maize (Kossou, 1989) in storage, there has been increasing interest in the application of Plant-Based Insecticides (PBIs) against field pests (Schmutterer, 1990). Extensive use has been made of neem extracts to control field pests of rice in Asia (Saxena, 1989) and cassava in West Africa (Olaifa and Adenuga, 1988). The main groups of insects that show sensitivity to PBIs include Lepidoptera, Coleoptera, Diptera (Agromyzidae) and Orthoptera (Schmutterer, 1988).

Current work on the use of PBIs on cowpea is dominated by neem. The impetus of this work came from the result of intensive laboratory research at IITA, and elsewhere, which show high activity against two of the major pests of the crop, *M. vitrata,* and *C. tomentosicollis* (Jackai *et al.,* 1992). In Ghana, Cobbinah and Osei-Owusu, (1988) and Tanzubil (1991, 2000) have demonstrated that neem has great potential as a field insecticide for use on cowpea. Whereas the emphasis in the past was on using the kernel or seed, recent work at IITA has included the leaf extracts, to utilize the abundance of neem leaves in most cowpea growing localities. A number of neem-based commercial insecticides are now available in many countries, especially in India, USA and Germany. In the Philippines, other plants, including *Vitex negundo, Derris* spp and *Tinospora rumphi* have shown varying levels of toxicity against a wide range of field pests (Jackai and Adalla, 1997).

The interest in PBIs is driven mostly by need and economics. There is a gap created by the inaccessibility of conventional insecticides. An additional incentive to explore these and other protectants such as vegetable oils (e.g., groundnut oil and *Dinnetia* oil) (Singh *et al.*, 1979; Tanzubil, 1987) is their perceived compatibility with the environment and other pest management interventions (Schmutterer, 1990). PBIs are generally not as effective as their synthetic counterparts, but their use can be augmented with other controls such as natural enemies (predators and parasitoids) and entomopathogens to provide acceptable levels of protection under field and storage conditions (Schmutterer, 1990).

2.4 The Origin, Characteristics and Distribution of the NeemTree

The neem tree, *Azadirachta indica* A. Juss (syn. *Antelaea azadirachta, Melia azadirachta)* belongs to the Meliaceae (mahogany) family. Its centres of origin lie in southern and southeastern Asia. It also occurs in the tropical and subtropical areas of Africa, America and Australia. During the last 30 years, neem has been introduced into many countries mainly for aforestation and fuel wood production and also for other purposes, including its use as an avenue or shade tree and as a producer of natural pesticides (Schmutterer, 1990).

The neem or margosa tree, also called Indian lilac, is an evergreen or deciduous, fast growing plant, which may reach a height of 25 m. The neem leaves are usually medium green, unpaired pinnate and may reach the length of 30 cm. The asymmetric, serrate leaflets number 7 to 17 and are up to 7 cm long. The fragrant flowers are white and small. The tree thrives primarily in tropical climates that have an annual rainfall of 400-800 mm with an extended dry season. Neem can tolerate severe droughts and poor shallow and even saline soils (Ketkar, 1976).

The matured tree produces fruits in drooping panicles, usually once a year, or sometimes twice. The fruits are oval (1.4 cm to 2.4 cm long) and when ripe have yellowish sweet pulp that encloses a brown seed kernel embedded in a hard white shell. Annual fruit yield of a mature tree may reach 50kg depending on environmental factors such as rainfall and soil conditions (Ketkar, 1976). Trees of 8 to 10 years of age yield ca. 9kg of fruits; trees of 15-20 years old yield ca. 13kg of fruits and trees above 20 years old yield ca. 19kg of fruits (Ascher, 1993). In West Africa (e.g. Nigeria), an average fruit yield of about 20.5kg/tree was obtained and seed kernel weight accounted only for about 10% that of the whole fruit (Schmutterer, 1990).

2.5 Active Ingredients in Neem

Mainly owing to its various effects on insects, azadirachtin (AZ) is considered the most important active principle in neem seed kernel. The quantity of this compound however varies depending on the environmental factors and genetic constitution. The highest yield of AZ obtained up to date was about 10g/kg of seed kernels (Schmutterer, 1990). Azadirachtin has deterrent, antiovipositional, antifeedant, growth disrupting, fecundity- and fitness-reducing properties on insects (Ascher, 1993). Azadirachtin is a steroid-like tetranortriterpenoid (limonoid). It is known to be formed by a group of closely related isomers called AZ A to AZ G. Azadirachtin A is the most important compound in terms of its quantity in neem seed kernel extracts. Azadirachtin E is regarded as the most effective insect growth regulator (IGR) (Rembold, 1989).

A considerable number of other active compounds such as salannin, salannol, salannolacetate, 3-deacetylsalannin, azadiradion, 14-epoxyazadiradion, gedunin, nimbinen and deacetylnimbinen were also isolated from the seed kernel (Jones *et al.,* 1989). Most of these compounds showed antifeedant activity in numerous insect biotests (Steets, 1976). IGR effects were also seen in other neem ingredients namely 22-23-dihydro-23 13-methoxyazadiractin, 3-tigloylazadirachtol and 1-tigloy1-3-acety1-11-methoxyazadirachtin (Kraus *et al.,* 1987).

Some vilasinin derivatives with strong antifeedant activities were also isolated from neem seed oil (Kraus *et al.*, 1987). Other compounds with similar properties from the same source are meliantriol, azadiradione and 14-epoxyazadiradoin (Lavie *et al.*, 1967) as well as 6-0-acetylnimbandiol, 3-deacetylsannin and acetylazadirachtinol (Kubo *et al.*, 1986). The IGR effects of the latter in most insects were as strong as those of AZ.

2.6 Neem Products and their Insecticidal Properties

Although the bark, hardwood, leaves, fruits and seeds of neem have been investigated chemically as to their main constituents, it is the renewable parts of the tree, namely seeds and leaves which have received major attention. Neem seed oil, an Indian commercial product, extracted by steam, solvents or mechanically extruded from the milled or crushed seeds, was a major starting point for most chemists. The seed kernel constitutes little more than 10% in weight of the fresh fruit, and the oil content in the kernel varies from 17% to 60% (Ascher, 1993). The triglyceride fraction of the seed oil has been investigated, mostly quantitatively in early works, by gas chromatography and has been known to contain chiefly oleic acid, followed by stearic and palmitic acids (Jones *et al.*, 1989). Apart from these and some sulphur-containing componds, all the well-characterized compounds identified in neem are triterpenoids or tetranortriterpenoids. It can be inferred from the chemical arrangement of the methyl groups at c-10, c-13 and c-14, and the side chain at c17, that all neem triterpenoids are derived from the parent tetracyclic triterpenoid tirucallol. Although this compound was never isolated from any neem product, all the numerous tetraterpenoids isolated and characterized from neem can be considered as successive arrangement and oxidative products of this compound (Jones *et al.*, 1989). Although neem leaves and bark are also used for pest control due to their abundance and ease of accessibility (Bottenberg and Singh, 1996), their active principles as compared to those of the seeds are considered rather very low (Schmutterer, 1990).

2.7 Insecticidal Effects of Neem Products

The nonconventional insecticidal and insectistatic effects of neem are manifold and include a gamut of physiological and behavioural manifestations in insects (Schmutterer, 1988, 1990). These effects generally depend on the concentration of the active principles and the species of insect tested (Schmutterer, 1990). The most important effect of AZ on insects from the applied viewpoint can be discussed as follows:

2.7.1 Settling behaviour

Settling behaviour, in this case, has been defined as the ability of the target insect to alight on the neem-treated plant for feeding and / or oviposition within the residual life period of the neem product (Ascher, 1993). Settling repellency exerted by neem-treated plants has been encountered in Lepidoptera, Diptera and Coleoptera, and this has been put to good and intensive use by the Indian tobacco-growing authorities, which recommend treating tobacco nurseries with neem to deter settling and oviposition by the leafworm *Spodoptera litura* Fab. (Joshi, 1987). Also, after an ultra-low volume application of 3% of neem seed oil, fewer adults of the brown rice planthopper, *Nilaparvata lugens* Stal. alighted on treated rice plants. For these olfactory repellent effects, no contact with the treated plants was possible (Heyde *et al.*, 1984).

2.7.2 Oviposition behaviour

The females of some lepidopterous insects are repelled by neem products on treated plants or other substrates and will not lay eggs on them under laboratory conditions. This has been observed in the cabbage webworm, *Crocidolomia binotalis* Zell., in which crude alcoholic diluted extracts of dried neem leaves were found to olfactorily repel females from treated cabbage leaves at a distance of about 25 cm (Fagoonee, 1981). The volatiles of neem seed kernels and their aqueous distillates offered at a distance also prevented contact and repelled the Afro-Asian cotton bollworm, *Helicoverpa armigera* Hb. and the fall armyworm, *Spodoptera frupperta* J.E. S. (Saxena, 1989).

2.7.3 Feeding Behaviour

There are numerous records on the antifeedant effects of neem derivatives on insects of various orders (Jacobson, 1986). An experiment conducted on the desert locust, *Schistocerca gregaria* Forsk using neem leaf extracts revealed strong antifeedant (phagodeterrent) effects on the insects (Chopra, 1928). Azadirachtin completely inhibited feeding of the very sensitive locust when it was offered as a 10-40µg/lm solution on sucrose-treated filter paper (Haskell *et al.*, 1969).

The food intake of homopterous insects; *N. lugens*, *Sogatella furcifera* Horv. (Delphacidae) and *Nephotetrix virescens* Dist. (Cicadellidae) was significantly reduced on rice plants sprayed with a 1-50% emulsion of neem oil (Heyde *et al.*, 1984). Studies on the feeding behaviour of larva of Lepidoptera such as *Spodoptera littoralis* Boisd.,*S. frugiperta* J.E.S., *S. exempla* Wlk., *Heliothis virescen* Fab. *Helicoverpa zea* Boisd, *H. armigera* Hb., *Trichoplusia ni* Hb. and *Mamestra brassicae,* L. (Noctuidae) demonstrated that insect feeding was reduced in all tests (Ascher, 1993).

2.7.4 Metamorphosis

The effects of neem derivatives on the metamorphosis of insects are of considerable theoretical and practical interest, because they result in various morphogenetic and mortality effects depending on the concentration applied (Schmutterer, 1990).

Dipping the eggs of the rice leaffolder, *Cnaphalocrosis medinalis* Gn. into neem oil largely prevented the first instar-larval emergence (Saxena *et al.*, 1981). The same applies to neem oil on *Callosobruchus* spp (Lepidoptera: Noctuidae) (Yadav, 1985). Injection of 0.751.1g/g body weight of AZ into last instar nymphs of the American cockroach, *Periplaneta Americana* L. delayed the moulting process by a number of days (Quadri and Narsaiah, 1978). The first instar nymphs of *Blatta orientalis* and *B. germanica* L. (Orthoptera: Blattidae) died after feeding on Lab-Chow pellets treated with Margosan-O, whereas 5th instar nymphs showed increased mortality and retarded development (Adler and Eubel. 1987). Also, infection of AZ at 2µg/g body weight into 4th and 5th instar nymphs of the African migratory locust, *Locusta migratoria migratoroides* R. & F. two days after moulting induced moulting-inhibition and mortality (Sieber and Rembold, 1983). Other insect species that have been found to be sensitive to the growth regulatory effects of neem include the east African coffee bug, *Antestiopsis orbitalis* Westw. (Leuschner, 1972); the Mexican bean beetle, *Epilachna varivestris* Muls (Steets, 1976), and the mediteranean fruit fly, *Ceratitis capitata* Wied. (Steffens and Schmutterer, 1982).

2.7.5 Fecundity and Egg Sterility

Various neem products exert a dose-dependent influence on the fecundity and egg fertility of female insects. Females of *Dysdercus fasciatus* Sign. (Heteroptera: Pyrrhocoridael derived from 5th instar nymphs topically treated with methanolic neem seed kernel extracts produced only 59% of the number of eggs produced by untreated bugs (Oschse, 1981). In *Oncopeltus fasciatus* Dallas (Heteroptera: Pyrrhocoridae), 7.8-125µg of the topically applied AZ per female reduced the number of deposited eggs by 20% of that of the controls. Concentrations between 8 and 16µg/ female caused complete sterility of the insect (Dorn *et al.*, 1987).

Treatment of rice plants with neem oil reduced the fecundity of various plant- and leafhoppers, such as *N. lugens, S. furcifera,* and *N. virescens.* Six percent neem oil drastically reduced the fecundity, and 3% to less than 50% of the normal number of viable eggs per female in the two latter species (Heyde *et al.*, 1984). Pea aphids, *Acyrthosiphon pisum* Harris which were kept from the first nymphal instar onwards on *Vicia faba* plants treated with 20ppm/l of purified methalonic neem seed kernel extract, produced only about one-twelfth the number of nymphs of control insects (Schauer, 1985).

2.7.6 Fitness (vigour, quality)

In homopterous insects such as *N. lugens, S. furcifera* and *N. virescens,* longevity was reduced by neem derivatives (Heyde *et al.*, 1984). Treatment of adult females of O. *fasciatus* with AZ at 0.25µg caused high mortality and reduced longevity of the insects to 11 days (Dorn *et al.*, 1987). The average life expectancy of females of *Liriomyza* spp (Diotera: Aaromyzidael was 5.8 days after treatment of 3rd larval-instars with ethanolic neem seed extracts compared to the controls, which had a mean of 10.7 days. Ten milligrammes of neem seed extract per kg of larval diet of *C. capitata* reduced the longevity of adult flies deriving from treated larvae so drastically that only 50% reached sexual maturity (Steffens and Schmutterer, 1982). Low concentrations of AZ also caused impotence in males of O. *fasciatus,* as they were unable to copulate (Dorn *et al.*, 1987).

2.8 Mechanism of Action of Neem Products

Various hypotheses exist regarding the mechanism of action of AZ on insects. Some authors have reported the reduction of ecdyson titre and/or the delay in ecdyson production after the application of the active principles. Rembold (1989) suggested interference with the neuroendocrine system controlling ecdyson and juvenile hormone (JH) synthesis as a high accumulation of stainable neurosecretory material was found in the corpora cardiaca of *L. migratoria* treated with AZ.

Investigations of Dorn*et al.* (1987) on *0.fasciatus* appeared to follow the same direction. The control by AZ of the JH titre in females of *L. migratoria* prevented vitellogenin production and therefore caused sterility (Rembold 1989). It was also suggested that AZ interferes with some transmitters involved in the regulation of ecdyson biosynthesis and/or release. A super numerary moult to a nonviable 6th instar larva has been observed so far only in *Manduca sexta* L. (Lepidoptera: Phingidae) (Haasler, 1984). For these reasons, AZ could generally be called an antihormonal active compound.

It was further found out by Cassier *et al.* (1987) that AZ also acts as an inhibitor of chitin biosynthesis.

2.9 Agricultural Potential of Neem-Based Insecticides

2.9.1 Control of Phytophagous Pests

A large amount of data is available detailing both the feeding deterrence and the growth disruptive properties of AZ and neem formulations to numerous species and stages of phytophagous insects of many orders in agriculture and forestry (Schmutterer, 1990; Ascher, 1993).

Lepidoptera and other phytophagous insects have been the main targets (Schmutterer and Hellpap, 1989). More recent works relate to the new application of AZ in the management of pests of ornamental crops (Price *et al.,* 1990); both the contact and the systemic action of the neem-based insecticide, Margosan-O (0.3% AZ, 14% neem oil) on the spiny bollworm, *Earias insulana* Boisd and significant IGR effects of low topical doses of Margosan-O to *S. littoralis* larvae (Meisner and Nemny, 1992). At low concentrations, however, the antifeedant effects of neem derivatives are usually of less importance than the growth disrupting effects observed sometime after the intake of the neem-treated substrate (Schmutterer, 1990).

Freely feeding larvae of Coleoptera, especially those of phytophagous Coccinellidae *(Epilachna, Henosepilachna)* and Chyrsomelidae *(Leptinotarsa)* are also rather sensitive to neem products. There is not only antifeedant and growth regulatory effects in these groups, but also a contact effect, for instance in larval *Leptinotarsa decemlineata* Say (Coleoptera: Chrysomelidae) (Steets, 1976).

In Orthoptera, the gustatory antifeedant effect seems to be of special importance. A number of locusts (e.g. the desert locust, *S. gregaria)* and grasshopper species refused to feed on neem-treated plants for up to several days, sometimes for a longer period (Schmutterer, 1990).

Concerning Hymenoptera, the freely feeding and caterpillar-like larvae of sawflies are target insects for successful neem applications. In this group, both the antifeedant and growth regulatory effects are important (Schmutterer, 1990).

Homopterous insects are sensitive to neem products to a varying degree. Nymphs of leaf- and plant-hoppers are affected by the antifeedant and growth regulatory effects of neem derivatives (Heyde *et al.*, 1984). Their ability to transmit certain viruses may be influenced by the neem oil and other derivatives owing to the reduction in the number of disease vectors and by the modification of the feeding behaviour of the insects (Saxena and Khan, 1985).

Among dipterous insects, mining flies (Agromyzidae) are targets for neem products that penetrate plant tissues and/or are translocated in the plant when taken up by its roots after oil treatment (Meisner *et al.*, 1987). Thrips are less sensitive to neem; oily formulations may lead to some success as the oil plays a dominant role in suffocating small insects (Pillai and Ponniah, 1988).

2.9.2 Control of Stored Product Pests

Neem has proved to be effective in protecting stored products, particularly grain, whose losses, if untreated, can be high. Such losses are frequent in developing countries due to the inability of farmers to apply expensive chemical pesticides. The effects of neem products on stored product pests include antifeedancy, oviposition deterrence, reduced egg hatch and emergence, and direct lethality (Naqvi *et al.*, 1990). The protection by neem may persist for a number of months depending on the species; related to insect behaviour (Makanjuola, 1989).

Seed damage is not always reduced to the same degree as with various synthetic pesticides (Sehgal and Ujagir, 1990). However, a clear benefit of neem is that subsequent germination of stored seed is not impaired by its treatment (Gupta *et al.*, 1989). The treatment of jute sacks with neem oil or AZ-rich products prevents penetration by coleopterous insects such as *Sitophilus* spp (Curculionidae) and *Tribolium* spp (Tenebrionedae) for several months (Saxena 1989). Neem oil also shows a strong ovicidal effect in bruchids (Yadav, 1985), but its antifeedancy and other efficacies may not be important in controlling these legume pests (Ketkar, 1987). Treatment of cowpea seeds with neem oil (~5m1/kg) resulted in -a protection against *Callosobruchus* spp (Coleoptera: Bruchidae) for several months in West Africa (Zehrer, 1984). More diverse utilization of neem includes the preservation of dry fish in Nigeria (Okorie *et al.*, 1990).

2.9.3 Control of Disease Pathogens

Azadirachtin, apart from its unique mode of action against insects, can also affect plant and animal pathogens including nematodes, fungi, viruses and protozoa. A variety of plant parasitic nematodes are reported to be affected by neem products. For example, root dipping and seed treatment with AZ, neem leaf extracts and neem oil prevented larval *Meloidogyne incognita* from causing root-knot infections in tomato, egg plant and okro (Siddiqui and Mashkoor, 1988; Abid and Maqbool, 1991; Pradhan *et al.*, 1991). Among a range of local tree seeds evaluated for nematicidal control in India, *A. indica* gave the best control of parasitic nematodes of subabul *(Leucaena leucocephala)* (Azmi, 1990). However, this treatment was only effective against nematodes infesting lentil when combined with synthetic insecticides (Gaur and Mishra, 1990). Interestingly, the residual effects of soil treatment for nematicidal control lasts for a number of months, with the yield of subsequent crops in the same plot being noticeably increased (Siddiqui and Mashkoor, 1991). Also, in countries such as India with both winter and summer growing seasons, and where soil conditions can vary drastically between areas, neem's efficacy was consistent all-year round, under all soil conditions (Alam, 1991).

There are numerous instances of the effects of AZ and neem extracts/products on fungal pathogens, including the inhibition of spore germination and mycelial growth of *Helminthosporium nodulosum* and *Pyricularia grisea* on finger millet, with acetone extracts of neem being more effective than water extracts (Jagannathan and Narasimham, 1988). Neem seed extracts also significantly reduced the infection of *Oriza sativa* seeds by *Trichoconiella padwickii* (Shetty *et al.*, 1989). In addition to infection of barley by a foot-rot pathogen, *Sclerotium rolfsii* has been reduced from 80% to 8% by neem oil (Singh and Dwivedi, 1990). Finally, certain fruit rots can cause huge economic losses and their control by neem extracts in the laboratory was very promising, as claimed by Arya (1988) who advocated the development of field trials in affected areas. Neem however, is not universally effective against fungi. Khan *et al.* (1988) recorded no effects of dried neem materials on 14 common pathogenic fungi (dermatophytes, yeasts and moulds) under laboratory conditions.

In addition to nematicidal and fungicidal properties, neem products can exhibit significant antiviral activity, e.g., in greenhouse trials against tobacco mosaic virus (Mishra and Rao, 1988) and cowpea mosaic virus (Singh *et al.,* 1988). Nimbin and nimbinin (components of neem) have also been shown to inhibit the development of potato virus X (PVX) (Verma, 1974). Antiviral activity of AZ was not, however, demonstrated against potato leafroll virus PLRV or potato virus Y (PVY) in tobacco seedlings (Nisbet, 1992). As far as antiprotozoan activity is concerned, AZ inhibited microfilarial release of *Brugia pahangi* without affecting the host mobility or viability (Barker *et al.*, 1989). Bray *et al.* (1990) also detected a weak antiplasmodial activity of gedunin and suggested that the claimed effectiveness of neem against malaria might be due to the anti-inflammatory and immunomodulating activities of the neem plant.Examples of neem's impact on parasites in insects are numerous and include the protozoan species of *Plasmodium*, *Entomoeba*, *Leishmania* and *Trypanosoma* (Phillipson and O'Nneil, 1989). AZ is also known to inhibit *Trypanosoma* infection of triatomid insects, including *Rhodnius prolixus* which transmit *T. cruzi* causing Chagas' disease (Rembold and Garcia, 1989).

2.10 Mammalian Toxicity and Effects on Beneficial Organisms

So *far*, no indications of mammalian toxicity of neem have been found with carefully prepared neem products under conditions of rigid test procedures. Such neem preparations, unless misused, can be considered safe for humans and other nontarget organisms (Ascher, 1993). It should, however be mentioned that infants in Malaysia and India who had been treated with large doses (5m1 or more) of neem oil as a home remedy against minor ailments, developed severe symptoms of poisoning within hours after injestion. These consisted of vomiting, drowsiness, metabolic acidosis and encephalopathy (Sinniah *et al.*, 1983). Also, a 4-month-old Indian child treated with 12ml neem oil twice (on two successive days), "for cough", died 12 days later. It was assumed that the oil may have been involved in the etiology of "Reye's syndrome" due to a synergistic effect between aflatoxins contaminating the oil samples used as meliatoxins present in the oil (Sinniah *et al*,, 1983). This specific problem of neem oil, fed to infants, in Southern and Southeastern Asia was reviewed by Jacobson (1986, 1989). Other parts of the neem tree may also be toxic to warm-blooded animals, such as neem leaves to sheep (Ali and Salih, 1982), goats and guinea pigs (Ali, 1987).

Neem has been shown to be outstandingly safe to beneficial organisms. Honeybees, parasitic insects such as wasps, predators such as spiders, earwigs, ants and predacious mites are only slightly, or not at all, harmed by azadirachtin and neem products (Schmutterer, 1990). This is due to the lack of, contact toxicity in some cases, and direct ovicidal effect; and the absence of toxicity against nonphytophagous adult insects. Neem products are therefore very selective although they may have a rather broad spectrum of activity (Ascher, 1993).

2.11 Persistence and Systemic Effects

Azadirachtin-containing extracts usually have a residual life of 4-8 days under field conditions. However, it has been shown by von der Heyde *et al.* (1984) that the persistence is prolonged when there is a systemic effect as the material is taken up by the plant. There are, of course, other exceptions, under specific conditions, to this relatively short residual life of neem preparations, e.g., with stored product insects in dark storage facilities, or in sheep's wool to control ticks and mites, where neem is active on the animal for not less than three months (Schmutterer, 1988).

The systemic effect of neem is of considerable interest for the control of insects that feed on the vascular tissues of plants. Very small amounts of the active compound are transported in the phloem, which may be the reason for the unsatisfactory control by neem of some phloem-feeding aphids. It is highly intriguing that leafhoppers, such as *N. virescens*, which are usually phloem-feeders, change to xylem feeding on neem-treated plants (Saxena, 1990).

2.12 Development of Resistance

To date, there is no reported case of insect resistance to neem (Ascher, 1993). Standard procedures of selection for resistance in the diamond back moth, *Plutella xylostella* L. (Lepidoptera: Yponomeutidae) (a problem insect which rapidly develops high level of resistance to numerous synthetic pesticides) for 42 generations have not led to development of resistance. This was true even in deltamethrin-resistant strains (Vollinger, 1987). The non-evolution of resistance to neem formulations may be due to their mixtures of various, often-related compounds; having several and different modes of action, accounting for manifold activities in biological organisms, such as antifeeding and repellent effects, including oviposition repellency; growth and development regulation; sterilizing effects, inhibition of oviposition and reduction of fecundity. Neem products also sometimes exert interesting physical effects on insects (e.g., autonomy induced by neem oil in adult locust), and occasionally even conventional type toxicity (Ascher, 1993).

2.13 Practical Problems of Neem Application

Like many other natural products, botanical pesticides show limited persistence under field conditions. Temperature, Ultra-violet light, PH, on treated plants, and other environmental factors may exert a more or less negative influence on the active principles. Therefore, the residual effect of neem-based products is generally restricted to only a few days (5-7 days) (Ascher, 1993). This short residual effect may lead to the necessity to repeat their application several times during the growing seasons at intervals of about 7 to 10 days, especially in the case of permanent immigration of pests from neighbouring areas. The delayed effect of neem products may also discourage farmers who are accustomed to synthetic pesticides with strong knockdown efficacy. After the application of neem products, most insect pests continue to feed on the treated plants for some time, causing loss of some leaves and other nongenerative parts, which may influence crop yield to some extent (Schmutterer, 1990).

Temperature has an indirect influence on the growth regulating effects of neem derivatives. Under low temperature conditions, most insect nymphs/adults are not killed within the residual period. Heavy rains may wash down the active material before it is taken up by the target insects. In India, field trials with neem oil in rice gave much better results during the dry season than in the rainy season. Therefore, the degree of efficacy of neem products, if not applied in high doses is often less than that of the synthetic, broad-spectrum pesticides. Furthermore, the application of neem-based pesticides against many adult insects does not normally lead to obvious mortality although it may result in substantial reduction in the fecundity (Schmutterer, 1980).

With certain insect pests with great capability to develop resistance, care needs to be taken that only a minimum amount of the treatment is applied. Under such situations, neem pesticides need to be used alternatively with other products to prevent, or at least, postpone the development of resistance even though until now, there has not been any sign of resistance development in neem products (Vollinger, 1987). Because insects are able to distinguish between treated and untreated parts of their host plants, sprays of neem-based pesticides also need to be applied carefully, either in high volume or by using techniques that guarantee an even distribution of the active material on the parts to be protected (Schmutterer, 1990).

2.14 Concentrations of Neem Seed Extracts Used in Control of Field Pests of Cowpea

Available results have shown that different authorities have recommended different concentrations of the neem seed extracts as effective against the major field pests of cowpea. Many in their studies tend to accord more attention to the efficacy of the product at the expense of the economics of control.

Bhat *et al.* (1988) for example, presented the first report of a field experiment to determine the effectiveness of various insecticidal formulations and of neem seed extracts in the control of *M. testulalis* in cowpea. Pests incidence was lowest in plots treated with Monocrotophos at 25ml/ha, followed by the neem seed extract at 25kg/ha, Phosalone at 250m1/ha and Quinalphos at 250ml/ha, with grain yields of 4.79, 4.70, 4.14 and 3.99t/ha respectively. No economic analysis was performed.

Cobbinah and Osei-Owusu (1988) investigated the efficacy of aqueous methalonic neem seed extracts at 5%, 10% and 20% (w/v) against major cowpea pests in Southern Ghana. Pest incidence was reduced and pod yield increased by the various concentrations of neem formulations. However, there was no significant difference in the percentage of cowpea pods attacked between the control and the 5% and 10% neem treatments. The high pod yield recorded from the 10% neem-treated plot was attributed to the combination of the insecticidal and the fertilizer properties of neem. Some phytotoxicity was however, observed on plants treated with the 10% and 20% neem emulsions at the pre-flowering stage. Here again, the economics of control was not considered.

Jackai *et al.* (1992) tested the insecticidal activity of aqueous seed extracts of neem at 5%, 10%, 15% and 20% on the legume pod borer, *M. testulalis* and the cowpea coreid bug, *C. tomentosicollis* using potted plants in IITA, Nigeria. Neem proved effective in acting as an insecticide and affected the rate of development of both pests at the concentration as low as 5% solution (w/v). Marginal survival was found to decrease with increasing neem concentration, but a point was reached where further increases in the amount of neem produced no significant changes in survival rates. No benefit-cost analysis was performed.

The use of neem seed extracts spray applications as low cost inputs in the management of flower thrips on the cowpea crop was investigated by Saxena and Kidiavai (1997) in Kenya. Applications of 5%, 10% and 20% aqueous extracts sprayed at 10 l/ha with an ultra-low volume applicator 31, 39 and 49 days after emergence often significantly reduced the number of larvae of the flower thrips on cowpea flowers recorded 2 days after each treatment. Fewer adults appeared on flowers at 51 days after emergence in all neem-treated plots. Cowpea grain yield was significantly higher in plots sprayed with 20% neem seed extract than in untreated control plots and was comparable to the grain yield in plots sprayed three times with Cypermethrin. Grain quality was superior in the neem-treated plots than in the Cypermathrin-treated plots. Net gain was more when the crop was sprayed with the neem extracts than with Cypermethrin.

Emosairue and Ubana (1998) also conducted a field evaluation trial on the effect of neem seed extracts at 5% and 10% (w/v) and the synthetic insecticide, Lambda-cyhalothrin in the control of major cowpea pests in Eastern Nigeria. All treatments significantly reduced pod and seed damage caused by *M. testulalis*. Whereas Lambda-cyhalothrin was significantly superior to the neem extracts, the two neem concentrations were not significantly different. Yield of the synthetic insecticide-treated plot was significantly higher than the control plot, but was not statistically different from the yields of the two neem-treated plots. Cost-benefit analysis showed that the 5% neem treatment gave the best cost-benefit ratio.

The most current field investigations on the potential for incorporating neem seed extracts into an Integrated Pest Management (IPM) system for cowpea crop in Northern Ghana was carried out by Tanzubil (2000). The results showed that aqueous neem seed extracts at 5% and 10% (w/v) were both efficacious against flower thrips, pod borers and pod-sucking bugs on cowpea. The addition of vegetable oils and local detergents to the extracts increased their efficacy and residual action on the treated crop. In combination with early planting, two applications of the 10% solution were as effective as Lambda-cyhalothrin, the synthetic insecticide widely recommended for cowpea pest control in the area.

The results from these and other field trials therefore indicate that a standard concentration of neem seed extracts that can provide the most effective control of the whole complex of field cowpea pests at the least cost has not yet been determined. Hence, there is the need to standardize the concentration of neem seed extracts for a more effective and economical control of the major field pests of cowpea for an increased and sustainable productivity of the crop, particularly, in the northern guinea savanna agroecological zone of Ghana. The present study is an attempt to further contribute to knowledge on the use of neem extracts in pest management on cowpea in Ghana.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Site

The research was conducted during the main cropping season (July-October, 2004) at the Experimental Farm of the Savanna Agricultural Research Institute (SARI), Nyankpala, (9°: 25’N ; 0°:58’W ; 500-900mm rainfall), 16 km west of Tamale, in the northern guinea savanna agroecological zone of Ghana.

3.2 Experimental Design and Treatments

The field was laid out in a Randomized Complete Block Design (RCBD). A total of 24 subplots, each measuring 7 m by 6 m with inter-and intra-row spacing of 0.75 m and 0.25 m, respectively were used. A 2-metre distance was allowed between the subplots so as to avoid spray drifts to adjacent plots. A total plot size of 45 m^2 was therefore covered.

Six treatments, each with four replicates, were used. The treatment layout was as follows:

- Water = Control (4 applications)
- 5% ANSE = 5% concentration (w/v) of aqueous neem seed extract (4 applications)
- 10% ANSE = 10% concentration (w/v) of aqueous neem seed extract (4 applications)
- 15% ANSE = 15% concentration (w/v) of aqueous neem seed

extract (4 applications)

- 20% ANSE = 20% concentration (w/v) of aqueous neem seed

  extract (4 applications)

- KRT = Karate (synthetic insecticide) @ 36g ai/ha (2

  applications). *Note:* ANSE = Aqueous neem seed extract

3.3 Land Preparation and Planting

The experimental field was first cleared of all thick bushes, herbage and shrubs, disc-ploughed and disc-harrowed to fine soil tilt during the first week of July. Each subplot was then ridged, pegged and labeled prior to planting.

An improved high yielding medium maturing (68 days) cowpea variety (Marfo-tuya), obtained from the Plant-breeding Unit of the Savanna Agricultural Research Institute (SARI), was used. Sowing was done during the 3rd week of July (i.e. 20-07-04): a time of the cropping season generally considered most appropriate for covering the peak incidence of all the major pests of the cowpea crop in the ecology (Tanzubil, 1991). A maximum of 4 seeds were sown in each hill and later thinned to 2 plants per stand two weeks after sowing.

3.4 Preparation of Neem Extracts

Mature neem seeds were collected from the ground under neem trees within the SARI Research Station. The seeds were air-dried and winnowed to remove all foreign materials to obtain the pure seed sample. The extracts were prepared a day prior to their application during each treatment occasion.

The method of preparation of neem extracts was chosen on the basis of simplicity, ease of adoption and convenience of use by the local farmers. It has been established that in the preparation of neem seed extract, about 20% of the material (by weight) goes into the aqueous phase, so that to obtain a 5% solution of the extract, about 600g of the neem seed powder (NSP) would be added to 15 litres of water (Dreyer, 1984). Thus, 600g seed weight (approximately half local "koko" bowl) was pounded into fine powder using a wooden mortar and a pestle. The powdered mass was then soaked in 15 litres of water (equal to the capacity of CP 15 knapsack sprayer). About 10g of "key soap" (a commercial detergent) was added to the content to help enhance the adhesiveness of the active ingredient and to reduce its volatile effect in the field (Schmutterer, 1988). The content was then stirred and allowed to stay overnight (≈ 12 hrs). After this period, the content was stirred again before being strained over a standard sieve with a fine nylon mesh (701.tm) to remove the solid particles. The solution thus obtained gave the 5% concentrated solution (w/v) of the extract, which was ready for use in the field.

The same principle was then applied, following the same procedure to obtain the 10%, 15% and 20% concentration of the extract; i.e. 10% concentration = 1,200g NSP in 15 litres of water; 15% concentration = 1,800g NSP in 15 litres of water; 20% concentration =2,400g

3.5 Application of Treatments

Application of the neem treatments was done at weekly intervals beginning from the 3rd week after planting. The CP 15 knapsack sprayer was used. The water and neem seed extract treatments were applied at 26, 34, 42 and 50 days after plant emergence (DAE). The Karate treatment was applied at 26 and 43 DAE. On each spraying occasion, all experimental units were treated the same day at about the same time. All plants in each subplot were sprayed until complete coverage or wetting was achieved. Any spray application that was followed by a significant rainfall within 6 hours after the spraying treatment was repeated the following day after the rain so that bias in the application of the treatments would be avoided (Passerini and Hill, 1993). Weeding was done manually at 25, 35 and 55 Days After Planting (DAP), using a hoe. All other recommended cultural practices, except for pests control, were common in all plots and were strictly followed throughout the experiment.

3.6 Sampling for Insect Pest Infestation

Sampling for insect pest infestations was done 2 days after each insecticide treatment. Six inner rows, excluding 1 m border from both ends of each row were selected from each subplot for sampling. Target insect pests included *A. craccivora, M. sjostedti, M. vitrata, C. tomentosicollis, M. jaculus, N. viridula, A. curvipes* and *R. dentipes.*

3:6.1 Sampling for Aphids

Sampling for aphids was done between 25 and 44 DAE. All plants in the selected six middle rows were counted and visually examined to record the number of plants infested by aphids (i.e., abundance), and then scored for severity or degree of infestation (i.e., incidence) on a 0-9 scale, where 0 = no aphids, 1= 1-4 aphids, 3 = 5-20 aphids, 5 = 21-100 aphids, 7 = 101-500 aphids, and 9 = >500 aphids per sub-plot (Jackai and Singh, 1988).

3:6.2 Sampling for Thrips

Thrips infestation was assessed between flower bud initiation and 50% podding stage (40-56 DAE). Beginning from flower bud initiation to 50% flowering, 20 flower buds (racemes) were randomly collected from each subplot and kept in vials containing 50% ethanol. Also, beginning from 50% flowering (40-48 DAE) to first pod maturity (55-64 DAE), 20 flowers were randomly collected and kept in vials containing 50% ethanol. The number of thrips (nymphs and adults) in each sample was then counted under binocular microscope in the laboratory to determine the abundance of thrips on the plants.

3:6.3 Sampling for Pod Borer

Pod borer infestation was also assessed between 50% flowering and first pod maturity. Ten flowers from each subplot were picked at random and kept in vials with 50% ethanol. These were also examined in the laboratory to record the number of pod borer larvae on the plants (i.e., abundance). Concurrently, proportions of flowers infested by the pod borer were estimated using the Rapid Visual Examination (RVE) method whereby 10 flowers were collected at random from each subplot, opened on the spot and examined for pod borer larvae or damage (Jackai *et al.*, 1992). RVE was also done on the mature pods to determine the extent of pod borer damage on the plants (i.e. incidence).

3:6.4 Assessment of Pod-Sucking Bugs Infestation

Pod-Sucking Bugs (PSBs) infestation was assessed between the podding and the harvest stages. Visual counts of adults and nymphs of the different PSB species were made on rows of cowpea plants within the marked area in each subplot. These were then recorded for PSBs abundance. Counting was done between 1400 and 1700 hrs (Hammond, 1983). Also, the matured pods were sampled and examined visually to determine the number of shriveled pods caused by PSBs infestation (i.e., abundance).

3.7 Estimate of Grain Yield

Dry grain yield in kilograms per unit area was estimated from the six middle rows of each subplot, excluding a 1-metre row from each border, after the pods were harvested, sun dried to 12% moisture content and winnowed to obtain the pure seeds. The results were then extrapolated to kilograms per hectare for each treatment using the following formula proposed by Asante *et al.* (2001):

$$\text{Grain yield / ha} = \frac{10{,}000}{\text{Area harvested}} \times \text{Grain yield / plot}$$

3.8 Estimate of Grain Quality

Grain quality estimation was based on a visual grain damage rating scale of 1-6, where 1 = 0-5% damaged grains, 2 = 6-25% damaged grains, 3 = 26-50% damaged grains, 4 = 5175% damaged grains, 5 = 76-95% damaged grains and 6 = > 95% damaged grains (Passerini and Hill, 1993). Damaged grains were counted to include all cowpea grains whose quality has been reduced as a result of infestation by the insect pests under consideration.

3.4 Estimate of Fodder Yield

All plants within the six middle rows of each subplot were uprooted after the pods were harvested. These were sun dried and then weighed using a standard weighing scale in the laboratory. The results of the plant biomass weights obtained for each treatment were then extrapolated to kilograms per hectare using the following formula proposed by Asante *et al.* (2001):

$$\text{Fodder Yield / ha} = \frac{10{,}000}{\text{Area harvested}} \times \text{Fodder Yield /plot}$$

3.7 Profits per Yield and Benefit-Cost Analysis

Differences in grain and fodder yields above the water treated (control) plot were assumed to be solely due to the insecticide applications. Therefore, partial budgeting was used to estimate the profit per hectare for each treatment. Profit was estimated by deducting total pests control cost from the income derived from the differences in yield above the control treatment. Cost of land preparation, sowing, and weed control were not included in the partial budgeting, since these were similar in all the treatments. Cost-benefit ratio, defined as the number of times the insecticide (synthetic and botanicals) control cost would be recouped from the value of the increase in yield of cowpea was calculated as:

$$\text{Cost-benefit ratio} = \frac{\text{Value of increased yield}}{\text{Cost of pest control}}$$ Asante *et al.* (2001).

3.8 Statistical Analysis

Differences in infestation by the insect pests, grain yield and fodder yield between the treatments were examined by subjecting all the data collected to Analysis of Variance (ANOVA) of the Randomized Complete Block Design (RCBD). Where ANOVA test indicated significant difference between treatments, the Duncan's Multiple Range Test (DMRT) was used to separate the treatment means at 5% level of significance. Student t-test was used to compare the abundance of thrip nymphs and thrip adults in the cowpea flowers.

CHAPTER FOUR

RESULTS

4.1 General Observations

During the first 2 weeks after plant emergence in the field, insect pest species such as cutworms, *Agrotis ipsilon* Hufnagel (Lepidoptera: Noctuidae); leafhoppers, *Empoasca dolichi* Paoli (Homoptera: Cicadelidae); and grasshoppers, *Zonocerus variegatus* L. (Orthoptera: Acrididae), were found on the cowpea plants. However, the populations of these pests did not attain economic injury or threshold levels but rather declined considerably to very low levels, resulting in increased vigour and luxuriant growth of the plants.

On the basis of significant damage incidence on crops and possible reduction in cowpea grain and fodder yields, the major insect pests encountered in the field include the black cowpea aphid, *Aphis craccivora* Koch (Homoptera: Aphididae); the cowpea flower thrip, *Megalurothrips sjostedti* Tryb. (Thysanoptera: Thripidae); the legume pod borer, *Maruca vitrata* Fab. (Lepidoptera: Pyralidae); and a complex of pod- and seed-sucking bugs identified as *Clavigralla tomentosicollis* Stal.; *Anaplocnemis curvipes* Fab.; *Mirperus jaculus* Fab. (Hemiptera: Coreidae); *Riptortus dentipes* Fab. (Heteroptera: Alydidae); and *Nezara viridula* L. (Heteroptera: Pentatomidae). Outbreak of *A. craccivora* occurred during the third week after plant emergence. The aphids were found in clusters around the stems and undersides of leaves and on developing shoots of the growing plants where they sucked the sap and caused leaf distortion and stunting of the infested plants. The flower thrips appeared during the flower bud (raceme) initiation and flowering stages of the crop.

Infestation by both adults and nymphs of thrips caused suppressed flower production and increased flower abortion. The pod borers infested both the flowers and the developing cowpea pods by inflicting damage on them, resulting in the abortion of flowers and poor seed formation. The larvae of the pod borer, which were the destructive stage of the pest, were known to be more active at night and hide in flowers, stems or in the soil beneath the plants during the day. Therefore, pods and flowers located within the leaf canopies, short peduncles, or those touching other plant parts were observed to be heavily infested and severely damaged by the pod borers. The pod-sucking bugs also attacked the developing cowpea pods, sucked the sap from them, resulting in shriveling and poor or no seed formation in the infested pods.

Important natural enemies of the pests such as parasitic wasps and lady bird beetle predators which were present in the field seemed to be less affected by the neem treatments as they were observed to be more active than their hosts or preys. Moreover, cowpea plants treated with the neem extracts appeared to exhibit less indeterminate growth habit compared with those in the control plot, which continued to remain green with new shoot development even until the fodder was harvested. It was also observed that cowpea plants treated with neem seed extracts up to the 15% concentration did not show any abnormal colour changes in their leaves. However, leaves of the 20% neem-treated plants developed some brownish colourations on them, especially at the preflowering stage. The neem-treated plants also appeared to show faster rate of leaf senescence and pod drying compared with those in the control, but this was not as fast as those in the Karate-treated plot.

4.2 The Effects of Neem Seed Extracts on *A. craccivora*

The effects of the different concentrations of neem seed extracts on the incidence and abundance of the black cowpea aphid, *Aphis craccivora* Koch, are presented in Table 3. The results showed that aphid incidence and abundance was generally low at the study site. Inspite of this, there was a significant difference between the treatment means in the abundance of *A. craccivora* on the cowpea plants ($F = 23.6$, $df = 5, 15$, $P < 0.01$). The proportion or percentage of plants infested in all the neem-treated plots was significantly lower than that of the control plot but significantly higher than that of the Karate-treated plot. Among the neem treatments, the 5% neem-treated plot recorded a significantly higher percentage infestation. However, the 10%, 15% and 20% neem treatments did not significantly differ form one another even though percentage infestation was found to decrease with increasing concentration of neem aeed extracts.

Moreover, the incidence or degree of infestation of *A. craccivora* was significantly different between the treatment means ($F = 15.2$, $df =5, 15$, $P < 0.01$). Similarly, the mean score of aphids in any of the neem-treated plots was significantly lower than that in the control plot but significantly higher than that in the Karate-treated plot. Among the neem treatments, the 5% neem-treated plot recorded a significantly higher mean aphid score than the 10% - 20% neem-treated plots. However, significant difference was not observed between the 10, 15% and 20% NSEs even though the degree of aphid infestation was found to decrease with increasing concentration of the extracts.

Table 3:

The incidence and abundance of *A. craccivora* on cowpea plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Gnana.

Treatment	Percent ± SE of plants infested	Mean aphid score ± SE
Control	36.6 ± 2.5 a	3.0 ± 0.3 a
5% NSE	10.5 ± 2.0 b	2.2 ± 0.2 b
10% NSE	6.7 ± 2.0 c	1.7 ± 0.1 c
15% NSE	6.3 ± 2.0 c	1.4 ± 0.3 c
20% NSE	5.5 ± 2 5 c	1.1 ±0.3 c
Karate	1.6 ± 2.5 d	0.2± 0.1 d
F (5,15) P-value	23.6 < 0.01	15.22 < 0.01

Mean severity of infestation (i.e. visual rating of the extent of infestation) using a 1-9 rating scale where 1 = 1-4 aphids; 3 = 5-20 aphids; 5 = 21-100 aphids; 7 = 101-500 aphids, and 9 = >500 aphids (Jackai and Singh. 1988).

Means within columns followed by a common letter do not differ significantly at P = 0.05 (Duncan’s Multiple Range Test).

Note: SE = Standard Error

4.3 The Effects of Neem Seed Extracts on *M. sjostedti*

Table 4 shows the effects of the different concentrations of neem seed extracts on the abundance of the cowpea flower thrip, *Megalurothrips sjostedti* Tryb. in the racemes and flowers of the cowpea plants. The results indicated a significant difference between the treatment means in the abundance of *M. sjostedti* in the racemes ($F = 279.9$, $df = 5, 15$, $P < 0.001$). The mean number of thrips per raceme was significantly lower in any of the neem-treated plots than in the control but significantly higher than that of the Karate-treated plot. Among the neem treatments, the number of thrips per raceme was significantly higher in the 5% than in the 10%. The 10% neem-treated plot also recorded a significantly higher number of thrips per raceme than the 15% and 20%. However, no significant difference was observed between the 15% and 20% neem-treated plots.

Similarly, significant difference was observed between the treatment means of the number of *M. sjostedti* recorded on flowers ($F = 245.7$, $df = 5, 15$, $P < 0.001$). The mean number of thrips per flower was significantly lower in all the neem-treated plots than in the control. The 5% neem-treated plot recorded a significantly higher number of thrips per flower than the 10%, which, in turn, recorded a significantly higher number than the 15% and 20%. However, the 15% and 20% neem-treated plots, as well as the Karate-treated plot were not significantly different from each other, even though the number of thrips per flower in the 15% neem-treated plot was higher than that of the 20%, which, in turn, recorded a higher number than the Karate-treated plot.

Table 4:

Number of M. *sjostedti* on cowpea racemes and flowers following spraying with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.

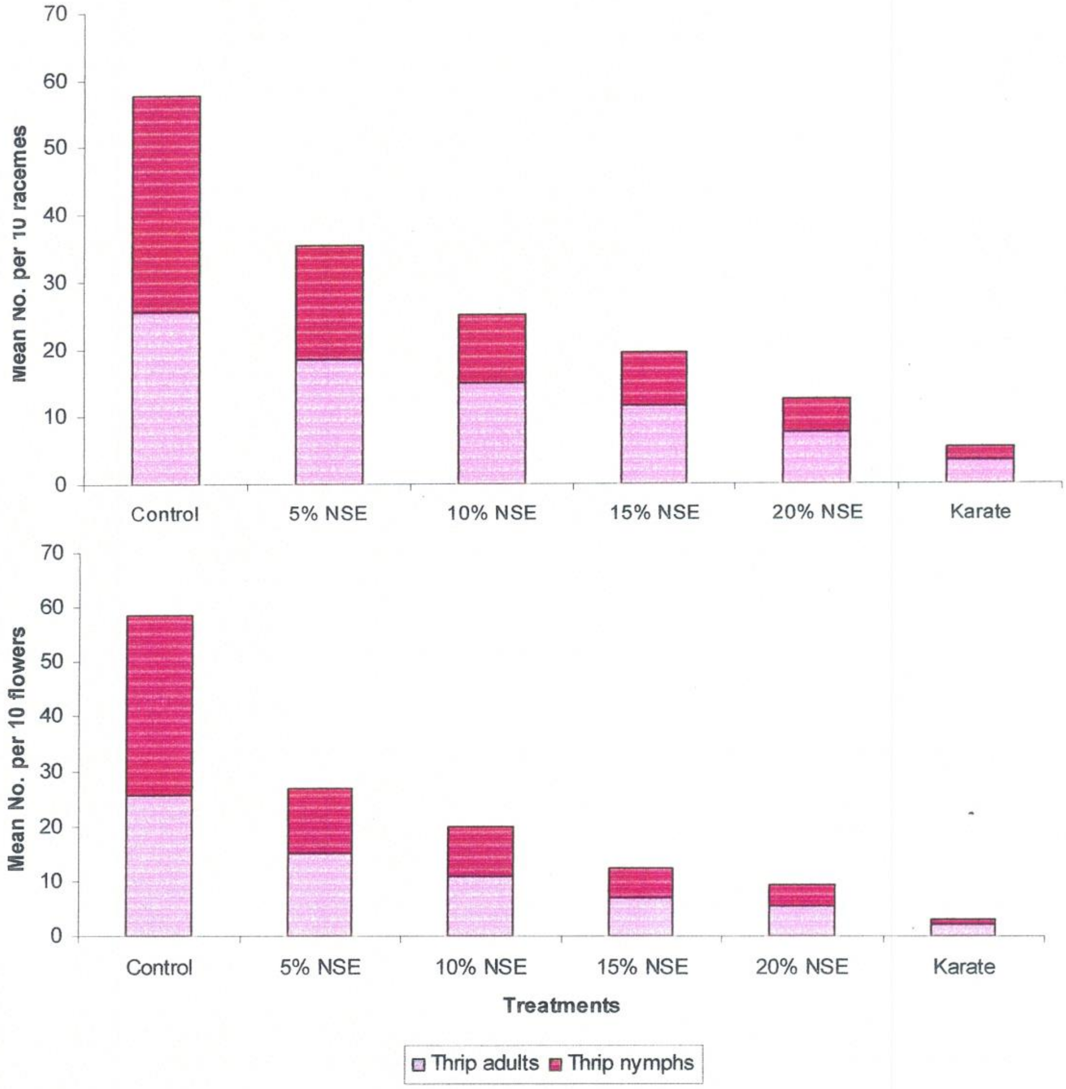
Treatment	**Mean number ± SE of thrips per 10 racemes**	**Mean number ± SE of thrips per 10 flowers**
Control	57.2± 1.0 a	58.0 ± 3.0 a
5% NSE	35.3± 1.9 b	37.0 ± 1.8 b
10% NSE	27.5 ± 1.6 c	20.0 ± 1.5 c
15% NSE	19.5 ± 0.6 d	12.5 ± 0.5 d
20% NSE	14.5 ± 0.6 d	9.5 ± 0.5 d
Karate	5.5 ± 0.4 e	3.0 ± 0.1 e
F (5,15) P-value	279.9 < 0.001	245.7 < 0.001

Means within columns followed by a common letter do not differ significantly at P = 0.05 (Duncan's*Multiple Range Test).*

The results also showed that in each of the insecticide-treated plots, the population of adult thrips in racemes and flowers was higher than that of nymphal thrips even though the difference was not statistically significant (t = 1.41-2.90, df = 3, P > 0.07-0.25). On the other hand, the population of adult thrips in racemes and flowers in the control plot was lower than that of nymphal thrips even though the difference was also not statistically different (t = 2.30-2.50, df = 3, P > 0.8-0.9) (Figure 2).

Figure 2:

The abundance of adults and nymphs of *M. sjostedti* on the racemes and flowers of cowpea plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.



4.4 The Effects of Neem Seed Extracts on *M. vitrata*

The effects of the different concentrations of neem seed extracts on the abundance of the legume pod borer, *Maruca vitrata* Fab. in the cowpea flowers are presented in Table 5. The results showed that there was significant difference between the treatment means of *M. vitrata* larvae infesting the flowers. The mean number of larvae per flower was found to decrease significantly with increasing concentration of neem seed extracts ($F = 107.8$, df =5,15, $P < 0.001$). All the neem-treated plots recorded a significantly lower number of larvae per flower than that of the control. The number of larvae per flower in the 5% neem-treated plot was significantly higher than that of the 10%. The 10% neem-treated plot also recorded a significantly higher number of larvae per flower than that of the 15%. However, the 15% and the 20% neem-treated, as well as the Karate-treated plots, were not significantly different from one another even though more larvae were recorded in the 15% neem-treated plot than that of the 20% which, in turn recorded more larvae per flower than that of the Karate.

Moreover, the proportion of flowers infested by the larvae also differed significantly between the treatments ($F = 66.7$, df = 5, 15, $P < 0.001$). All the neem-treated plots recorded a significantly lower flower infestation than the control plot. Among the neem treatments, the 5% neem-treated plot recorded a significantly higher infestation of flowers than that of the 10%. The 10% neem-treated plot also recorded a significantly higher percent flower infestation than that of the 15%. However, the 15% and 20% neem-treated plots were not significantly different from each other. The 20% neem-treated plot did not also differ significantly from that of the Karate, even though it recorded a higher percent infestation of the flowers

Table 5:

The abundance of M. *vitrata* on cowpea flowers, on plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.

Treatments	**Mean number ± SE of larvae per 10 flowers**	**Proportion (%) ± SE of flowers infested by larvae**
Control	27.0 ± 1.6 a	72.5 ± 5.2 a
5% NSE	16.0± 1.6 b	47.5 ± 3.2 b
10% NSE	9.5 ± 0.6 c	38.7 ± 2.4 c
15% NSE	2.8 ±0.9 d	23.7± 1.3 d
20% NSE	2.3 ± 0.3 d	20.0 ± 2.0 de
Karate	1.0 ± 0.0 d	12.5 ± 1.4 e
F (5,15) **P-value**	107.8 < 0.001	66.7 < 0.001

Means within columns followed by a common letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test).

Table 6:

Cowpea pods and pod damage by M. *vitrata* on cowpea plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Gnana.

Treatments	**Mean number of pods per plant (n = 6)**	**Mean number ± SE of damaged pods**	**Proportion (%) ± SE of damaged pods**
Control	4.3	3.1 ± 0.2 a	72.8 ± 6.9 a
5% NSE	8.3	3.6 ± 0.3 a	44.1 ± 5.2 b
10% NAE	10.1	3.4 ± 0.4 a	33.6 ± 3.9 b
15% NSE	16.1	2.2 ± 0.2 b	13.7± 1.4 c
20% NSE	16.8	2.0 ± 0.4 b	12.2 ± 2.1 c
Karate	18.4	1.4 ± 0.2 b	7.5± 1.3 c
F (5,15) P-value		9.8 < 0.001	50.7 <0.001

n = number of plants sampled

Means within columns followed by a common letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test).

The incidence of *M. vitrata* damage to the developing cowpea pods was found to be significantly affected by the treatments (Table 6). There was significant difference between the treatment means of pods damaged by *M. vitrata* ($F = 9.8$, $df = 5, 15$, $P < 0.001$). However, the mean number of damaged pods in the control, 5% and 10% neem-treated plots was not significantly different. Moreover, differences between the 15% and 20% neem-treated, as well as the Karate-treated plot, were not statistically significant although the number of damaged pods was found to decrease with increasing concentration of the neem extracts. The Karate-treated plot recorded the lowest number of damaged pods than any of the neem treatments.

The proportion of damaged cowpea pods caused by *M vitrata* also differed significantly between the treatments ($F = 50.7$, $df = 5, 15$, $P < 0.001$). All the neem-treated plots recorded a significantly lower percent of damaged pods than the control plot. However, there was no significant difference between the 5% and 10% neem-treated plots, but both differed significantly from that of the 15% and 20%. Also, differences between the 15%, 20% neem-treated and the Karate-treated plots were not statistically significant. Overall, the Karate-treated plot recorded the lowest percent of damaged pods.

4.5 The Effects of Neem Seed Extracts on Pod-Sucking Bugs

The effects of the different concentrations of neem seed extracts on the abundance of pod-sucking bugs (PSBs) on the cowpea plants are shown in Table 7. The results showed that the population of PSBs was significantly affected by the treatments ($F = 66.4$, $df = 5, 15$, $P < 0.001$). The mean number of PSBs per 5-metre row of cowpea was found to decrease consistently with increasing concentration of neem seed extracts. The mean number of PSBs in each of the neem-treated plots was significantly lower than that of the control plot but higher than that of the Karate-treated plot.

Table 7:

The abundance of Pod-Sucking Bugs (PSBs) on cowpea plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.

Treatments	**Mean number ± SE of adults and nymphs of PSBs per 5-metre row of cowpea**
Control	32.8 ± 3.6 a
5% NSE	24.3 ± 4.4 b
10% NSE	16.6 ± 3.2 be
15% NSE	11.8 ± 2.5 cd
20% NSE	10.9 ± 3.2 d
Karate	5.6 ± 1.5 e
$F_{(5,15)}$	66.4
P-value	< 0.001

The PSB-complex comprised *Riptortus dentipes, Anaplocnemis curvipes, Clavigralla tomentosicollis, Nezara viridula and Mirperus jaculus.* Means followed by a common letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test).

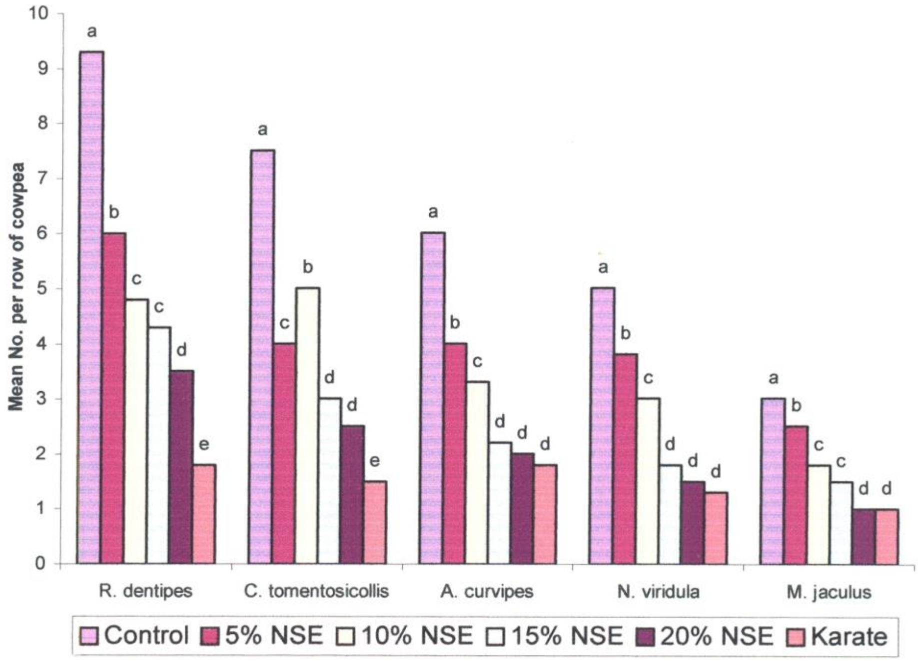
However, the mean number of PSBs in the 5% neem-treated plot was not significantly different from that of the 10%. Also, the number of PSBs in the 10% neem-treated plot did not differ significantly from that recorded on the 15%. Moreover, the differences between the 15% and 20% neem-treated plots were not significant.

The treatments also had a significant effect on the abundance of the different species of PSBs present in the field (Figure 3). The population of *Riptortus dentipes* Fab., which was the most dominant PSB in the study area, was found to decrease significantly with increasing concentration of neem seed extracts ($F = 201.9$, $df = 5, 15$, $P = 0.001$). All the neem-treated plots were significantly lower than the control plot but significantly higher than the Karate-treated plot in the mean number of *R. dentipes*. However, the 10% and 15% neem-treated plots were not significantly different from each other although more *R. dentipes* was recorded in the 10% than in the 15% neem-treated plot.

Significant difference was also observed between the treatment means in the abundance of *Clavigralla tomentosicollis* Stal. ($F = 15.3$, $df = 5, 15$, $P < 0.001$). All the neem-treated plots were significantly lower than the control plot but significantly higher than the Karate-treated plot in the number of *C. tomentosicollis* recorded. Also, significant differences were found in the mean number of *C. tomentosicollis* between the 5%, 10% and 15% neem-treated plots. However, the 15% and the 20% neem-treated plots were not significantly different from each other but they were significantly different from the Karate-treated plot.

The abundance of *Anaplocnemis curvipes* Fab., was also found to differ significantly between the treatment means ($F = 13.2$, $df = 5,15$, $P < 0.01$). The mean number of *A. curvipes* in each neem-treated plot was significantly different from that in the control plot.

Figure 3:
The abundance of the different species of pod-sucking bugs on cowpea plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.



Means within histogram followed by a common letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test).

The mean number of *A. curvipes* in the 5% neem-treated plot was significantly higher from that in the 15% and 20%. However, the 15% and 20% neem-treated plots, as well as the Karate-treated plot were not significantly different from one another although *A. curvipes* population was higher in the 15% neem-treated plot than in the 20%, with the Karate-treated plot recording the lowest population.

The treatments also had significant effect on the abundance of *Nezara viridula* L. on the cowpea plants (F = 11.8, df = 5, 15, P < 0.01). The mean number of *N. viridula* in each neem-treated plot was significantly higher than that in the control. Among the neem treatments, the 5% neem-treated plot recorded a significantly higher number of *N. viridula* than that of the 10%. The 10% neem-treated plot also recorded a significantly higher number than that of the 15%. However, the 15% and the 20% neem-treated and the Karate-treated plots did not differ significantly from each other in the population of *N. viridula.*

The population of *Mirperus jaculus*, which was the least abundant PSB in the field, was also significantly affected by the treatments (F = 9.8, df = 5, 15, P < 0.01). All the neem-treated plots recorded a significantly lower number of *M. jaculus* than the control plot. The 5% neem-treated plot recorded a significantly higher number than that of the 10%, 15% and 20%. However, the 10% and 15% neem-treated plots were not significantly different from each other but significantly different from the 20%. Moreover, the mean number of M *jaculus* recorded on the 20% neem-treated plot was not statistically different from that of the Karate. The overall damage incidence of PSBs on the developing cowpea pods was significantly different between the treatments (Table 8).

Table 8:

Damage by Pod-Sucking Bug (PSB) infestation on cowpea plants spryed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.

Treatment	Mean number of pods per plant (n = 6)	Mean number ± SE of shriveled pods	Proportion (%) ± SE of shriveled pods
Control	3.4	2.9 ± 0.2 b	85.4 ± 5.4 a
5% NSE	5.4	3.6 ± 0.2 a	67.7 ± 5.4 b
10% NSE	10.0	2.8 ± 0.6 b	29.0 ± 7.5 c
15% NSE	15.1	1.7 ± 0.3 d	11.2 ± 2.4 d
20% NSE	15.9	2.2 ± 0.3 c	10.5 ± 1.0 d
Karate	19.8	1.7 ± 0.1 d	8.5 ± 0.6 d
F (5,15) P-value		4.9 < 0.01	52.3 < 0.001

n = number of plants sampled

Means within columns followed by a common letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test).

The mean number of shriveled pods was found to decrease significantly with increasing concentration of the neem extracts (F= 4.9, d 5, 15, P < 0.001) up to the 15%. It was observed that the 5% neem treatment recorded significantly the highest number of shriveled pods. Also, the mean number of shriveled pods was significantly higher in the 20% neem-treated plot than in the 15% whereas the 15% neem-treated plot recorded the same number as that of the Karate.

The proportion or percent of shriveled pods also differed significantly between the treatments (F = 52.3, df = 5, 15, P < 0.001). Unlike the mean number of shriveled pods, all the neem-treated plots recorded a significantly lower percent of shriveled pods than the control. The proportion of shriveled pods decreased significantly with increasing neem concentration from 5% to 15%. However, no difference was observed between the 15%, 20% NSEs and the Karate treatments.

4.6 The Effects of Neem Seed Extracts on Cowpea Pod, Grain and Fodder Yields

Table 9 shows the effects of the different concentrations of neem seed extracts on the pod yield, grain yield and grain quality of the cowpea crop. The results have shown that cowpea pod yield was significantly affected by the treatments (F = 12.1, df = 5, 15, P < 0.01). The mean number of pods produced was found to increase consistently with increasing concentration of neem seed extracts (see also Plate 1). The mean number of pods per plant in the 5% neem-treated plot was higher than that of the control plot even though no significant difference existed between them.

Table 9:

Number of pods, grain yield and grain quality obtained from cowpea plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.

Treatment	**Mean number ± SE of pods per plant (n = 6)**	**Mean grain yield (kg ha^{-1})**	**Mean grain damage rating**
Control	3.4 ± 0.3 a	203.3 a	4.8 a
5% NSE	5.4 ± 0.4 a	408.0 b	3.5 b
10% NSE	10.0 ± 0.8 b	709.0 c	3.0 c
15% NSE	15.1 ± 1.3 c	1455.5 d	2.7 d
20% NSE	15.9 ± 1.4 c	1471.3 d	2.5 d
Karate	19.8 ± 0.6 d	1698.3 e	2.3 d
F (5,15)	12.1	24.4	42.0
P-value	< 0.01	< 0.001	< 0.001

n = number of plants sampled

Damaged grains include all cowpea seeds whose quality has been reduced as a result of infestation by the field insect pests.

Grain damage rating based on a visual scale of 1-6, where 1 = 0-5%; 2 = 6-25%; 3 =26-50%; 4 = 51-75%; 5 = 76-95% and 6 = >95%.

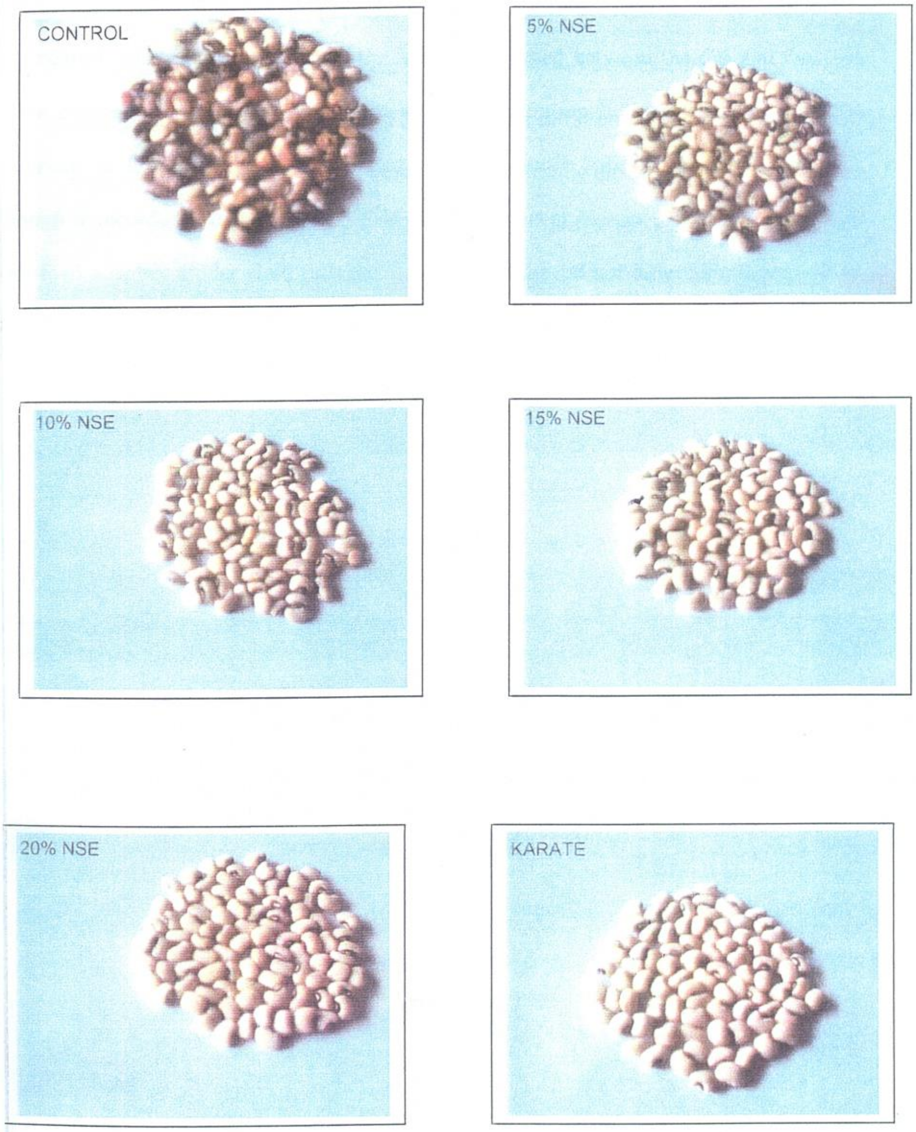
Means within columns followed by a common letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test).

Plate 1: Cowpea plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.

However, significant differences were found to exist between the 5%, 10% and 15% NSEs treatments, whereas the 15% and 20% NSEs treatments did not differ from one another. Overall, the Karate-treated plot produced significantly higher number of pods per plant than any of the other treatments. Moreover, cowpea grain yield was significantly affected by the treatments ($F = 24.4$, $df = 5, 15$, $P < 0.001$) (Table 9). The mean grain yield in each neem-treated plot was significantly higher than that in the control plot but significantly lower than that in the Karate-treated plot. Among the neem treatments, the 5% neem-treated plot recorded a significantly lower yield of cowpea grain than the higher concentrations. The 10% neem-treated plot also recorded a significantly lower grain yield than the 15% neem-treated plot. However, the grain yield obtained from the 15% neem-treated plot was not significantly different from that obtained from the 20% although the 20% neem-treated plot recorded a slightly higher grain yield than that of the 15%.

Cowpea grain quality, expressed as the mean grain damage rating based on a visual scale, was also significantly affected by the treatments ($F = 42.0$, $df = 5, 15$, $P < 0.001$). The mean rating of damaged grains in each neem-treated plot was significantly lower than that of the control plot. The 5% neem-treated plot recorded significantly higher grain damage than that of the 10%, 15% and 20%. However, the 15% and 20% neem-treated and the Karate-treated plots did not differ significantly from each other although the grain damage rating in the 15% neem-treated plot was found to be higher than that of the 20%, which, in turn was higher than that of the Karate. Grain quality thus, appeared to increase with increasing concentration of the neem extracts (see Plate 2).

Plate 2: Cowpea grains obtained from the plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.



Cowpea fodder yield was also found to be significantly affected by the treatments ($F = 10.4$ df = 5, 15, $P < 0.001$) (Table 10). Contrary to the grain yield, mean fodder yield decreased consistently with increasing concentration of the neem extracts. With the exeption of the 5% NSE, all the other neem concentrations were significantly higher than the control. Also, significant difference was not observed between the 5% and the 10% neem concentrations. Similarly, the 10% neem concentration did not differ from the 15% whereas the 15% concentration was also not significantly different from the 20% even though it recorded a higher fodder yield. The 20% neem extract treatment, which also recorded a higher fodder yield than the Karate treatment did not differ significantly from it.

Table 10:

Fodder yield obtained from cowpea plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.

Treatment	Mean fodder yield (kg ha^{-1})
Control	2,442.5 a
5'Yo NSE	1,851.8 ab
10% NSE	1,359.5 bc
15% NSE	806.0 cd
20% NSE	791.5 d
Karate	495.0 d
F (5,15)	10.4
P-value	< 0.001

Fodder yield estimate from uprooted plants including the roots after harvesting the pods.

Means followed by a common letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test)

4.7 The Cost-benefit Analysis from Cowpea Grain and Fodder

The profit per hectare and the cost-benefit ratios obtained from the grain yield of the cowpea crop sprayed with the different concentrations of neem seed extracts are presented in Table 11. Partial budgeting has shown that the profit per hectare obtained from the cowpea grain increased with increasing concentration of the neem extracts from 5% to the 15% thereafter; further increase in concentration provided a decrease in profit. Each neem treatment was found to provide a higher profit per hectare ($101-367) than the control ($54.2) but a lower profit per hectare than the Karate treatment ($421.0). Among the neem treatments, the 5eem treatment provided a lower profit ($101.5) than the 10% neem treatment ($174.9). The 10% neem treatment also provided a lower profit than the 15% neem treatment ($366.8). The profit per hectare obtained from the 15% neem treatment was however, found to be slightly higher than that obtained from the 20% ($363.8). Cost-benefit analysis showed that the 15% neem treatment provided the highest cost-benefit ratio (17.1) while the 10% neem treatment provided the lowest (12.2). Moreover, the cost-benefit ratio obtained from the 5% neem treatment was higher (14.2) than that obtained from the karate treatment (13.5) even though the Karate treatment recorded a higher profit per hectare. However, the cost-benefit ratio obtained from the Karate treatment was higher than that obtained from the 20% neem treatment (12.7).

Table 12 presents the profit per hectare and the cost-benefit ratios obtained from the fodder yield of the cowpea crop sprayed with the different concentrations of neem seed extracts. Partial budgeting has shown that the profit per hectare decreased with increasing concentration of the neem extracts. Each neem treatment provided a lower profit than the control ($108.5) but a higher profit than the Karate treatment ($-9.1).

Table 11:

Profit (in Cedis and Dollars) per hectare and cost-benefit ratios obtained from the grain yield of cowpea plants sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.

Treatment	**Mean grain yield (kg ha^{-1})**	**Value of yield**		**Cost of treatment**		**Profit per hectare**		**Cost-benefit ratio**
		$	**¢**	**$**	**¢**	**$**	**¢**	
Control	203.3	54.2	488,000	-	-	54.2	488,000	-
5% NSE	408.0	108.7	978,000	7.1	64,000	101.5	914,000	14.2
10% NSE	709.0	189.1	1,702,000	14.2	128,000	174.9	1,574,000	12.2
15% NSE	1455.5	388.1	3,494,000	21.3	192,000	366.8	3,302,000	17.1
20% NSE	1471.5	392.3	3,531,000	28.4	256,000	363.8	3,275,000	12.7
Karate	1698.3	452.8	4,075,900	31.1	280,000	421	3,795,900	13.5

Means followed by a common letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test). Exchange rate as at time of study: 09,000 = US$1

Selling price for cowpea seeds as at time of study: ¢2,400/kg (Source; Market Information Branch, Ministry of Agriculture, Tamale, Ghana).

Cost of treatments include only cost of chemicals applied throughout the cropping; cost of neem seed: ¢8,000/kg, cost of Karate: 070,000/litre (Source: Market Information Branch, Ministry of Agriculture, Tamale, Ghana).

Cost-benefit ratio is the number of times the cost of insecticide control was recouped from the value of the increased yield.

Table 12:

Profit (in Cedis and Dollars) per hectare and benefit-cost ratios obtained from the fodder yield of cowpea sprayed with neem seed extracts (NSEs) at the Nyankpala Experiment Station, Nyankpala, Northern Ghana.

Treatment	**Mean fodder yield (kg ha^{-1})**	**Value of yield 1**		**Cost of treatment**		**Profit per hectare**		**Benefit-cost ratio**
		$	**¢**	**$**	**¢**	**$**	**¢**	
Control	2,442.5	108.5	977,000	-	-	108.5	977000	-
5% NSE	1,851.8	82.3	740,720	7.1	64,000	75.1	676720	10.5
10% NSE	1,359.5	60.4	543,800	14.2	128,000	46.2	415800	3.2
15% NSE	806.0	35.8	322,400	21.3	192,000	14.4	130,400	0.6
20% NSE	791.5	35.2	316,600	28.4	256,000	6.7	60600	0.2
Karate	495.0	22.6	198,000	31.1	280,000	-9.1	-82000	-0.7

Means followed by a common letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test). Exchange rate as at time of study: 09,000 = US$1 Selling price for cowpea fodder as at time of study: 0400/kg (Source; Market Information Branch, Ministry of Agriculture, Tamale, Ghana).Cost of treatments include only cost of chemicals applied throughout the cropping; cost of neem seed: 08,000/kg; cost of Karate: 070,000/litre (Source: Market Information Branch, Ministry of Agriculture. Tamale, Ghana).Cost-benefit ratio is the number of times the insecticide control cost was recouped from the value of the increased yield.

Among the neem treatments, the 5% neem treatment provided a higher profit ($75.1) than the 10% ($46.2) in fodder yield. The 10% neem treatment also provided a higher profit than the 15% ($14.4), which, in turn, provided a higher profit than the 20% ($6.7). Cost-benefit analysis showed that cost-benefit ratio also decreased with increasing concentration of the neem extracts. The 5% neem treatment provided the highest (10.5) cost-benefit ratio while the Karate treatment provided the lowest (-0.7). Moreover, the cost-benefit ratio obtained from the 10% neem treatment was higher (3.2) than that obtained from the 15% neem treatment (0.6) which, in turn, was higher than that obtained from the 20% neem treatment (0.2).

CHAPTER FIVE

DISCUSSION

5.1 General Discussion

The present study has demonstrated that neem seed extracts at various concentrations was effective at reducing the incidence and abundance of the major field insect pests of cowpea. The reduction in pest infestation might probably be the result of the repellent, antifeedant and growth disruptive effects of the neem insecticides on the insects. Schmutterer (1990) reported that neem derivatives usually act as olfactory repellents, antifeedants (phagoterrents) and growth regulators on insect pests, the combined effect of which may lead to considerable decline in their populations. Also, important natural enemies of the pests that were present in the field appeared less, or not at all, probably harmed by the neem treatments. Ascher (1993) reported that neem products have some level of selectivity to beneficial insects of the cowpea crop. The delayed effect and the low knockdown efficacy of neem (Mordue and Blackwell, 1993) might explain why some insect pests continued feeding on the plants for some time after the application of the neem insecticides.

The brownish colorations observed in the 20% neem-treated plants at the preflowering stage might suggest the phytotoxicity effect of the neem products on the cowpea plants. Cobbinnah and Osei-Owusu (1988) made similar observations on cowpea and eggplant seedlings treated with 20% extract of the neem seed. Cowpea plants treated with the neem extracts also appeared to be more sensitive to drought, compared with those in the control plot, probably due to an induced osmotic pressure gradient by the neem products on the plants. Jackai *et al.* (1992) made similar observations on cowpea plants sprayed with seed extracts from neem. All the neem-treated plants also appeared to exhibit faster rate of leaf senescence and pod drying compared with those in the control plot, suggesting that the neem extracts had the effect of shortening the maturity period of the cowpea crop. This effect was found to be more pronounced in the Karate-treated plants.

Rainfall and temperature appeared to be the major environmental factors that could inhibit the effectiveness of the neem products in the field. The high temperatures experienced during the study might have contributed to an increased volatile effect of the active principles of the neem products. Also, heavy rainfall was capable of washing away the products from the plants before the target insects took them up and thus, making it necessary to repeat the application of the extracts, especially after every significant rain occurring within 6 hours after the spraying. Schmutterer (1990) observed that environmental factors such as ultra-violet light, temperature and rainfall usually *act* to reduce the residual life of neem products under field conditions.

5.2 The Effects of Neem Seed Extracts on *A. craccivora*

The study has shown that the increase in concentration of the neem seed extracts resulted in the reduction of the incidence and abundance of the black cowpea aphid, *Aphis craccivora* Koch on the cowpea plants. The 5% neem-treated plot recorded a significantly higher aphid score and percent aphid infestation than that of the 10%, suggesting that the 10% neem treatment was more effective than the 5% neem treatment in reducing aphid incidence and abundance on the cowpea crop. Also, no significant difference was found between the 10%, 15% and the 20% neem-treated plots in terms of the mean aphid score and percent aphid infestation. However, all the neem-treated plots recorded a significantly higher aphid score and percent aphid infestation than the Karate-treated plot.

Previous trials conducted by Schauer (1984) reported that aphid population buildup in tobacco plants was influenced only by the increase in concentration of neem from 1000ppm/1 to 1500ppm/1, a treatment at which a reduction in aphid numbers by 80% was achieved. In a study conducted by Lowery *et al.* (1993), aqueous seed extracts from neem reduced aphids numbers on pepper and strawberry in a dose-dependent manner with estimated concentrations for a 50% reduction in aphid population ranging from 0.2% to 1.4% under laboratory conditions. Under field conditions, neem seed extract at 2.0% was as effective as the botanical insecticide, Pyrethrum, for the control of aphids on the plants. The neem treatments, though not comparable to the Karate insecticide, acted as effective aphicides even at the lowest concentration of 5%. Exposure of the products to the insects on the cowpea foliage probably led to uptake of the active principles by contact and feeding, suggesting an additive effect of direct contact toxicity and systemic activity of the products, which led to their increased insecticidal effect on the insects. This agrees with the findings made by Stark *et al.* (1990) who, in a laboratory trial with various neem formulations on several fruitfly and aphid species reported that neem seed extracts exert both contact and systemic effects on aphids, the combined effect of which resulted in nearly 100% mortality of the insects.

The low aphid incidence at the study site could probably be due to the action of rainfall and temperature (Ascher, 1993). The continuous heavy rain experienced during the initial crop growth stages was capable of washing away a significant number of aphids from the plants. Also, temperatures were relatively cool during the sampling periods, with average mean daily temperatures between 20°C and 15°C. This cool weather conditions could reduce aphid feeding, mobility and capacity to reproduce, thus causing a subsequent decline in their populations in the field (Schmutterer, 1990).

5.3 The Effects of Neem Seed Extracts on *M. siostedti*

The study has shown that all the neem treatments were more effective than the control but less effective than the Karate treatment in reducing the abundance of the cowpea flower thrip, *Megalurothrips sjostedti* Tryb. on the racemes and flowers of the cowpea crop. Among the neem treatments, the 5% was less effective than the 10%, which, in turn, was less effective than the 15%, whereas the 15% was as effective as the 20% in reducing the abundance of *M. sjostedti*. Moreover, all the neem-treated, as well as the Karate-treated plots recorded fewer nymphal thrips than adult on both the racemes and the flowers, whereas in the case of the control, more nymphs than adults were recorded. This relatively high sensitivity of the nymphal thrips to the neem products could be due to their relatively less mobile and more confined and gregarious feeding habits on the cowpea plants. Saxena and Kidiavai (1997) observed that thrips nymphs were capable of causing severer damage to cowpea racemes and flowers than the adults due to their large numbers, low mobility, confined habit and gregarious feeding on the plants and thus, enhancing the rate of uptake and translocation of the active principles of the neem products, leading to high mortality and a subsequent decline in their population.

Tamo *et al.* (1993) enumerated three major factors that contribute to the destructiveness of *M. sjostedti* on its host cowpea plants:

(i) its ability to survive on a wide range of alternate host plants throughout the ecological distribution of cowpea, thus, surviving dry season conditions

(ii) the insufficient mortality factors regulating the population of the insect, and

(iii) the destructive effect of nymphal feeding on the development of cowpea racemes and flowers.

The reduced thrip infestation on the neem-treated plants could be attributable to the reduction in fecundity of the adults, coupled with a reduced growth and development of the nymphs. Fewer adults were recorded on both the racemes and the flowers of the neem-treated plants as compared with the untreated control plants, probably as a result of these debilitating effects of the neem products on the growth and development of the nymphal thrips into adults. Saxena and Kidiavai (1997) reported similar results of neem extract treatments on the population of *M. sjostedti* larvae on cowpea flowers and attributed this to a reduction in fecundity of the adult thrips, or the reduced growth and development of the nymphs. Dreyer (1986) reported a significantly fewer number of thrips nymphs on flower buds, less shedding of flower buds and increased production of pods on cowpea plants sprayed with 5% or 10% aqueous neem seed extracts, compared with the untreated control plants, with no significant drop in the number of thrips adults. Foliar spraying with aqueous neem seed extracts also significantly reduced the infestation of thrips on cowpea and resulted in higher grain yield compared with the untreated control in Ghana and Nigeria (Ivbijaro and Bolaji, 1990; Tanzubil, 1991). In Tanzania, damage to the cowpea crop was reduced and the population of *M. sjostedti* was suppressed as effectively with aqueous neem seed extracts as with Lindane (Hongo and Karel, 1986).

Although some thrips-resistant and high yielding cowpea varieties have been developed for cultivation (Ansari, 1984), the results of this study have confirmed that the use of neem in thrip management is necessary, in order to reduce flower losses and increase pod production in the cowpea crop. Even if one disregards the issue of unavailability and unaffordability of synthetic insecticides, it is clear that the possible net gain obtained with the use of neem seed extracts in thrips management for cowpea may be higher than that obtained with the use of synthetic insecticides.

5.4 The Effects of Neem Seed Extracts on *M. vitrata*

The study has shown that the reduction in abundance of the larvae of the legume pod borer, *Maruca vitrata* Fab. on the cowpea flowers and their subsequent damage to the pods was generally dependent on the concentration of the neem seed extracts. In other words, an increase in insecticidal activity and the adverse effects of neem on the insects might be the result of the increased concentration of the extracts, which led to a decrease in the number of pod borer larvae on the flowers and their damage incidence on the pods.

Previous experiments conducted by Cobbinah and Osei-Owusu (1988) using various formulations of neem to determine their effectiveness for the control of the major pests of cowpea in Southern Ghana showed that pod borer incidence and abundance were more reduced on cowpea plants treated with 20% aqueous methanol extracts of neem seed compared with those treated with 5% or 10% solution of the same extract. Ivbijaro and Bolaji (1990) also observed no significant difference between neem seed extract treatments and that of Cypermethrin + Dimethoate in the reduction of *M. vitrata* population on cowpea. The insecticidal activity of the neem products on the insects might have been achieved by the systemic translocation of more of the active principles of the neem insecticides, since it is known that the borers are not usually likely to have direct contact with the neem products on the plant surfaces (Bottenberg and Singh, 1996). Bottenberg and Singh (1996) moreover, reported that higher concentrations and increased number of applications are usually required in order to improve the positive effects of neem on pod borers infesting cowpea. Jackai *el al.* (1992), in a semi-field experiment to determine the insecticidal activity of aqueous neem seed extracts at 5%, 10%, 15% and 20% concentrations against some major cowpea pests in Northern Nigeria, reported that neem was effective in acting as insecticide and affected the rate of pod borer development at concentration as low as 5%. Marginal survival was found to decrease with increasing concentration of neem, up to a point where further increase in concentration produced no significant increase in the survival rates of the insects. This might explain why no significant difference in pod borer incidence was found between the 15% and the 20% concentrations of the extracts in the present study.

Although complete larval mortality was not recorded at any concentration in the present study, larval feeding of *M. vitrata* on the cowpea flowers and pods was effectively reduced and as a result there was a reduced flower and pod damage in all the neem-treated plants compared with the control. The neem derivatives might have acted as feeding deterrents on the insects to the extent that the larvae did not feed at all and so died as a result of prolonged starvation. Ivbijaro (1983) reported a reduction in fecundity and emergence of *Callosobruchus* spp using neem oil and suggested a possible larvicidal and other negative physiological attributes of the neem products on the insects. Dreyer (1982) and Jackai *et al.* (1992) reported that in addition to azadirachtin, other products present in the neem seed might be acting as larvicidal, feeding deterrents or suppressants. Butterworth and Mogan (1971) working with *Schistocerca gregaria* (Forst.) reported an inhibitory effect of neem on the feeding ability of the insect. At low concentrations (5g/300m1 seed extract), azadirachtin prolonged development of the nymphs, which took twice the normal development time to become adults. At higher concentrations, the products either deformed the insects or killed them outright. Roscoe (1972) also reported prolonged growth of lepidopterous larvae in low rates of azadirachtin, and deformities in and/or death of the adults in high doses.

It was observed from the present study that some cowpea flowers that sustained pod borer damages on them did not record any pod borer larvae on them as expected. It could be deduced that the larvae found on the neem-treated plants during the day had moved out of the infested pods the previous night and bore into the fresh ones due to the toxicity of the neem on the surfaces of the previously infested pods. Also, during sampling in the neem-treated plots, pod borer larvae were found in other parts of the plants other than the flowers or pods. This might indicate an antifeedant and repellent effects of the extracts on the insects, and suggests that by exposing the larvae to the heat of the sun and attack by natural enemies with an increase in the duration of exposure to the recommended concentration of the neem extracts, effective management of the larvae could be achieved in the field.

5.5 The Effects of Neem Seed Extracts on Pod-sucking Bugs

The reduced incidence and abundance of pod-sucking bugs (PSBs) in the insecticide-treated plots compared with the control plot recorded in the present study showed that the neem sprays were effective in reducing PSBs infestation in the field. The 15% and 20% neem-treated plots were not significantly different from the Karate-treated plot in the proportion of shriveled pods, suggesting that neem seed extract at 15% or 20% was as effective as the Karate insecticide in reducing the proportion of shriveled pods caused byPSBs.

Seymour *et al.* (1995) reported that treating pecan nuts with neem seed extracts significantly decreased the number of feeding sites of *N viridula* compared with the control. There was however, no significant difference in the feeding frequency of the bug between 0.5% and 5% concentrations of the extract. Abdulai *et al.* (2002) reported that the antifeedant activity of Neemix 4.5 CE, a commercial formulation from azadirachtin, on *N. viridula* was significantly greater on cowpea pods treated with 5% solution of the product than those treated with 0.5% solution. Saxena and Khan (1985) also reported a lower pod bug incidence on cowpea plants treated with higher concentrations of the neem extracts compared to those treated with lower concentrations, due to the probing effect of the insects on contactwith the neem treated plants.

Passerini and Hill (1993) described three modes of injestion of neeem-treated plants by the saheliangrasshopper, *Kraussaria angulifera* (Krauss.) as palpation, biting and nibbling. Palpation and nibbling were exhibited in response to the toxicity and repellent effect of the neem insecticide on treated millet. In the present study, it was evident that the neem extracts did repel the bugs on approaching the treated plants as they appeared to exibit negative piercing and sucking response by initially flying away before alighting back on the treated pods to attempt feeding. This might have led to prolonged starvation and increased mortality. Similar behavioural manifestations were reported by Jackai *et al.* (1992) for *C. tomentosicollis* Stal. on cowpea. Abdulai *et al.* (2002) observed that male and female *N. viridula* exhibited similar feeding behavioural patterns on neem-treated cowpea pods. Bowling (1980) also made similar observations for other pod suckers infesting soybean.

The toxic and growth destructive effects of neem on the instar nymphs of pod-sucking bugs have been documented by several workers. Smirle and Wei (1996) reported an increased LC50 for neem oil within three days after treatment in the pear sawfly, *Caliroa cerasi* L. as a result of the toxic and growth disruptive effect of the neem products. Neem-based derivatives may act as moulting suppressants, affecting ecdysis and resulting in malformation or death of most heteropterous insects (Ascher, 1993). Dorn *et al.* (1987) reported a reduced capacity of the nymphs of *Oncopeltus fasciatus* Dallas to moult into adults under prolonged exposure to neem. Jackai *et al.* (1992) observed a prolonged nymphal development time on *C. tomentosicollis* exposed to neem-treated cowpea plants. Koul (1984a) also observed fecundity and sterility effects of neem in females of *Dysdercus koenigii* Sign resulting in fewer numbers of eggs produced as compared to that from the control. Females of *O.fasciatus* derived from topically treated nymphs also produced fewer eggs than untreated bugs (Schmutterer 1990). The growth inhibitory effects of neem extracts on the pod-sucking bugs in the present study could be attributed to the insecticidal properties of the major component of neem, azadirachtin, which is known to interfere with neuroendocrine control of moulting and reproduction in the insects (Aerts and Mordue, 1997). Despite the slow speed of kill, the growth disruptive effects of neem treatments have been reported to reduce PSBs' capacity to harm crops several days before their death (Jackai *et al.*, 1992). It could be possible that some of the bug nymphs that died might have been weakened two days after the neem treatments, and probably stopped feeding a few days before their eventual death (Schmutterer, 1990).

Tanzubil (2000) reported that aqueous neem seed extract at 10% was as effective as the synthetic pyrethriod, Lambda Cyhalothrin (Karate), in suppressing the population of PSBs infesting cowpea, but its efficacy drastically declined when applied under continues rainfall conditions as the active ingredient of the product was easily drained away by the rain drops. This might explain the relatively low effectiveness of the neem extracts in reducing PSB incidence compared with the Karate insecticide. The torrential rainfall experienced during the pod bearing stage of the crop in the present study might have acted to dilute or wash away the neem products from the cowpea plants, and thus, decreased their insecticidal effect on the insects.

5.6 The Effects of Neem Seed Extracts on Cowpea Grain and Fodder Yields

The results have demonstrated that compea grain yield increased with the increase in the concentration of the neem seed extracts. The increase in grain yield might be due to the reduction in the abundance of the major insect pests and their subsequent damage to the cowpea crop as a result of the insecticide treatments. Cobbinah and Osei-Owusu (1988) obtained a significantly higher pod yield from cowpea plants treated with 20% emulsified neem seed compared with the untreated control. Saxena and Kidiavai (1997) also obtained a significantly higher grain yield from cowpea plants treated with 20% neem seed extracts compared with the control. Tanzubil (2000) on the other hand, reported a significantly higher grain yield in Karate-treated cowpea plots compared with 5% or 10% neem seed extract-treated plots in Northern Ghana. However, Ivbijaro and Bolaji (1990) claimed that although seed yield of cowpea, after treatment with Cypermethrin + Dimethoate, was significantly higher than the yield obtained from neem seed extract treatment, the marginal increase in yield compared with the control was achieved by foliar spraying with the extracts from neem.

Cowpea grain quality was also found to improve with the increase in concentration of the neem seed extracts. The proportion of damaged grain was significantly lower in all the neem treatments as compared to the control, indicating that the botanical sprays resulted in a reduced proportion of damaged grains in the cowpea crop. Passerini and Hill (1993), in a field trial using locally formulated aqueous extracts from the neem seed found out that neem extract concentrations as low as 1% were more effective in reducing the number of damaged grains and increasing grain quality in millet than the untreated control. In the present study, the 15% and/or the 20% neem seed extracts were as effective as the Karate insecticide in reducing the proportion of damaged grains and increasing grain quality in the cowpea crop. Saxena and Kidiavai (1997) also obtained a more superior grain quality in neem-treated cowpea plot than in the untreated control or Cypermethrin-treated plots.

The present study however, showed that the insecticide treatments generally had a negative influence on the fodder yield of the cowpea crop. The higher fodder yield obtained from the control plot compared with the insecticide-treated plots is an indication that maximum fodder yield was possible even without the insecticide sprays. The reduced pest incidence and abundance in the insecticide-treated plots possibly provided a more favourable growth environment for the cowpea plants and this might have increased the partitioning of much of the plant biomass into pods and seeds, resulting in an increased grain yield with low dry matter content after harvest. Moreover, the fact that the cowpea variety used in the study was not the dual-purpose type might explain the low dry matter content of the neem-treated plants.

5.7 Cost-benefit Analysis from Cowpea Grain and Fodder

Partial budgeting has shown that it would be most profitable to produce cowpea for grains using the Karate insecticide compared with the use of any of the neem extract treatments. Moreover, it would be more profitable to produce cowpea for grains using the higher concentrations (15% and 20%) of neem seed extracts in terms of profit per hectare. Though the Karate treatment gave the highest profit per hectare, the cost-benefit ratio obtained from its use was lower than that of the 5% or 15% neem extract due to the high cost associated with its use. It would therefore be more cost beneficial to produce cowpea for grains using the 15% or the 5% neem cextract instead of the Karate insecticide, or the 20% neem extracts. Saxena and Kidiavai (1997), in a field station trial to control flower thrips on cowpea in Southeastern Kenya recorded a higher net gain from the 5% neem treatment than from the 20% neem treatment. Emosairue and Ubana (1998) has reported that the Karate treatment, though provided the highest yield and the highest profit of cowpea grain, was less cost beneficial than the 5% neem extract treatment.

Partial budgeting also showed that it would be more economical to produce cowpea for fodder without the neem or Karate insecticide sprays. The negative value of profit obtained from the Karate treatment meant that if a grower cultivated the cowpea crop, solely for fodder, with the Karate insecticide, he would run at a loss, and would have to pay additional US$ 13.0 (¢82,000.00) in order to cover the cost of pest control. Where neem extracts are to be used in cowpea pest control, the highest profit from the fodder would be achieved by the use of the 5% extract. Any further increase in concentration may lead to diminishing returns, resulting in a reduced profit. The no insecticide-sprayed treatment, thus, proved to be the most cost effective for use in producing cowpea for fodder.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This present study has demonstrated that aqueous extracts from the neem seed have considerable potential for the management of the major field insect pests of cowpea in the guinea savanna ecology of Ghana. The incidence and abundance of all the major insect pests encountered in the trial were found to decrease consistently with increasing concentration of the extracts, indicating a dose-dependent response of the insects to the neem products. Although the levels of control were variable, the 15% and 20% neem treatments sometimes provided levels of control similar to each other and to the Karate insecticide.

Aphid incidence and abundance was reduced in all the neem-treated plots, probably as a result of a direct contact toxicity and systemic activity of the neem products on the insects. The nymphal thrips were found to be more sensitive to the neem insecticides than the adult thrips as a result of their large numbers, low mobility, confined habit and gregarious feeding on the plants. This could provide a useful guide for their effective management in cowpea farms, by targeting the neem applications at the nymphal stages of the insect. The abundance of the pod borers on flowers, as well as their incidence on the developing pods were also significantly reduced by the neem extracts treatments. The emergence of the pod borer larvae from the flowers and pods and their entry into fresh ones was drastically slowed down, or effectively prevented by the toxic effects of the neem products, providing a clue to the development of comprehensive strategies for their effective management in the field. Pod-sucking bug infestation was also significantly reduced in all the neem treatments probably as a result of the repellent, antifeedant and growth regulatory effects of the active principles of the neem on them.

The reduction in the incidence and abundance of these pests on the cowpea plants resulted in a corresponding increase in the grain yield and quality of the crop. Cowpea grain yield was significantly increased with increasing concentration of neem, up to 15% where further increase in concentration did not provide a significant increase in grain yield. The grain yield obtained from any of the neem extract treatments was however, not comparable to that obtained from the Karate treatment, but the grain quality from the 15% or the 20% neem treatment was as superior as that of the Karate treatment. Cowpea fodder yield however, decreased with increasing concentration of the neem extracts.

The cost-benefit analysis from the grain and fodder yields showed that the 15% and 5% neem extracts gave the best cost-benefit ratio respectively, suggesting that cowpea production for quality marketable grains and for fodder would be most economical when the 15% and 5% extracts, respectively, are used.

6.2 Recommendations

The results of the present study have shown that even though the Karate treatment provided the highest profit per hectare in terms of cowpea grain, the 15% neem treatment gave the best cost-benefit ratio, and thus, would be most capable of providing maximum economic returns to the grower. Therefore, the 15% neem seed extract would be most recommendable for use in controlling the major field insect pests of cowpea for maximum grain yield in the savanna ecology of Ghana. In situations where the grower is strapped with limited cash resources however, the 5% extract may be used in order to help cut down the cost of pest control. The 5% extract may be especially recommended for dual-purpose cowpea cultivars and/or where mixed farming is practiced, in order to help maintain reasonable yields and maximum utilization of both grain and fodder.

The time of application of the extracts need to correspond with the three traditional vulnerable crop growth stages of the crop and high risk periods of the pest infestation; namely the vegetative growth stage when aphids incidence is high, the flowering stage when flower thrips and pod borer infestations are high, and at the pod bearing stage when pod borer and pod-sucking bug damages are more severe. A major constraint to the use of neem seed extracts in cowpea pest management under field conditions has been the negative influence of rainfall on the active principles, and the short residual life of the extracts on the treated plants, conditions that require frequent repeated applications of the extracts in order to obtain satisfactory results in the field (Tanzubil, 2000). Accurate information about the weather therefore needs to be obtained before the application of the extracts so as to avoid such effect of rainfall on the product. The addition of inert ingredients such as detergents or vegetable oil to the extracts before spraying may also be a desirable way of increasing the potency of the extracts and the duration of their protective action in the field. As neem products are ultra-violet- sensitive, the target insects must take them up as soon as possible during feeding. The application of the extracts should therefore coincide with the active feeding phases of the target insects or the most sensitive larval/nymphal instars, as there are also remarkable differences in sensitivity during metamorphosis (Schmutterer, 1987).

The mature neem seed used in this study for making the extracts is a renewable natural resource with multiple uses. Its relatively low, and sometimes negligible cost in cowpea pest management could be an advantage, especially for cash-strapped farmers in the tropics. Awareness of the considerable potential of neem seed extracts in controlling field insect pests of cowpea is growing rapidly in African countries, where neem is widely distributed and readily available to users. The tools required for the preparation of the extracts have also been designed for the sake of simplicity, ease of adoption and convenience of use by cowpea farmers in most localities. The use of neem seed extracts for cowpea pests management has the added benefit of weak or inconsequential side effects on the natural enemies of pest and crop pollinators, and other ecologically important nontarget organisms, a factor, which is considered as a prerequisite for successful Integrated Pest Management (IPM) for cowpea (Schmutterer, 1995).

Due to the site- or location-specific nature of the present findings, it could be suggested that further trials be conducted to investigate the effects of the extracts under different geographical distributions of both the pests and the cowpea crop. The possible effects of phytotoxicity of the extracts on the plants also need to be confirmed. Further investigations should also consider the effect of the extracts on the grain and fodder yields of the dual-purpose cowpea varieties. There is also the need to find out more ways of enhancing the pest control efficacy of neem seed extracts by the addition of simple synergists and sun-shields to protect them from rapid degradation by ultra-violet light and other negative environmental factors. Finally, the insecticidal potential and residual activity of neem seeds extracts from different geographical distributions is another area needing further investigation, since it is believed or thought that neem seeds from Africa are more potent than those from other areas such as India and Asia (Ascher, 1993).

REFERENCES

Abdulai,M., Shepard, B. M. and Mitchel, P. L. (2002) Antifeedant and toxic effects of neem *(Azadirachta indica* A. Juss.)-based formulation, Neemix, against *Nezara viridula* L. (Hemiptera: Pentatomidae). *J. Entomol. Sci*. 38 (3): 398-408.

Abid, M., and Maqbool, M. A. (1991) Effect of bare-root dip treatment in neem oil cake and neem leaf extract on root-knot development and growth of tomato and egg plant. *Pakistan J. Nemat*9: 13-16.

Adalla, C. B. (1994) Progress in incorporating insect resistance in grain and vegetable legumes. Final lecture delivered on March 9, 1994 as holder of UichancoProfessorial Chair in Pest Management. Los Banos, The Phlippines. Pp. 17.

Adler, V. E., and Eubel, E. C. (1987) Effect of Margosan-O on six species of cockroaches (Orthoptera: Blaberidae, Blattidae and Blattilidae). *In:* Natural Pesticides from the neem tree and other tropical plants. Proc. 3rd Int. Neem Conf. Nairobi, 1986. Eschborn: GTZ. Pp. 387-392.

Aerts, R. J., and A. J. Mordue (Luntz) (1997) Feeding deterrence and toxicity of neem triterpinoids. *J. Chem. Ecol.* 23: 2117-2132.

Afun, J. V. K., Jackai, L. E. N., and Hodgson, C. K. (1991) Calendar and monitored insecticide application for the control of cowpea pests. *Crop Prot*. 10: 363-370.

Alam, M. M. (1991) Control of plant-parasitic nematodes of some vegetables in the field with neem seed oil. *Pakistan J. Nemat*.9: 21-30.

Alghali, A. M. (1992) Insecticide application schedules to reduce grain yield losses caused by insect pests of cowpea in Nigeria. *Insect Sci*. *Appl.* 13: 725-730.

Ali, B. H. (1987). The toxicity of *Azadirachta indica* leaves in goats and guinea pigs. *Vet.Human Toxicol.* 29:16.

Ali, B. H., and A. M. M. Salih (1982). Suspected *Azadirachta indica* toxicity in sheep. *Vet. Rec.* 111: 494.

Ampong-Nyarko, K, S. K. V. Reddy, and K. N. Saxena (1994) Reduction in insect pest attack on sorghum and cowpea by intercropping. *Entomologia Exp. Appl.* 70: 179-184.

Ansari, A. K (1984) Biology of *Aphis craccivora* (Koch) and varietal resistance of cowpeas. **PhD** thesis, Univ. Reading, UK, pp. 273.

Arya, A. (1988) Control of *Phomopsi.s* fruit rot by leaf extracts of certain medicinal plants. *In:* Kaushi P. (ed.). Indigenous medicinal plants. New Delhi, Pp. 41-46.

Asante, S. K, Tamo, M. and Jackai, L. E. N. (2001) Integrated management of cowpea insect pests using elite cultivars, date of planting and minimum insecticide application. *J. African Crop Sci. Jour.* 9 (4): 655-665.

Ascher, K. R. S. (1993) Nonconventional insecticidal effects of pesticides available from the neem tree, *Azadirachta indica. In:* Archaives of Insect Biochemistry and ftysiology. 22: 433-449.

Azmi, M. I. (1990) Control of plant parasitic nematodes by incorporating deoiled cakes Of tree seeds on su-babul *(Leucaena leucocephala (Lam.) Indian Forest Entomol.* 116: 812-814.

Barker, G. C., Mercer, J. G., Svoboda, J. A. Thomson, M. J., Rees, H. H. and Howells,

R. E. (1989) Effects of potential inhibitors on *Brugia pahangi* in vitro: Microfilarial action and inhibition of microfilarial production. *Parasitology* 99: 409-416.

Bhat, N. S., Raju, G. T. Manjunatha, T. M. Nagabhushana, G. G. and Deshpande, V. P. (1988) Chemical control of cowpea pod borers. *Indian Plant Protection.*16 (2): 197-200.

Ballidawa, C. W. (1985) Plant species diversity and crop pest control: an analytical review. *Insect Sci. Appl.* 6: 479-487.

Booker, H. J. (1965) Pests of cowpea and their control in Northern Nigeria.*Bull. Entomol. Res.* 55: 663-672.

Bottenberg, H., and B. B. Singh (1996) Effects of neem leaf extracts applied using the 'broom' method on cowpea pests and yield. *Int. J. Pest Mgt*. 42: 207-209.

Bottenberg, H., M. Tamo, D. Aroudokoun, L. E. N. Jackai, B. B. Singh, and Youm, O. (1997) Population dynamics and migration of cowpea pests in Northern Nigeria: implication for IPM programmes. Pp 271-284. *In:* B. B. Singh, R. R. Mogan Raj, K. E. Dashiell, and L. E. N. Jackai (eds.). Advances in cowpea research.Copublication of IITA and JIRCAS.IITA, Ibadan, Nigeria.

Bowling, C. C. (1980) The stylet sheath as an indicator of feeding activity by the southern green sting bug on soybean. *J. Econ. Entomol.*73: 1-3.

Bray, D. H., Warhurst, D. C. Connolly, J. D. O'Neill, M. J. and Phillipson, J. D. (1990) Plants as sources of antimalarial drugs. Part 7. Activity of some species of Meliaceae plants and their constituent limonoids. *Phytother. Res.* 4: 29-35.

Breniere, J. (1967) Les problems entomologiques du et des graminees de grand culture.

Rapport de mission du 31 aout an 15 octobre, 1967. Institat de recherches agronomiques tropicales, Paris, France, pp. 44.

Butterworth, J. H., and Mogan, E. D. (1971) Investigation of the locus feeding inhibition by seeds of the neem tree *(Azadirachta indica). J. Isect Physiol.* 17: 967-977.

Cassier P. D., Chalaye N., Besse D., Papilon M., Baldara L., and Forcheron A. (1987) Ecdysteroids and activation of epidermal cells in locust. Poster VIII. Ecdyson Workshop, Marburg, 1987, pp. 39.

Chopra, R. L. (1928) Annual reproduction of the entomologist to the Government of Punjab, Lyallpur, for the year 1925-1926. Rep. Dept. Agric. Punjab. 1(Pt.2): 67-125.

Cobinnah, J. R., and Osei-Owosu, K. (1988) Effects of neem seed extracts on insect pests of eggplant, okro and cowpea. *Insect Sci. Appl.* 9(5): 601-607.

Dissemond, A., and Hindorf, H. (1990) influence of sorghum/maize/cowpea intercropping on pest, disease and weed situation at Mbita, Kenya.*In:* Proc. IPM in Tropical and Subtropical Cropping Systems. Frankfurt, Germany, pp. 843-851.

Dorn, A. (1986) Effect of azadirachtin on reproduction and egg development of the heteropteran, *Oncopeltus fasciatus. J. AppL Entomol.* 102: 313-319.

Dorn, A., Rademacher, J. M. and Sehn, E. (1987) Effects of azadirachtin on the reproductive organs and fertility in the milkweed bug, *Oncopeltus fasciatus. In:* Natural pesticides from the neem tree and other tropical plants. Proc. 3rd Int. Neem Conf., Nairobi, 1986. Eschborn: GTZ, pp. 273-288.

Dreyer, M. (1982) Some practical information including oil production and storage of seeds (Mimeograph).

Dreyer, M. (1984) Effects of aqueous neem seed extracts and neem oil on the main pests of *cucurbita pepo* in Togo. Pro. 3rd Int. Neem Conf. Rauischholzhausen, pp. 435-444.

Dreyer, M. (1986) Untersuchungen zur Wirksamkeit von Wasserextrakten und andern Produkten aus Niemsamen gegen schadlinge an Gemuse und Feldkulturen in Togo. Doctoral thesis, Univ. Giessen, Germany.

Duke, J. A. (1990) Introduction to food legumes. pp.1-42. *In:* Singh, S. R. (ed.). Insect pests of tropical food legumes. John Wiley and Sons, Chichester, UK.

Ezueh, M. L, and Taylor, A. T. (1994) Effects of timing of intercropping with maize on cowpea susceptibility to three major pests.*Trop. Agric.* 61: 82-86.

Emosairue, S. O., and Ubana, U. B. (1998) Field evaluation of neem for the control of some cowpea insect pests in Southeastern Nigeria. *Global J. Pure Applied Sci.* 4 (3): 237-241.

Fagoonee, I. (1981) Behavioural response of *Crocidolomia binotalis* to neem.*In:* Natural pesticides from the neem tree. Proc. 1st Int. Neem Conf Rottach-Egerm, 1980. Eschborn: GTZ, pp. 297.

Gaur, H. S., **and Mishra, S. D. (1990)** Integrated control of nematodes in lentil with aldicarb neem cake and seed treatment with Thimet and its residual effect on the subsequent mung crop. *Indian J. Entomol.*5.1: 283-287.

Gupta, H. C., Verma, J. P. Bareth, S. S. and Mathur, B. N. (1989) Evaluation of some nonedible oils as grain protectants in wheat and their subsequent effects on germination. *Indian J. Entomol.*50: 147-150.

Haasler, C. (1984) Effects of neem seed extracts on post-embryonic development of the tobacco hornworm, *Manduca sexta* . *In:* Natural pesticides from the neem tree and other tropical plants.Proc. 2nd Int. Neem Conf., Rauishholzhausen. 1883. Eschborn: GTZ., pp.321-330.

Hammond, W. N. O. (1983) The ecology of pod-sucking bugs of cowpea with special reference to *Clavigralla* spp. and their host range in Nigeria. MSc. Thesis, University of Ghana, Legon, Ghana.Pp. 140.

Haskell, P. T., and Luntz, J. A. and Mordue, M. W. (1969) The role of the mouthpart receptors on the feeding behaviour of *Schistocerca gregaria*. *Entomol. Expt. Appl.* 12: 591-610.

Heyde, V. D - J., Saxena, R. C. and Shmutterer, H. (1984) Neem oil and neem extracts as potential insecticides for the control of Heminpteran rice pests. *In:* Natural Pesticides from the neem tree and other tropical Plants. Proc. 3rd Int. Neem Conf., Nairobi, 1986, pp. 377-390.

Hongo, H., and Karel, A. K. (1986) The effects of plant extracts on insect pests of common beans. *J. Appl. Entomol.* 102: 164-169.

International Institute of Tropical Agricultuer (IITA) (1986) Annual report of grain legume improvement programme for 1985, IITA, Ibadan, Nigeria. 127 pp.

Ivbijaro, M. F. (1983) Preservation of cowpea *(Vigra unguiculata* L. Walp) with neem *(Azadirachta indica* A. Juss) seeds. *Protection Ecol.* 5: 177-182.

Ivbijaro, M. F. (1990) The efficacy of *Azadirachta indica* (A. Juss) and *Piper guineense* (Schum and Thonn) on the control of *Callosobruchus maculatus* F. *Insect Sci. Appl.* 11: 149-152.

Ivbijaro, M. F., and Bolaji, O. O. (1990) Effects of Cypermethrin+Demethoate and extracts of *Piper guineense* and *Azadirachta indica* on the pests and yield of cowpea *(Vigna unguiculata) J. Agric. Sci*. 115(2): 227-231.

Jackai, L. E. N. (1993) The use of neem in controlling cowpea pests. IITA Res. 7: 5-11.

Jackai, L. E. N., and Adalla, C. B. (1997) Pest management practices in cowpea. A review. Pp. 240-258. *In:* Singh, B. B., D. R. Mogan Raj, K. E. Dashiell and L. E. N. Jackai (eds.). Advances in cowpea research.Co-publication of IITA and JERCAS. IITA, Ibadan, Nigeria.

Jackai, L. E. N., E. E. Inang, and P. Nwobi (1992) The potential of controlling post-flowering pests of cowpea using neem *(Azadirachta indica* A. Juss). *Trop. Pest Mgt*. 38(10): 56-60.

Jackal, L. E. N., Robert, J. M. F. and Singh, S. R. (1988) Cowpea seed treatment with Carbosulfan: potential incidence of seedling pests. *Crop Protection*.7: 384-390.

Jackal, L. E. N., and Daoust, R. A. (1986) Insect pests of cowpea.*Ann. Rev. Entomol.* 31: 9-19.

Jackal, L. E. N., and Singh, S. R. (1988) Screening techniques for host resistance to insect pests of cowpea. *Trop. Grain Legumes Bull.* 35: 2-18.

Jacobson, M. (1986) The neem tree: natural resistance par excellence. *In:* Green, M. B., P. A. Hindin (eds.). Natural resistance of plants to pests: role of allelochemicals. ACS Symp. Ser. No.296: pp. 220-232.

Jacobson, M. (1989) Focus on phytochemical pesticides. Vol. 1.The neem tree. Boca Raton: CRC Press, pp. 178.

Jagannathan, R., and Narasimhan, V. (1988) Effects of plant extracts on two fiangal pathogens of finger millet. *Indian J. Mycol. Plant Path.*18: 250-254.

Jones, P. S., Ley, S. V. Mogan, E. D. and Santafianos, D. (1989) The chemistry of the neem tree. *In:* Focus on phytochemical pesticides. Vol. 1. The neem tree. Boca Raton: CRC Press, pp. 178.

Joshi, B. G. (1987) Use of neem products on tobacco in India. Proc. 3rd Int. Neem Conf., 1986, Nairobi. Pp. 479-494.

Karungi, J., Adipala, E. Ogenga-Latigo, M. W. Kyamanywa, S. and Oyobo, N. (2000) Pest management in cowpea. Part 1. Influence of planting time and plant density on cowpea field pest infestation in Eastern Uganda. *Crop Protection.*19: 231-236.

Ketkar, C. M. (1976) Utilization of neem *(A. indica* A. Juss) and its by-products. Final Tech. Rep., Khadi & Village Indust. Comm., Bombay, India, pp. 11.

Ketkar, C. M. (1987) Use of tree-derived nonedible oils as surface protectants for stored legumes against *Callosobruchus* spp. *In:* Natural pesticides from the neem tree and other tropical plants. Proc. 3rd Int. Neem Conf., Nairobi. 1986. Eschborn: GTZ**.,** pp**.** 535-542.

Khan, M., Schneider, B. Wassilew, S. **W. and Spanemann, V. (1988)** The effects of raw materials of the neem tree, neem oils and neem extracts on dermatophytes, yeasts and molds. *Z. Hautkr.* 63: 499-502.

Kossou, D. K. (1989) Evaluation des differnts products du neem, *Azadirachta indica* A. Juss pour le controle de *Sitophilus zeamais* Motch sur le mais en post-recole. *Insect Sci. Appl. 10:* 365-372.

Koul, O. (1984a) Azadirachtin: 1-Interaction with the development of red cotton bugs. J. *Appl. Entomol.* 36: 85-86.

Koul, O. (1984b) Azadirachtin: 11-Interaction with the reproductive behaviour of red cotton bugs. *J. Appl. Entomol.* 98: 221-223.

Kraus, W., Baumann, S. Bokel, M. Pohnl, H. and Schwinger, M. (1987) Control of insect feeding and development by constituents of *Melia azadarach* and *Azadirachta indica*.In: Proc. 3rd Int. Neem Conf., Nairobi, 1986, pp. 111-125.

Kubo, I., Matsumoto, A. and Matsumoto, T. (1986) New insect ecdysis inhibitory limonoid, deacetylazadirachtinol isolated from neem oil. *Tetrahedron Lett*.42: 489-496.

Kyamanywa, S., Balidawa, C. W. and Ampofo, K. J. O. (1993) Effect of maize plants on colonization of cowpea plants by bean flower thrips, *Megalurothrips sjostedti*. *Entomologia Expt. Appl.* 69: 61-68.

Lavie, D., Levy, E. C. and Jain, M. K. (1967) Limonoids of biogenetic interest from neem.*Tetrahedron Lett*.27: 3927-3939.

Letourneau, D. K. (1990) Mechanism of predator accumulation in mixed crop system. *Ecol. Entomol.* 15: 63-69.

Leuschner, K. (1972) Effect of an unknown substance on a shieldbug. *Natur wessenschaften*.59: 217.

Litsinger, J. A., and Ruhendi (1984) Rice stubble and straw mulch suppression of pre-flowering insect pests of cowpea shown after puddled rice. *Envt. Ecol.* 13(2): 509-514.

Lowery, D. T., Isman, M. B. and Brard, N. L. (1993) Laboratory and field evaluation of neem for the control of aphids (Homoptera: Aphididae). *J. Econ. Entomol.* 86(3): 864-870.

Makanjuola, W. A. (1989) Evaluation of extracts of neem (*Azadirachta indica*) for the control of stored product pests. *J.Stored Product Res.* 25(4): 231-237.

Mattesson, P. C. (1992) The effect of intercropping cerals with minimum Permethrin applications on insects pests of cowpea and their natural enemies in Nigeria. *Trop. Pest Mgt*. 28: 372-380.

Meinser, J., Melamed-Madjar, V., Yathom, S., and Ascher, K. S. R. (1987) The influence of neem on the European corn borer (*Ostrinia nubilalis*) and the serpentine leaf miner (*Liriomyza trifolii*). In: Natural pesticides from the neem tree and other tropical plants. Proc. 3rd Int. Nem Conf., Nairobi. 1996. Eschborn: GTZ, pp. 461-477.

Meisner, J., and Nemmy, N. E. (1992) The effects of Margosan-O on the development of the Egyptian cotton leafworm, *Spodoptera litoralis* (Boisd) (Lepidoptera: Noctuidae). *J. Appl. Entomol.* 113: 330 – 333.

Mensah, G. W. K. (1998) Relative efffectivenesss of insecticide sprays on insect damage and yield of three cowpea cultivars in Swaziland. *Insect Sci. Appl.* 19: 101 – 108.

Mishra, A. S., and Rao, G. P. (1988) Inhibition of tabocco masic virus by root extracts of ghiher plants. *Phytophytlactica*. 20: 93-94.

Mordue (Luntz), A. J., and Blackwell, A. (1993) Azadirachtin: An update. *J. Insect Physiol.* 39: 903-924.

Naqvi, S. N. H., Tabassum, R., Zia, N., and Nurulain, S. M. (1990) Toxicity and eresidual effect of neem extracts (factor C) against stored grain pest. *Pakistan J. Entomol.* 22: 271-277.

Ndoye, M. (1978) Pest of cowpea and htir control in Senegal, pp. 113-115. *In:* S. R.

Singh, H. E. Emden and T. A. Taylor (eds.).Pests of grain legumes: Ecology and control. Academic Press, London, UK.Pp. 102.

Ng, N. Q., and M. Marechal (1985) Cowpea taxonomy, origin and gemplasm. pp. 11-21. *In:* S. R. Singh, and K. **0.** Rachie (eds.).Cowpea research, production and utilization.John Wiley and Sons, Chichester, UK.

Nisbet, A. J. (1992) The effect of azadirachtin on the feeding behaviour and virus transmission of the green peach aphid, *Myzus persicae* (Sulzer). PhD thesis, Univ. Glasgow, UK.

Nonveiller, G. (1984) Catalogue de insects du Cameroon d'intert agricola. Imprimerie `Novi Dani', Belgrad, Yugoshlavia, pp. 210.

Oschse, L. (1981) Zur Wirkung von Rohextrakten aus samen des Niembaumes *(Azadirachta indica)* auf die Baumwollrotwanze *(Dysdercus fasciatus* Sign.) Dipl. Thesis, Univ. Giessen. FRG.*As Cited By:* Schmutterer, H. (1990) Properties and potential of natural pesticides from the neem tree. *Ann. Rev. Entomol.* 35: 271-297.

Okigbo, B. N., and Greenland (1976) Intercropping systems in tropical Africa. American Society of Agronomy, MD. Wisconsin. Pp. 12.

Okorie, T. G., Siyanbola, O. O. and Ebochuo, V. O. (1990) Neem seed powder as a protectant for dried Tilapia fish against *Dermestes maculatus* (De Geer) infestation. *Insect Sci. Appl.* 11: 153-158.

Olaifa, J. I., and Adenuga, A. O. (1988) Neem products for protecting field cassava from grasshopper damage.*Insect Sci. Appl.* 9: 267-276.

Passerini, J., and Hill, S. B. (1993) Field and laboratory trials using locally produced neem insecticides against the sahelian grasshopper, *Kraussaria angulifera* (Orthoptera: Acrididae) on millet in Mali.*Bull. Entomol. Res.* 83: 121-126.

Phllipson, J. D., and O'Neil, M. J. (1989) New leads to the treatment of protozoal infections based on natural product molecules. *Actapharan.Nord. 1:* 131-144.

Pillai, M. A. K., and Ponniah, S. (1988) Neem for the control of rice thrips. *Rice Res. Newl.* 13: 33-34.

Pradhan, P. S., Das, S. N. and Dora, D. K. (1991) Effects of some organic oils on the infectivity of the root-knot nematode *(Meloidogyne incognita)* infecting tomato.*Indian J. Nemat.*19: 162-165.

Price, J. F., D. J. Schuster, and McClain, P. M. (1990) Azadirachtin form neem tree *(Azadirachta indica* A. Juss) seeds for the management of sweet potato whitefly *(Bemisia tabacci* (Gennadius) on ornamentals. *Proc. Fla. State Hort Soc.* 103: 186-188.

Quadri, S. H., and Narsiah, J. (1978) Effect of azadirachtin on the moulting behaviour of last instar nymphs of *Periplaneta americana. Indian J. Expt. Biol.* 16: 141.

Rembold, H. (1989) Isomeric azadirachtins and their modes of actions. *In:* Focus on phytochemical pesticides. Vol. 1. The neem tree. Boca Raton: CRC Press. Pp. 47-67.

Rembold, H., and Garcia (1989) Azadirachtin inhibits *Trypanosoma crizi* infections of its triatomine insect host, *Rhodnius prolixus. Natur wissensehaften.*76: 77-78.

Richards, P. (1985) Indigenous agricultural revolution: ecology and food production in West Africa.Univin Hyman, London, UK. pp. 192.

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

Saxena, R. C., Liquido, N. J. and Justo, H. D. (1981) Neem seed oil, a potential for the control of the rice planthopper, *Nilaparvata lugens*. Pp.171-188. *In:* H. Schmutterer, K. R. S Ascher and H. Rembold (eds.). Natural pesticides from the neem tree.Proc. 1st Int. Neem Conf., Rottach-Egerm, Federal Republic of Germany.pp. 1980, 297.

Saxena, R. C., and Khan, Z. R. (1985) Electronically recorded disturbances in the feeding and behaviour of *Nephotettix virescens* (Homoptera: Cicadellidae) on neem oil-treated plants. J. *Econ Entomol.* 78: 222-226.

Saxena, R. C. (1989) Insecticides from neem.110-135 pp.*In:* Insecticides of plant origin. J. J. Amason, B. J. R. Philgene and P. Morand (eds.). ACS Symp. Ser. No.387. American Chemical Soc., Washington, DC.

Saxena, R. C. (1990) The neem plant: business opportunities. Reprint of a lecture at Conference on Opportunities in Environmental Conservation and Rehabilitation, Manila, pp. 17.

Saxena, R. C., and Kidiavai, E. L. (1997) Neem seed extracts spray applications as low-cost inputs for the management of flower thrips in the cowpea crop. *Phytoparasitica.* 25(2): 99-110.

Schauer, M. (1984) Effect of various formulated neem seed extracts on *Acyrthosiphon pisum* and *Aphis fabae. In:* Schmutterer, H. and Ascher, K. R. S. eds. Natural pesticides from the neem tree and other tropical plants oo. 140-150. Proc. 2nd Int. Neem Conf., GTZ, Eschborn.

Schauer, M. (1985) Die wirkung von Nieminhaltsstoffen auf blattlause and die Rubenblattwanze.PhD. Thesis. Univ. Giessen, FRG. *As Cited By:* Schmutterer, H. (1990) Properties and potential of natural pesticides from the neem tree. ***Ann.*** *Rev. Entomol.* 35: 271-297.

Schmutterer, H. (1987) Insect growth disruption and fecundity reducing ingredients from neem and chinaberry trees.pp.119-170. *In:* E. D. Mogan, and N. B. Mandava (eds.). Handbook of natural pesticides. 111 (part B): Boca Raton. CRC press.Pp. 180.

Schmutterer, H. (1988). Potential of azadirachtin-contaning pesticides for integrated pest control in developing and industrialized contries. *J. Insect Physiol.* 34: 713-*719*.

Schmutterer, H., and Hellpap (1989) Effects of neem on pests of vegetables and fruit trees.*In:* Focus on phytochemical pesticides. Vol. 1.The neem tree. Boca Ratton: CRC press, pp.69-86.

Schmutterer, H. (1990) Properties and potential of natural pesticides from the neem tree. *Ann. Rev. Entomol.* 35: 271-297.

Schmutterer, H. (1995) The neem tree and other Meliceae plants: source of unique natural products for integrated pest management, medicine, industrial and other purposes. VCH, Weinheim, Germany.

Sehgal, V. K., and Ujagir, R. (1990) Effect of synthetic pyrethroids, neem extracts and other insecticides for the control of pod damage by *Helicoverpa amigera* (Hubner) on chick pea and pod damage-yield relationship at Pantnagart in Northern India. *Crop Prot.* 9: 29-32.

Seymour, J., Bowman, G. and Crouch, M. (1995) Effect of neem seed ectracts on feeding frequency of *Nezara viridula* L. on pecan nuts. *J. Aust Entomol.* Soc. 34: 221-223.

Shetty, S. A., Prakash, H. S. and Shetty, H. S. (1989) Efficacy of certain plant extracts against seed-borne infections by *Trichoconiella padwickii* in paddy rice. *Can. J. Bot*. 67, 1956-1958.

Siddiqui, M. A., and Mashkoor, A. M. (1988) Effect of seed treatment with azadirachtin on root-knot development on, and growth of some vegetables. *Ann. Appl. Biol.* 112: 20-21.

Siddqui, M. A., and Mashkoor, A. M. (1991) Efficacy of oilseed cake and nematicides against plant-parasitic nematodes attacking tomato in relation to ploughing. *J. Bangladesh Acad. Sci*. 15: 23-29.

Sieber, K. P., and Rembold (1983) Effect of azadirachtin on endocrine control of moulting in *Locusta migratoria*. *Z. Inst*. *Physiol.* 29: 523-527.

Singh, A. K., Singh, M. and Singh, A. K. (1988) Antiviral activity and physical properties of neem extracts. *Indian J. Virol.*4: 76-81.

Singh, B. B., and Ntare, B. R. (1985) Development of improved cowpea varieties in Africa.105-115 pp.*In:* Cowpea research, production and utilization. S. R. Singh and K. 0. Rachie (eds.). John Wiley and Sons, Chichester, England.

Singh, B. B., Chambliss, O. L. and Sharma, B. (1997) Recent advances in cowpea breeding. pp 30-49. *In:* Advances in cowpea research. B. B. Singh, D. R. Mogan, K. E. Dashiell and L. E. N. Jackai (eds.). Copublication of IITA and JIRCAS, IITA, Ibadan, Nigeria.

Singh, S. R., and van Emden, H. F. (1979) Insect pests of grain legumes.*Ann. Rev. Entomol.* 24: 255-278.

Singh, S. R. (1980) Biology of cowpea pests and potential for host plant resistance. Pp. 398-421.

421. *In:* Biology and breeding for resistance to arthropods and pathogens in agricultural plants. M. K. Harris (ed.). Texas A. and M. Univ. Bull. M. P. 1451, College Station, TX, USA.

Singh, S. R., and Rachie, K. O. (eds.) (1985) Cowpea research, production and utilization. John Wiley and Sons, Chichester, UK.

Singh, S. R, Jackai, L. E. N., Dos Santos, J. H. and Adalla, C. B. (1990) Insect pests of cowpea. *In:* Insect pests of tropical food legumes. Singh, S. R. (ed.). John Wiley and Sons, Chichester, U.K, pp. 43-89.

Singh, R. K., and Dwivedi, R. S. (1990) Fungicidal properties of neem and blue gum against *Sclerotuim rolfsii* Sacc., and foot-rot pathogens of barley. *Acta.Bot. India,* 18: 260-262.Sinniah, D., and S. Baskaran (1981) Margosa oil poisoning as a cause of Reye's syndrome.*Lancet I*. 8218:487

Sinniah, D., Baskaran, G. Looi, L. M. and Leong, K. L. (1983) Reye-like syndrome due to Margosan oil poisoning; report of a case with postmorthem findings. *Am. J. Gastro enterol.77:* 158.

Smirle, M. J., and Wei, S. (1996) Effect of neem oil on feeding behaviour and development of a pear sawfly, *Caliroa cerasi* L. *Entomol. apt. Appl.* 80: 403-407.

Stark, J. D., Vargas, R. L. and Thalman, R. K. (1990) Azadirachtin: effect on metamorphosis, longevity and reproduction of three fruitfly (Diptera: Tephitidae) and aphid (Homoptera: Aphididae) species. *J. Econ. Entomol.*83: 2168-2174.

Steffens, R., and Schmutterer, H. (1982) The effect of crude mathalonic neem seed kernel extracts on metamorphosis and quality of adults of the mediterranean fruit fly, *Ceratitis capitata* (Diptera: Tephritidae). Z. *Angew. Entomol.*14: 78-103.

Steets, R. (1976) Die wirkung von Rohextrakten aus den meliaceen.*Azadirachta indica* and *Melia azadarach, Z. Angew Entomol.*77: 306-312.

Tamo, M., Baumgartner, J. Delucchi, V. and Herren, H. R. (1993) Assessment of key factors responsible for the pest status of bean flower thrip, *Megalurothrips sjostedti* (Thysanoptera: Thripidae) in West Africa. *Bull. Entomol. Res.* 83: 251258.

Tamo, M., Bottenberg, H. Arodokoun, D. Y. and Adeoti, R. (1997) The feasibility of biological control of two major cowpea insect pests. pp. 259-270. *In:* Advances in cowpea research. B. B. Singh, D. R. Mogan Raj, K. E. Dashiell and L. E. N. Jackai (eds.). Co-publication of IITA and JIRCAS, IITA, Ibadan, Nigeria.

Tanzubil, P. B. (1987) The use of neem products in controlling the cowpea weevil, *Callosobruchus maculatus. In:* Natural pesticides from the neem tree and other tropical plants. Proc. 3rd Int. Neem Conf., Nairobi, 1986. Eschborn: GTZ. Pp. 517-523.

Tanzubil, P. B. (1991) Control of some insect pests of cowpea with neem in northern Ghana. *Trop. Pest Mgt.,* 37: 216-217.

Tanzubil, P. B. (2000) Field evaluation of neem *(Azadirachta indica)* extracts for the control of insect pests of cowpea in northern Ghana. *J. Trop. Forest Products.*6(2): 165-172.

Verma, V. S. (1974) Chemical compounds from *Azadiracta indica* as inhibitors of potato virus X. *Acta.Microbiol.Pol.* 6: 9-13.

Vollinger, M. (1987) The possible development of resistance against neem seed kernel and Deltamethrin in *Plutella xylostella*. Proc. 3rd Int. Neem Conf., Nairobi. Pp. 547-554.

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

Zehrer, W. (1984) The effect of the traditional preservatives used in Northern Togo, and of neem oil for the control of stored product pests. *In:* Natural pesticides from the neem tree and other tropical plants. Proc. 2nd Int. Neem Conf., Rauischhlozhausen, 1983. Eschborn: GTZ, pp. 453-460.

APPENDIX

Analysis of variance of data obtained from the pest incidence and abundance, and yields of grain and fodder of cowpea plants sprayed with neem seed extracts or Karate

Variate: **% of plants infested by aphids**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	75.00	25.00	1.89	
Treatmt	5	1559.88	311.98	23.62	<.01
Residual	15	198.12	13.21		
Total	23	1833.00			

Grand mean 9.50

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	6.7 c	6.3 c	5.5 c	10.5 b	56.6 a	1.6 d

s.e.d. 2.570

Variate: **% of pods damaged by maruca larvae**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	427.73	142.58	2.89	
Treatmt	5	12499.16	2499.83	50.74	<.001
Residual	*15*	738.97	49.26		
Total	23	13665.87			

Grand mean 30.6

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	33.5 b	13.7 c	12.1 c	44.0 b	72.8 a	7.5 c

s.e.d. 4.96

Variate: **% of flowers infested by maruca larvae**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	175.00	58.33	2.00	
Treatmt	5	9720.83	1944.17	66.66	<.001
Residual	15	437.50	29.17		
Total	23	10333.33			

Grand mean 35.8

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	38.7 c	23.8 d	20.0 de	47.5 b	72.5 a	12.5 e

s.e.d. 3.82

Variate: **Mean No of A. curvipes**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	5.000	1.667	1.61	
Treatmt	5	78.833	15.767	15.26	<.001
Residual	*15*	*15.500*	1.033		
Total	23	99.333			

Grand mean 3.17

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE

	3.3 c	2.2 d	2.0 d	4.0 b	6.0 a	1.8 d
s.e.d.	0.719					

Variate: **Mean No of C. tomentosicollis**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep *stratum*	3	9.833	3.278	1.34	
Treatmt	5	163.333	32.667	13.36	<.001
Residual	15	36.667	2.444		
Total	23	209.833			

Grand mean 4.08

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	5.0 c	3.0 d	2. 5 d	4.0 b	7.5 a	1.5 e
s.e.d.	1.106					

Variate: **Mean No of M. jaculus**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	7.667	2.556	0.64	
Treatmt	5	24.500	4.900	1.23	0.344
Residual	15	59.833	3.989		
Total	23	92.000			

Grand mean 2.00

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	1.8 c	1.8 c	1.0 d	2.5 b	3.0 a	1.0 d
s.e.d.	1.412					

Variate: **Mean No of N. viridula**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	11.500	3.833	3.83	
Treatmt	5	59.333	11.867	11.87	<.001
Residual	15	15.000	1.000		
Total	23	85.833			

Grand mean 2.58

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	3.0 c	1.8 d	1.5 d	3.8 b	5.0 a	1.3 d
s.e.d.	0.707					

Variate: **Mean No of R. dentipes**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.500	0.500	0.11	
Treatmt	d.f.	s.s.	m.s.	v.r.	F p
Rep stratum	3	24.792	8.264	1.03	
Treatmt	5	8106.708	1621.342	201.90	<.001
Residual	15	120.458	8.031		
Total	23	8251.958			

Grand mean 20.54

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	4.8 c	4.3 c	3.5 d	6.0 b	9.3 a	1.8 e
s.e.d.	2.004					

Variate: **Mean No of adult thrips per 10 racemes**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	76.33	25.44	1.75	
Treatmt	5	6049.50	1209.90	279.9	<.001
Residual	15	218.17	14.54		
Total	23	6344.00			

Grand mean 24.00

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	25.5 c	13.5 d	11.5 d	40.0 b	48.0 a	4.5 e
s.e.d.	2.697					

Variate: **Mean No of damaged pods**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.2833	0.4278	1.41	
Treatmt	5	14.7983	2.9597	9.75	<.001
Residual	15	4.5517	0.3034		
Total	23	20.6333			

Grand mean 2.58

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	3.35 a	2.15 b	2.03 b	3.55 a	3.05 a	1.37 b
s.e.d.	0.390					

Variate: **Mean No of Maruca larvae per 10 flowers**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	16.833	5.611	1.46	
Treatmt	5	2074.000	414.800	107.90	<.001
Residual	15	57.667	3.844		
Total	23	2148.500			

Grand mean 9.75

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	9.50 c	2.75 d	2.25 d	16.00 b	27.00 a	1.00 d
s.e.d.	1.386					

Variate: **Mean No of nynph thrips per 10 flowers**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	27.00	9.00	0.79	
Treatmt	5	14634.33	2926.87	258.25	<.001
Residual	15	170.00	11.33		
Total	23	14831.33			

Grand mean 20.17

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	12.75c	4.25 d	3.50 d	27.50b	65.0 a	1.25e
s.e.d.	2.380					

Variate: **Mean No of nymph thrips per 10 racemes**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	34.83	11.61	0.78	
Treatmt	5	8135.83	1627.17	109.37	<.001
Residual	*15*	*223.17*	*14.88*		
Total	23	8393.83			

Grand mean 21.92

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	20.25 c	10.50 d	9.75 d	30.00b	58.25 a	2.75 e
s.e.d.	2.727					

Variate: **Mean No of pods per plant**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	39.063	13.021	2.84	
Treatmt	5	629.135	125.827	27.40	<.001
Residual	15	68.882	4.592		
Total	23	737.080			

Grand mean 12.30

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	10.05 b	16.05 c	16.80 c	8.27 b	4.25 a	18.37c
s.e.d.	1.515					

Variate: **Mean No PSBs**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	85.125	28.375	4.67	
Treatmt	5	2015.708	403.142	66.36	<.001
Residual	*15*	*91.125*	*6.075*		
Total	23	2191.958			

Grand mean 17.21

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	18.00 bc	11.75 cd	10.75d	24.50b	32.75a	5.50d
s.e.d.	1.743					

Variate: **Mean No of pods per plant 2**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	7.655	2.552	0.72	
Treatmt	5	821.307	164.261	46.26	<.001
Residual	15	53.258	3.551		
Total	23	882.220			

Grand mean 11.58

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	9.98b	15.05c	15.88 c	5.40a	3.40 a	19.78d
s.e.d.	1.332					

Variate: **Mean aphid score**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.3017	0.1006	0.49	
Treatmt	5	15.6400	3.1280	15.22	<.001
Residual	*15*	*3.0833*	*0.2056*		
Total	23	19.0250			

Grand mean 1.525

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	1.675 c	1.375 c	1.125c	2.175b	2.675a	0.125d

s.e.d. 0.3206

Variate: **Mean No of shriveled pods**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.2417	0.0806	0.17	
Treatmt	5	11.5983	2.3197	4.92	0.007
Residual	*15*	7.0783	0.4719		
Total	23	18.9183			

Grand mean 2.46

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	2.77 b	1.68 d	2.15 c	3.60 a	2.87 b	1.68 d

s.e.d. 0.486

Variate: **Mean No of thrips per 10 flowers**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	59.125	19.708	2.50	
Treatmt	5	9675.708	1935.142	245.73	<.001
Residual	*15*	*118.125*	7.875		
Total	23	9852.958			

Grand mean 17.96

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	13.00 c	4.25d	3.75d	27.00b	58.50a	1.25e

s.e.d. 1.984

Variate: **Mean No of thrips per 10 racemes**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	7.125	2.375	0.39	
Treatmt	5	8456.208	1691.242	279.93	<.001
Residual	*15*	*90.625*	6.042		
Total	23	8553.958			

Grand mean 22.46

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	20.00 c	10.50 d	8.50 d	35.25b	57.50a	3.00e

s.e.d. 1.738

Variate: **% of pods damaged by maruca**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	137.67	45.89	0.87	
Treatmt	5	11052.83	2210.57	42.03	<.001
Residual	*15*	*788.83*	*52.59*		
Total	23	11979.33			

Grand mean 35.3

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	33.6 c	13.7 c	12.2 c	44.1 b	72.8 a	7.5 c

s.e.d. 5.13

Variate: **% of shriveled pods**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	223.17	74.39	0.91	
Treatmt	5	21500.38	4300.08	52.33	<.001
Residual	*15*	*1232.64*	*82.18*		
Total	23	22956.20			

Grand mean 35.9

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	29.0 c	11.2 d	13.5 d	67.7 b	85.4 a	8.5d

s.e.d. 6.41

Variate: **Mean Grain yield**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	137160.	45720.	0.70	
Treatmt	5	7946263.	1589253.	24.36	<.001
Residual	*15*	*978713.*	*65248.*		
Total	23	9062137.			

Grand mean 991.

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	709.0 c	1456.5 d	1471.3 d	408.0 b	203.3 a	1698.3 e

s.e.d. 180.6

Variate: **Fodder yield**

Source of variation	d.f.	s.s.	m.s.	v.r	. F pr.
Rep stratum	3	180203.	60068.	0.28	
Treatmt	5	11053705.	2210741.	10.37	<.001
Residual	*15*	*3199175.*	*213278.*		
Total	23	14433083.			

Grand mean 1291.

Treatmt	10%NSE	15%NSE	20%NSE	5%NSE	Control	KARATE
	1360.5 bc	806.0 cd	792.5 d	1852.8 ab	2443.5 a	495.0 d

s.e.d. 326.6

Student-t Test for Nymphal and Adult Thrips

Paired Samples Statistics

TREAT			*Mean*	*N*	Std. Deviation	Std. Error Mean
control	Racemes	NYMPHS	28.88	4	0.48	0.24
		ADULTS	27.25	4	1.04	0.52
	flowers	NYMPHS	28.75	4	0.65	0.32
		ADULTS	27.83	4	*0.48*	*0.24*
5% NSE	Racemes	NYMPHS	16.75	4	0.29	0.14
		ADULTS	17.88	4	0.63	0.31
	flowers	NYMPHS	13.63	4	0.25	0.13
		ADULTS	14.88	4	0.75	0.38
10% NSE	Racemes	NYMPHS	14.25	4	0.65	0.32
		ADULTS	15.25	4	0.87	0.43
	flowers	NYMPHS	9.75	4	0.29	0.14
		ADULTS	10.88	4	0.63	0.31
15% NSE	Racemes	NYMPHS	9.00	4	0.71	0.35
		ADULTS	10.25	4	0.65	0.32
	flowers	NYMPHS	5.00	4	0.71	0.35
		ADULTS	5.75	4	0.65	0.32
20% NSE	Racemes	NYMPHS	7.50	4	0.41	0.20
		ADULTS	8.38	4	0.25	0.13
	flowers	NYMPHS	4.50	4	0.41	0.20
		ADULTS	5.00	4	0.41	0.20
Karate	Racemes	NYMPHS	2.5U	4	0.41	0.20
		ADULTS	3.13	4	0.48	0.24
	flowers	NYMPHS	1.25	4	0.29	0.14
		ADULTS	2.00	4	0.71	0.35

Paired Samples Test — Paired Differences

TREAT			t	df	Sig. (2-tailed)
control	racemes	NYMPHS - ADULTS	-2.30	3	0.09
	flowers	NYMPHS - ADULTS	-2.50	3	0.08
5% NSE	racemes	NYMPHS - ADULTS	-2.63	3	0.08
	flowers	NYMPHS - ADULTS	-2.61	3	0.08
10% NSE	racemes	NYMPHS - ADULTS	-2.90	3	0.09
	flowers	NYMPHS - ADULTS	-2.70	3	0.07
15% NSE	racemes	NYMPHS - ADULTS	-2.10	3	0.13
	flowers	NYMPHS - ADULTS	-1.57	3	0.22
20% NSE	racernes	NYMPHS - ADULTS	-2.78	3	0.07
	flowers	NYMPHS - ADULTS	-1.41	3	0.25
Karate	racemes	NYMPHS - ADULTS	-2.61	3	0.08
	flowers	NYMPHS - ADULTS	-1.73	3	0.18