STUDIES ON ABUNDANCE, IMPACT AND NATURAL ENEMIES OF INSECT PESTS OF OKRA AND CHILIES AND EFFICACY OF NEEM PRODUCTS IN THEIR CONTROL

By

Muchemi, Kagumba Samuel (B.Ed. Sc. Hons)

Kenyatta University,

Department of Zoology.

A thesis submitted in partial fulfillment for the degree of Master of Science in Agricultural Entomology of Kenyatta University

April 2000

KENYATTA UNIVERSITY LIBRARY

Muchemi, Kagumba
Studies on abundance, impact and natural

2000/258256

DECLARATION BY CANDIDATE

This thesis is my original work and has not been presented for a degree in any other University or any other award.

Samuel, K. Muchemi

DECLARATION BY SUPERVISORS

We confirm that the work reported in this thesis was carried out by the candidate under our supervision.

1. Dr. C. P. K. O. Ogol,

   Department of Zoology,

   Kenyatta University,

   Nairobi.

Date 16/5/2000 -- signature ----------------------------

2. Dr. S. S. Sithanantham

   IPM export vegetables co-ordinator,

   International Centre of Insect Physiology and Ecology (I.C.I.P.E),

   Nairobi.

Date 29. 4. 2000 -- signature ----------------------------

DEDICATION

To my parents, Grace and Michael; Brothers, Moses and Stephen, Sisters; Alice, Monica, Leah and Florence and a close friend and fiancée, Wanjiru.

ACKNOWLEDGEMENT

I am greatly indebted to Dr V. Musewe, head of the capacity building department and Dr. S. S. Sithanantham co-ordinator of IPM export vegetable project at I.C.I.P.E for granting the scholarship for my studies through the Dissertation and Research Internship Program (DRIP). I should not fail to thank Dr. S. S. Sithanantham for his availability, guidance and supervision during my study.

My sincere appreciation goes to Dr. C. P. K. O. Ogol of Kenyatta University for his acceptance to be my supervisor, his guidance, encouragement, material support and most importantly his close and tireless supervision even when he had other issues to attend to. Without his support, I could not have accomplished this study. Drs. E. Kokwaro and E. Kairu in the department of zoology, Kenyatta University were of great help during my studies for their advice and encouragement.

I greatly appreciate the offer by Professor Mbuvi, the director of the Institute of Dry land Research Development and Utilization (IDRDU) of the University of Nairobi (U.o.N) to undertake the research at the Kibwezi field station. Dr. Florence Olubayo, a lecturer in the University of Nairobi was of much help during the formative stages of the research work. The farm manager at Kibwezi, Mr. Samson Muriungi was committed to the success of my research work by offering material and technical support.

I equally appreciate the help extended to me by the staff on the farm, Misters Miano, Mutua, Ogembo and Karaba were readily available during all farm activities.

I am greateful to Mr. Ragama and Njuguna for their statistical help during data analysis. Dr. Odulaja, the ICIPE biostatistician, willingly offered the SAS package for the data analysis. I am also thankful to my colleagues Tom, Baya and Matoka for their encouragement and Mrs Gathu for her endless moral support.

A sincere gratitude is expressed to Dr. Susan Kimani of Biosystematics at ICIPE, Mr. and Mrs. Karanja and Kirubi for the trust they had for me while using their computers. I am indebted to my former colleagues and work mates in secondary schools for their support and I would like Misters Mburu, Wainaina and Muhoro to know that I recognised that they stood by me at all times.

I am especially thankful to my parents, brothers and sisters for their understanding, financial and moral support. My fiancée Leah, was always by my side in times of need. To all my friends, I am thankful to all for their good will.

ABSTRACT

Studies on abundance, impact and natural enemies of insect pests of okra and chilies and efficacy of neem products in their control were conducted at Kibwezi (2°21-5'S, 38°2-5'E) a semi arid region of the Eastern province of Kenya. Okra seeds were planted directly, while one-month old chili seedlings were transplanted in 4 x 3m. plots in the field during the months of September 1998 and January 1999 in two cropping seasons. The plots were left for natural infestations but various species of insect pests were noted. Sampling was carried out and insect pests that infested okra and chilies at certain stages of the crops' growth were identified. Aphids and whiteflies were found to transmit leaf curl disease to the chilies whereas, flower beetles, flower thrips and fruit borers, which, infested the fruits from reproductive stage to maturity, damage the fruits of both crops.

In some instances and at certain growth stages, insect pest population, percentage damaged leaves and associated yield loss differed significantly between the pesticide treated and unprotected (control) plots. Foliar damage on okra resulted from the feeding habits of caterpillars, leaf miners and leaf beetles while that of chilies resulted from the leaf curl virus disease infection. A 19.3% and 23.5% yield loss for okra and chilies resulted from insect infestation respectively. Controlling insect pests at certain growth stages resulted in gains of the avoidable yield loss from insect pest infestation.

The most common natural enemies of aphids comprised of various species of coccinellid beetles, parasitic wasps and the predatory larvae of syrphid flies. A carabid beetle and both larval and adult forms of coccinellid beetles preyed on red spider mites. They significantly reduced the insect pest population mostly on okra and chilies.

A formulation of 20ml/l of neem oil was more effective against most pest populations on okra and chilies than the 15ml/l-neem oil, 25 and 50g/l-neem powder (obtained from the kernels) and 50g/l-neem seed kernel extract [(NSKE) obtained by grinding the seeds]. However, the neem products conserved populations of natural enemies and other beneficial insects. All the neem formulations were effective in reducing the amount of foliar damage on okra. Although similar formulations of neem products had varied effects on the yield loss from insect infestations on both the crops, the marketable yield was improved by all the formulations.

Results from these studies can be enhanced by conducting other research to establish the distribution and infestation of insect pests, their physiological impact and dose optimization of neem products and associated yield loss within and between localities on both the crops.

TABLE OF CONTENTS

CHAPTER TWO

CHAPTER FIVE

CHAPTER SIX

CHAPTER SEVEN

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

1.1 GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1.1 Introduction

1.1.2 Food and Agriculture

The world's population is estimated to be at 6 billion people and the world's arable land resources are about 1.5 billion ha (FAO, 1972). With such a population at the moment, the per capita land available is only 0.25 ha. Hence in the world today, there is insufficient arable land (even assuming that energy resources and other technology are available) to meet the food requirements (Pimentel, 1986). To feed this population will require significant increases in food production. For example, legumes must be increased by 173 %, vegetable by 233 % and cereals 330 % by the year 2100, when the population is predicted to reach 16 billion people (Pimentel *et al*., 1975).

1.1.3 Vegetable production

Vegetables are of mixed origin and can be traced to various parts of Europe as well as Asia, Africa and South America. The range of latitudes within which such crops are grown varies from 20^0 north to 20^0 south of the equator (Simmonds, 1976; Grubben, 1977; Tindall, 1983). Since these vegetables have become wide spread, they bear different common names or vernacular names according to the region. A useful reference citing areas of production and yields of common vegetables is given by the 1976 and 1981 FAO production yearbooks (table1).

Vegetable production is one of man' s basic components in farming. Wherever he settled for long enough to produce a crop, he always cultivated vegetables for human and animal food. The level of success and productivity mainly depended on the climate and seasons and the range of species cultivated (Raymond, 1985). Significant technological advances have been made in the recent years which can lead to increased efficiency of vegetable production in many parts of the world (Tindall, 1983).

The production areas of vegetables range from large scale farm enterprises and market gardens growing for profit to private gardens or homesteads, where vegetables are an essential element of the families own efforts to supplement their diets or income. Vegetables are also cultivated in some societies as physical recreation or even for a past time or hobby as stated by Raymond (1985). He also mentioned that, further extension and development of urban community has led the commercial production to play an increasingly important role in meeting the vegetable requirements of the population. Commercial production has extended considerably during the last few decades in many parts of the world as a large-scale enterprise to provide continuity of supply for the fresh market, processors and export (HCDA, 1996).

Most vegetable growers have a relatively limited choice in the selection of their production, but vegetable crops in comparison to field crops are high output crops. Their cultivation is intensive and in a year, two or three crops with varying yields can be raised (Veeraragavathatham *et al.*, 1998), due to the ease of cultivation and their versatility for growing in plains and hills of different altitudes (Simmonds, 1976; Grubben, 1977; Tindall, 1983). They are crops, which can be fitted easily into many remunerative crop rotations, and cropping patterns like inter cropping, multiple cropping and companion cropping. By virtue of the foregoing characteristics, vegetable production provides employment for labour round the year unlike other seasonal crops (Veeraragavathatham *et al.*, 1998).

The climatic conditions in any given area will normally determine the planting system. In humid lowland areas, raised or cambered beds or ridges are normally prepared for most vegetable crops. In semi-arid areas or for dry season cultivation, sunken beds are most widely used and where rainfall is moderate and well distributed, cultivation on flat beds is used (Herklots, 1972).

1.1.3.1 **Vegetable Production in Kenya**

Cultivation of export vegetables is evolving as an important income-generating activity for multitudes of small-scale farmers in Africa. In Kenya, it's estimated that over 300,000 farm-families earn their income from cultivation and marketing of export vegetables (Sithanantham *et al.*, 1998). The annual production by the year 2000 is expected to exceed 100,000 Metric tonnes (HCDA, 1996). Large and small-scale farmers engage in vegetable growing either under irrigation, or rain-fed for local and urban consumption or for export markets. Vegetable crops also support many industries such as the cooking oil and fat processing industry, seed industry, fertilizer and plant protection chemical industries, farm machinery and implements and packing and marketing industries (Veeraragavathatham *et al.*, 1998).

Though native vegetables are cultivated in Kenya for local consumption, other vegetables from mixed origins have been grown mainly for commercial purposes. The FAO (1973) annual world production report of vegetables exceeded 54.24 million metric tonnes. The production of chilies and okra in Kenya between 1995/1996, for example, exceeded twelve tonnes (table 2) while the production of assorted export vegetables from Kibwezi irrigation project, exceeded five thousand cartons in the months of January and February of 1995 (fig. 1).

The major producing areas in Kenya include some parts of Central, Rift Valley, Eastern and Coast Provinces. The type of vegetables grown depend on the ecological factors of the area and some of the major vegetables include, peas, onions, tomatoes, cabbages, capsicum, eggplant, lettuce, cucurbits, okra, karella, French beans among others (E. A seed Co, 1996).

1.1.3.2 **Asian vegetables**

The Asian vegetables have their origin in Asia and currently in Kenya they take a big percentage of the total out put of vegetables (HCDA, 1996). The main vegetables grown in Kenya include okra, capsicums, karella, cucurbits, lettuce and brinjals among others. Between 1994 and 1996, for instance, thousands of cartons of Asian vegetables were exported from Kibwezi irrigation project (fig. 1). These vegetables supply important vitamins and minerals that the human body needs for a healthy and active life, while several are of roughage nature and aid in digestion (Veeraragavathatham *et al*., 1998). Furthermore, spicy vegetables add flavour and mint to food as well as being protective against diseases like cancer and other bacterial and fungal infections. Moreover, nutritionists have reported that spicy vegetables not only prevent infection but also play a role in reducing blood sugar and cholesterol levels (Veeraragavathatham *et al*., 1998).

1.1.4 **Okra** ***Hibiscus esculentus*** **L. Malvaceae**

There are many cultivars of okra that vary in colour, time for maturity, stem length and shape of the fruits. Pusa sawani, the variety which was used in the trials has a height of up to 2m, has hairy and woody stem when mature, leaves are alternate with upper leaves more deeply lobed than the lower ones. Flowers are axillary and solitary with yellow corolla, the fruits are dark green, ridged, pointed and pyramidal and 10-25 cm. long with a diameter of 2-3 cm. (Tindall, 1983). Okra probably originated from tropical Africa (Hill and Waller, 1994) or possibly tropical Asia (Tindall, 1983) and is widespread throughout the tropics. It is tolerant to a wide range of rainfall with supplementary irrigation required up to the fruiting period (Tindall, 1983). The pods may be harvested 50-70 days from sowing and succession harvesting of young pods is done, as mature pods become fibrous. Harvesting may be done up to 30 days giving an average of 2-3 tonnes /ha. of green pods (Tindall, 1983). An average of 500 cartons/ ha of okra has been obtained in Kibwezi irrigation project in two years (table 3) equivalent to 5 tonnes/ha.

Immature fruits are boiled or fried and used as vegetable, they can be added to soups and stews or may be dried and powdered for use as flavoring. The young shoots and leaves are also edible with high minerals and vitamins levels (Tindall, 1983).

1.1.5 **Chilies** ***Capsicum annuum*** **L. Solanaceae**

Chili has probably an origin from Peru (Hill and Waller, 1994) or probably Mexico (Tindall, 1983) and is now widely distributed throughout tropical and subtropical areas. Many cultivated forms exist based on the morphological forms of fruits and colour

(Tindall, 1983). The long pepper (orrhy/anaheim variety) has been selected for trials, and is an annual or short-lived perennial herb of up to 1.5m in height. The stems are often branched and growth is normally indeterminate, the leaves are alternate, simple and the tip is pointed, the flowers are single with white petals. The fruit is a many seeded berry, hollow, long with two or more locules, green to red when ripened with pungent smell, 20-30cm in length and 4cm in diameter (Tindall, 1983).

An average rainfall of 600-1200mm is adequate but excessive rainfall affects flowering and fruit setting and may also encourage fruit rot and decay (Tindall, 1983). A water deficit may result to flower and/ or bud abscission. The first fruits are hand picked after 70 after transplanting and picking continues for about 60 days. Yield varies between 12-20 tonnes/ha. (Tindall, 1983) and an average of 759 cartons/ ha (equivalent to 7.59 tonnes/ha) was obtained from Kibwezi irrigation project over a two year period (table 4).

Chilies are used in soup and stews, are also eaten raw in salads and the pungent substance of chilies is capsaicin (Tindall, 1983). They are also used in curries or dried to make cayenne pepper and paprika (Hill and Waller, 1994) with high content of minerals and vitamins.

1.1.6 **Constraints in vegetable production**

Despite the continued increase of production and acreage under vegetable crops, farmers are experiencing production problems ranging from high cost of production to poor market value of their produce. One major problem encountered by the vegetable growers is the effective prevention and control of pests and diseases (Tindall, 1983). Pests attack vegetables and the resulting yield losses are high. World crop losses to pests are currently estimated to be about 37% (Pimentel, 1986). Losses to pests may have been intensified by the use of new intensive crop production technology introduced with the new scientific revolution (Cramer, 1975).

The overuse of land under vegetable production for long without crop rotation especially by small-scale holders has resulted in poor soil fertility. Ignorance among the marginalised people and lack of knowledge on the soil management has resulted to far reaching effects on yields. Leaching of soil minerals due to irrigation, mining of fertility constituents of the soil without the continuous enrichment of soil with cheap organic manure or the expensive inorganic fertilizers render the soil infertile and therefore unsuitable for proper crop growth (Hill and Waller, 1994). Vegetable crops in the tropical countries are oftenly attacked seriously by arthropod pests because they are grown mostly as intensive crops with considerable inputs such as fertilizers and irrigation water. Due to this, cultivation is within a limited area with narrow crop rotations and hence insects find optimum conditions to develop high populations (ILACO, 1981).

1.2 LITERATURE REVIEW

1.2.1 Insect pests of okra

The crop has a broad spectrum of pests as is common with other Malvaceae plants. A very large number of insect pests from many taxonomic groups can be found feeding on the plant. Defoliation and stem boring by a wide range of caterpillars and beetles tends to be both sporadic and localized and so serious is the damage caused (Waller, 1994).

The major group of pests of okra include the green leafhoppers, *Empoasca* sp. (Cicadellidae) which are sapsuckers (Hill, 1983). They have been commonly observed in this crop and feed principally on leaves, thus inhibiting food translocation and may also transmit diseases and cause curling of leaves. Some caterpillar pests have been found to bore into the fruits of okra and/or feed on the leaves. The spiny bollworms *Earias* sp., *E. biplaga* Wlk. and *E. insulana* (Boisid.) (Noctuidae) bore into terminal shoots of young plants causing death of the tip and cause subsequent development of side shoot (Tindall, 1983). Flower buds and young capsules are shed after being bored into (Hill and Waller, 1994). *Heliothis armigera* (Noctuidae) bores clean circular holes on flower buds and pods. Among common bugs attacking okra is the cottonseed bug, *Oxycarenus hyalinipennis* (Lygaeidae) which is a sapsucker. Other pests include cotton stainers *Dysdercus* sp. (F.) (Pyrrhocoridae), the most common one reported on okra being *D. superstitious* whose adults feed in large numbers on the fruits and seeds by sucking the sap. The blister beetles (Meloidae) destroy flowers and reduce fruit set, the cotton leaf roller, *Sylepta derogata* (Pyralidae) larvae roll leaves and feed inside the leaf-roll. The pink bollworm, *Pectinophora gossypiella,* (Gelechiidae) larvae feed on developing capsules (Hill and Waller, 1994).

The adults and nymphs of melon aphid, *Aphis gossypii* Glover (Aphidae) suck cell sap causing leaf distortion and cupping, and in severe infestation they may debilitate the plant. They are serious vectors of viral diseases (Tindall, 1983). Among the leaf-eating beetles infesting okra is the *Lagria villosa* T. which, feeds on a wide range of other plants including pumpkin and winter squash (Tindall, 1983). The adult flea beetle, *Nisotra* sp. (Chrysomelidae) feeds on the outer layers of leaf tissue and is particularly damaging when it attacks the cotyledons while the larva feeds on the roots without significant damage (Tindall, 1983).

Root-knot nematodes, *Meloidogyne* species (Heteroderidae) stimulate the formation of root galls interfering with plant water supply and result in stunted and chlorotic growth. Affected plants can be pre disposed to diseases (Tindall, 1983).

1.2.2 **Insect pests of chilies**

Insect pests are not as important on chilies (peppers) as diseases or weeds (Critchley, 1997). The major pests include, aphids, mainly *Aphis gossypii* and *Myzus persicae* (Aphididae) which are polyphagous. The damage is both direct by feeding and indirect through disease transmission. They typically distort young leaves and shoots. The main viral diseases they transmit are mosaic and leaf-curl. Thrips (Thripidae) infest foliage (Hill, 1983), flowers, leaves, fruit twigs or buds while other species act as vectors of diseases. They are thought to be transmitting the mosaic and leaf-curl diseases in India and south East Asia, and are the probable vectors of mosaic and leaf-curl virus. The adults and nymphs suck cell sap resulting in distorted shoots and leaves and underdeveloped fruits (Tindall, 1983). Among the species of thrips infesting chilies are *Thrips tabaci* (onion thrips) and *Scirtothrips dorsalis* H., (chili thrips) which infest flowers and leaves causing scarification of foliage (Hill and Waller, 1994).

Some caterpillar pests tunnel into the developing fruits causing deformation of the fruit. Two common caterpillar pests, *Helicoverpa amigera* and *Spodoptera litura* (Noctuidae) bore into the fruits. The striped blister beetle, *Epicauta albovittata* (Meloidae) is a heavy defoliator (Hill, 1983). The adults occur in large counts and cause damage by mining irregular-shaped holes in the lamina and eventually defoliating the plant (Hill and Waller, 1994).

The fruit fly, *Ceratitis capitata* (Wied.), (Tephritidae) larvae tunnel into the fruits and introduce pathogens, which facilitate fruit rotting. The eggs are laid in groups below the fruit skin, the fruit then falls prematurely and the larvae pupate in the soil (Tindall, 1983). Whiteflies, especially *Bemisia tabaci* (Aleyrodidae) have been found to infest the foliage of chilies, and they damage the plant by sucking the sap and transmitting viral diseases (Vacante, 1989).

Other pests infesting chilies include the green leafhoppers or jassids, *Empoasca* sp. (Cicadelllidae) which are sapsuckers with toxic saliva that feeding causes tissue necrosis. The capsicum gall midge, *Asphondylia capsici* (Cecidomyiidae) larvae cause flower drop and make galls inside developing fruits causing fruits to deform and to remain small (Hill and Waller, 1994). The yellow tea mite *Polyphagotarsonemus latus* (Tarsonemidae) causes the leaves to be scarified and causes severe damage to chilies at flowering and fruiting stages (Hill, 1983).

In Ghana, for instance, few insect pests were reported by Critchley (1997) infesting chilies. The leaf beetles and flea beetles, *Lema* sp. (Chrysomelidae) are minor pests of localized importance. Both larvae and adults feed on young leaves and shoot tips and cause minor defoliation. The Coreid and leaf-footed bugs (Coreidae) are piercing and sucking insects on new growth and developing fruit, causing distortion, poor development and shoot die-back. Termites (Termitidae) are pests on isolated or damaged plants during cultivation especially in the dry season. Grasshoppers and locusts (Acrididae) are probably bivoltine but do little economic damage as they are predominantly graminivorous and probably only alight on chilies to rest between flights.

1.2.3 **Control strategies of insect pests**

Science and technology in pest control can help man to overcome future food crises that face humanity as pest numbers rapidly increase. The problems associated with pest control are inextricably bound to complex biological and environmental aspects of crop management as well as to the other aspects of the ecosystem to man.

One of the major problems has been that of starvation on one hand and the threat of worldwide environmental pollution on the other (Debach and Rosen, 1991). Neither of the problems can be solved without aggravating the other. Thus, in order to feed the world population, we must devise effective means to control the many pests that take a heavy toll on agricultural crops without increasing environmental pollution.

1.2.3.1 **Chemical control**

Modern era of chemical pest control began with the invention of synthetic organic insecticides in the early 1940's (Debach and Rosen, 1991). First came DDT and then other chlorinated hydrocarbons that have broad-spectrum pesticidal effect. The organophosphates and carbamates followed, and these have shorter residual activity. Both the organophosphates and carbamates have high toxicity to all living things. The pyrethroids replaced the old synthetic chemicals (Kumar, 1984). Mostly, modern pesticides have provided potent means of suppressing arthropod pests. Agriculture accounts for more than half of the total pesticides used worldwide (Luck *et al.*, 1977), and it has been evident that chemical control has been instrumental and it is far from reaching global arthropod control.

Although man has tended towards use of chemical pesticides, most of them are biocides, toxic to humans as well as to many other non-target organisms. Between 400,000 and 2 million pesticide poisoning cases occur every year and most of them among farmers in developing countries, while 10,000 to 40,000 result in death (Postel, 1987). The need for safer, less costly alternatives to chemical control is evident from the side effects of pesticide use. Some promising control methods include use of cultural control, resistant varieties, pheromones, biological control and plant bio-pesticides within an integrated pest management system.

1.2.3.2. **Biological control**

Biological control is the utilization of natural enemies to reduce the damage caused by noxious organisms to tolerable levels. In applied forms or in the scientific standpoint, okra, the leaf-eating caterpillar *Sylepta derogata* could be controlled effectively with aqueous neem kernel extract (ANKE) even at a low concentration of 25g/liter of water (Dreyer, 1987).

The incidence of *B. tabaci* adults on okra was reduced by aqueous extracts from seeds and leaves of neem especially with seed extracts being more effective (Siddig 1981). The cotton aphid *A. gossypii* was controlled effectively on okra by four weekly sprays of 50g/l aqueous neem seed extract (ANSE) and 2% neem oil, the effects being similar to those of the synthetic carbamate butocarboxim (Dreyer and Hellpap, 1991).

1.3 Justification of the study

In Kenya, the horticultural crops are rapidly becoming part of income generation activities among many farmers. Okra and chilies are newly introduced in Kenya (in the late 1980's), although their cultivation else where dates back to the eighteenth century. They comprise a big proportion of the vegetables meant for export. However, the decreasing levels of attainable yields due to increasing soil infertility, pests and diseases infestation threaten the farming of these vegetables. Of these, disease and pest infestations are of great economic value to the farmers.

This study provides the lacking baseline information regarding the important insect pests that affect the crop production, possible environment-friendly control measures and the appropriate time for the control. Similarly, information on the damage and associated yield loss from insect infestation in these two crops is inadequate. Not much work has been done in Kenya relating to insect pests of okra and chilies among the low socio-economic farmers of the tropical semi-arid regions in Kenya and hence the need to conduct the study.

1.4 Objectives of the study

The dynamics and infestations of insect pests and associated yields loss form an important component of crop production. The control of insect pests by use of chemicals, plant products and the natural enemies are important components of integrated pest management strategy. The studies were carried out over two crop seasons in a semi- arid tropical region of Kenya on two Asian export vegetables (okra and chilies) in order to;

i) Characterize the insect pest spectrum of chilies and okra in relation to plant phenology (plant growth stage) under the prevailing weather conditions,

ii) Identifying the common natural enemies regulating the insect pest populations,

iii) Determine the damage and yield loss caused by insect pest infestations

iv) Assess the impact of neem formulations on insect pests, associated yield loss and natural enemies on both crops.

1.5 References

Adhikary, S (1984). Results of field trials to control common pests of okra, *Hibiscus esculentus* L. In Togo by application of crude methanolic extracts of leaves and kernels of the neem tree *A. Indica* A. Juss. *Z. Angew. Entomology.* **16**: 234-47.

Anonymous, (1998). Kibwezi irrigation Project Farm reports, pp 5-20. Kibwezi, Kenya.

Cramer, H. (1975). Plant protection and world crop production, *PflanzenschutzNa-Ichrichten* **20**(1): 19-67.

Critchley, B. (1997). Pests of vegetables: Their identification and control in Ghana, pp 49-112. Natural Resource Institute, U.K

Debach, P. and Rosen, D. (1991). Biological control by natural enemies, pp 13-54. University of Cambridge, New York.

Dreyer, M. (1987). Field and laboratory trials with simple neem products as protectants against pests of vegetable and field crops in Togo. Proc. 3rd International Neem Conference. Nairobi, Kenya

Dreyer, M. and Hellpap, C. (1991). Neem- A promising natural insecticide for small-scale vegetable production in tropical and sub-tropical countries. *Zeitsemift für Planze-Krankheiten. Pflkrankh*

East Africa seeds company (1996). Consumer booklet. Nairobi, Kenya

FAO (1972). *Production yearbook* Food and Agriculture Organization, Rome

FAO (1973). *World Production yearbook* (1973), Food and Agriculture Organization, Rome.

FAO (1976). *Production yearbook* Food and Agriculture Organization vol. 29, Rome

FAO (19781). *Production yearbook* Food and Agriculture Organization vol.34, Rome

Grubben, G. (1977) Tropical vegetables and their genetic resources, AGPE: IBPGR/77/23, International board for plant genetic resources, Food and Agriculture Organization, Rome.

Herklots, G. (1972). Vegetables in Southeast Asia. in Tindall, H. (1983) pp 90-145. Oxford University press. London.

Hill, D. (1983). Agricultural Insect Pests of the Tropics and their control, pp 96-134. Cambridge University Press, London

Hill, D. and Waller, J. (1994). Pests and diseases of tropical crops, pp 10-134. Cambridge University press, London

Horticultural Crops Development Authority (HCDA) (1996). *Export crop Bulletin* no. 9. and 10. June, Nairobi, Kenya

ILACO (1981). Agricultural Compendium for Rural Development in the Tropics and subtropics, pp 234-56. Elsevier scientific publishing company, Amsterdam

Jacobson, M. (ed.) (1989). Pharmacological and toxicological effects of neem in 1988 focus on phytochemical pesticides. Vol. 1. The neem tree, pp 133-153. CRC press, *Boca Ratton, FL*

Kanungo, D., Randhawa, N., Parmar, B. (Eds) (1993). Neem research and development, pp 250-262. *Society of Pesticide Science*, India

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

Kumar, R. (1984). Insect pests control (with special reference to African agriculture), pp 166-170. Edward Arnold, London

Luck, R., Bosch, R and Garcia, R. (1977). Chemical insect control- A troubled pest management strategy. *Biosciences*, **27**: 606-13

Pimentel, D. (1986). CRC handbook of pest management in Agriculture (vol.1), CRC press, Florida. **1**:3-11

Pimentel, D., Dritschilo, W., Krummel, J. and Kutzman, J. (1975). Energy and land constraints in food-protein production, *Science*, 190. Florida

Postel, S. (1987). Defusing the toxic threat: controlling pesticides and industrial waste, pp 67-123. *World watch paper* 79. Washington DC. World Watch Institute

Randhawa, N. and Parmar, B. (Eds) (1993). Neem research and development. *Society of Pesticide Science*, **5**: 346-52

Raymond, A. (1985). Vegetable seed production, pp 32-67. University of Bath, Longman

Redknap, R. (1981). The use of crushed berries in the control of some insect pests in Gambia. Proceedings of 1st international Neem conference, *Rottach, Egern, Germany*, 1980.

Sachan, J. and Pal, S. (1976). Insecticides and Cakes for the Control of White Grub *Holotrica insularis.* Brenske pp, 245-8 Western Rajasthan, India

Schumutterer, H. (1995). The neem trees *Azadirachta Indica* A. Juss. And other meliaceous plants (source of unique natural products for integrated pest management, medicine, industry and other purposes*)*, pp 256-67. *Vett publication Incorporation*, New York

Schumutterer, H., Ascher, K and Rembld, H. (Eds) (1981). Natural pesticides from the neem tree- proceedings of 1st institution Neem conference, *Roltach-Egern, Germany*, 1980.

Siddig, S. (1981). Evaluation of neem *Azadirachta Indica* A. Juss as a protectant against some major pests in Sudan. *Shambat Research Station* **3**: 223-27.

Simmonds, N. (1976). The evolution of crop plants, Longman, Harlow. In. David, D. (1993) insect pest management, pp 82-130 . C.A.B international, Wallingford, UK

Sithanantham, S., Lako, G., Nyarko, K., and Bob, M. (1998). Improved Pest Management Approaches for Africa; A thematic study. ICIPE/IFAD publication (manuscript), Nairobi, Kenya

Tindall, H. (1983). Vegetables in the tropics, pp 90-145. Oxford University press. London.

Vacante, V. (1989). *Bemisia tabaci* on capsicum. *Applied Entomology and Zoology.* **4**: 7

Veeraragavathatham, D., Jawaharlal, M. and Ramadas, S. (1998). A guide on vegetable culture, pp 5-12. Suri associates, Coimbatore, India

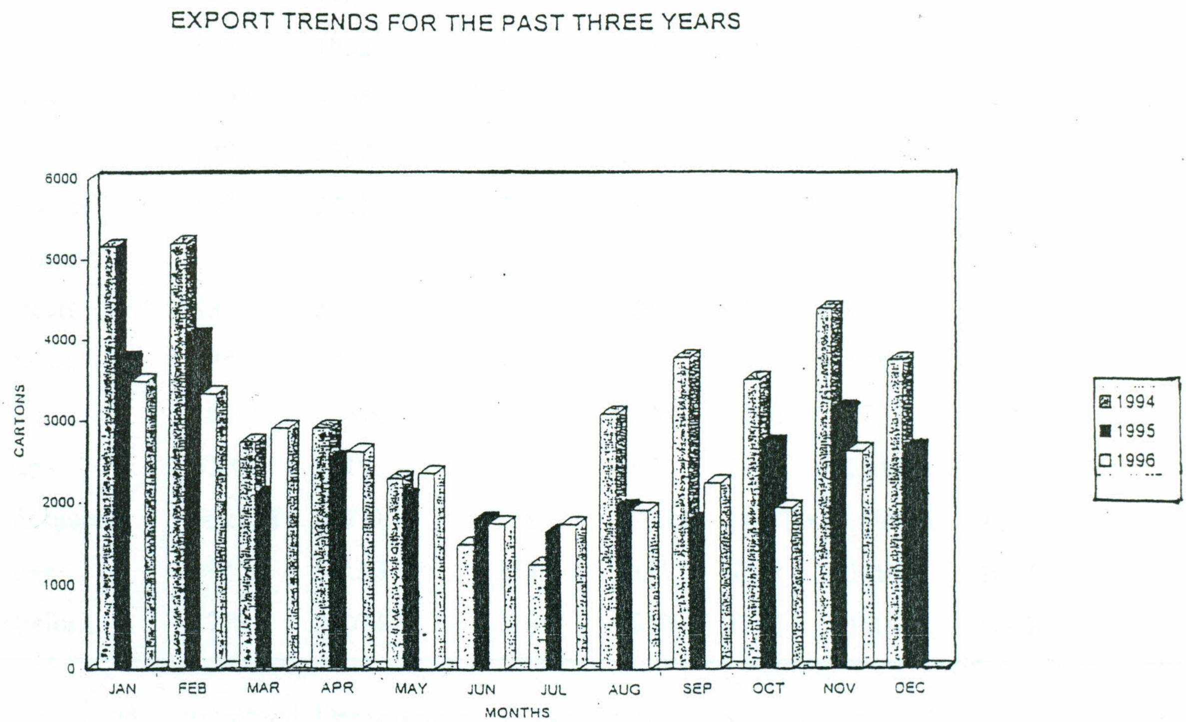

Fig. 1. Export trend of Asian export vegetables from Kibwezi irrigation project over a period of three years.

Table 1. The world's vegetable production ('000 Metric tonnes) in 1975 and 1980.

Vegetable	Rest of the world		Africa		Asia		Europe	
	1975	1980	1975	1980	1975	1980	1975	1980
Artichokes	1413	1296	91	99	17	15	116	69
Cabbages	16411	35139	494	640	6466	15401	1299	571
Cantaloupes	4450	6676	4450	6676	1456	3183	290	305
Carrots	5356	10087	256	384	669	2611	227	419
Cucumber	5257	10524	216	305	1998	5312	33	46
Eggplants	2592	4508	342	442	1630	3418	3	7
Garlic	1495	2380	195	210	663	1368	128	181
Green beans	2029	2428	205	298	312	646	71	117
Green chilies and peppers	4347	6888	808	1062	724	2813	136	169
Green peas	4781	4239	906	113	381	604	145	145
Onions	16031	19410	1243	1528	7406	8705	1041	1722
Pumpkins	5292	5219	823	997	1155	2146	751	682
Roots & tubers	562238	487113	77847	83903	213780	179275	42865	42189
Tomatoes	39476	50153	3589	5121	6238	11855	1862	2947
Watermelons	17781	25071	1761	2050	7745	14065	1063	1020

Source: Food Agricultural Organization (FAO) of the United Nations. FAO production yearbook (1976) Vol. 29 and (1981) Vol. 34. Rome.

Table 2. The production of okra and chilies in Kenya between 1995-1996

Vegetable	Weight (metric tones)	Value (K£)
Chilies	5, 925	5, 408, 172
Okra	6, 183	5, 841, 732
Total	12, 108	11, 249, 904

Source: Provincial reports, MOALD & M 1995/1996.

Table 3. Average yield/ha of okra for the year 1996 and 1997

Year	Number of cartons/ha.	Value (K. Sh.)
1996	509	63, 241
1997	498	56, 042
Total	1, 007	119, 283

Source: Kibwezi farm reports (1998).

Table 4. Average yield /ha of chilies for the 1996 and 1997

Variety	Year	Number of cartons/ha	Value (K.Sh)
Long chilies	1996	0	0
	1997	941	72,220
Bullets	1996	1,006	80,395
	1997	708	3,860
Thin chilies	1996	580	29,765
	1997	308	3,280
Sweet pepper	1996	0	0
	1997	217	3,070
Total	1996	1,586	110,160
	1997	2,174	117,430

Source: Kibwezi farm reports (1998).

CHAPTER TWO

2.0 INSECT PEST INFESTATIONS AT DIFFERENT PHENOLOGICAL STAGES OF OKRA

2.1 Introduction

A very large number of insect pests from several taxonomic groups feed on okra as is common with other plants in the family Malvaceae (Hill and Waller, 1994). Several pests are often found attacking the same plant simultaneously. In many occasions insect pests are found near the damaged part. However in other instances, the damaged part may be found without the insect, though the damage may be characteristic of certain insect or a group of insects. According to Hill and Waller (1994), insect pest damage has been categorized into three groups;

i). Generalists; insects feeding by biting pieces of plant material and chewing. These insects cause damage to plant by loss of photosynthesizing tissues that may result in defoliation, destruction of buds and shoots, boring or tunneling of stems, roots and tubers and formation of galls among others

ii). Sap suckers with piercing mouth-parts; damage resulting from these group of insects include wilting, leaf curl, stunting or death especially from insects with toxic saliva

iii). Vectors of diseases; these are serious pests to crops as they can lead to severe outbreaks of diseases even with low insect counts. Insects may create wounds on parts of the plant, which eventually becomes septic due to bacterial or fungal infection. Other groups of insects are intermediate hosts for disease causing organisms.

The present studies were aimed at establishing the pest spectra of okra at different plant growth stages under the hot climatic conditions. An important aspect that was considered was establishing the most critical stage for pest attack and that would require intervention.

2.2 MATERIALS AND METHODS

2.2.1 Study site

The studies were carried out during two seasons at the University of Nairobi (U.o.N) Kibwezi irrigation project (K.I.P) field station at Kibwezi in Eastern province of Kenya (2°21-5'S, 38°2-5'E and 700m above the sea level) (Fig. 2.1). The site has bimodal rainfall with a mean annual rainfall of 600mm. The rainfall is reliable during the short cropping season (October to December) but is unreliable during the long cropping season (March to May) (Anonymous, 1996). This information was also supported by the meteorological data collected during the study (fig. 2.2). The average annual temperature is between 25^0c-30^0c with the hottest months being September to October and January to February with mean temperatures of 35^0c (Anonymous, 1996). The main soil type is eutric luvisols with a pH averaging at 7- 7.8 (Ekipara and Muya, 1991).

2.2.2 Experimental design and plot lay out

The experimental plots were laid out in a completely randomized block design (Simmonds, 1976) with six treatments (table 2.1) replicated four times.

Okra seeds (Pusa sawani variety) were sown on October 1998 and February 1999 in 4 x 3 sq. m. plots with a row to row and plant to plant spacing of 60 and 15 cm respectively with an average plant population of 100 plant/plot. A 1m-wide buffer strip of bare ground separated the plots. The common fungal and bacterial diseases were controlled by foliar applications of copper-based fungicides and the normal agrotechniques were adopted on all the plots. Foliar applications of either knock down [Karate (Lamda Cyhalothrin), Sumithion (Fenitrothion) and Lannate (Methomyl)] and/ or systemic insecticides, Rogor (Dimethoate) and Evisect, were sprayed alternately on weekly basis to the specified growth stages at rates recommended and directed by the manufacturers and the Horticultural Crops Development Authority (HCDA), (1996).

2.2.3 **Abundance of insect pests**

During the short and long rains cropping season of October to January 1998 and February to May 1999 respectively, one week after crop emergence and three days after chemical insecticide application, five okra plants were randomly sampled from each plot.

Estimation of the numbers of aphids, white flies and red spider mites was done using a modification of Saika and Muniyappa (1989) and Mote (1977) empirical scales of 1-5 (table 2.2). The under surface of each leaf was closely examined for these pests. The numbers of white flies were counted during the early morning hours (6-8 hrs.) when they were inactive.

The numbers of leaf hopper nymphs and adults, leaf beetles, cotton stainers and other sucking bugs, flower beetles, flower thrips, leaf miners, leaf eating caterpillars and pod borers were estimated from the five randomly selected plants of each plot. Their populations were determined by actual counts. Some leaf-eating caterpillars from the border rows were handpicked and reared in petri dishes in the laboratory on their natural diet until adult emerged to recover any parasitoid. Flower thrips were estimated by picking five flowers per replicate and preserving them in 70% alcohol for 2-3 hours as proposed by Bournier *et al.,* (1982). The leaf miners were estimated by counting freshly mined tunnels by the larvae from the four upper most leaves. Data obtained were expressed as the number of insect pest per five plants. Adult and nymphal stages of insect sample specimens were collected and preserved in 70% alcohol or dry mounted and sent to the Biosystematics department (I.C.I.P.E) and Kenya Plant Health Inspectorate Services (KEPHIS) for identification.

2.2.4 **Data analysis**

To standardize the data, square root transformation was performed on scores and numbers of insect data collected over the two seasons. To test for treatment effects, data collected were averaged for each individual treatment and plant growth stage during the two cropping seasons and analyzed using repeated-measures two way analysis of variance ANOVA (PROC GLM, SAS, 1995). The means were separated using the Student-Newman-Keuls (SNK) test. Overall population patterns of insect pests in the control plots over time were illustrated by plotting the data collected against each plant growth stage.

2.3 RESULTS

2.3.1 Abundance of insect pests on okra

A complex of insect pest species infested okra during the two season trials. A total of eleven different insect pest orders were observed infesting okra at different plant growth stages (table 2.3).

There was a variation in the crop growth duration in the two seasons as demonstrated by the number of sampling occasions. The first season had a sampling period of eight weeks while the second season had a sampling period of seven weeks.

Both seasons showed similarities regarding occurrence of most pests, although the second season had an addition of an extra pest (red spider mite) and disappearance of leaf hoppers and leaf beetles, which were observed in the first season. Aphids, white flies and red spider mites infested the crop in large numbers (fig. 2.3 a.). Aphid (plates 2.1) infestation started in low numbers in the early vegetative growth stage of both seasons and increased at an increasing rate with plant growth. The highest population of aphids was observed in the maturity stage of the two cropping seasons. The first crop season, however, had high mean scores of aphids than the second crop season. Whitefly infestation was low and occurred after the short rains in the early vegetative stage of both crops seasons. Their population increased to a stable state in the late vegetative stage. However, they disappeared from the second season crop at the late vegetative stage, while in the first crop season, their population decreased with crop maturity. Red spider mite occurred on the second season crop only during the maturity stage. Infestation by sucking pests that included cotton stainers, sucking bugs and leafhoppers (fig. 2.3.b) was noted in both season crops. Cotton stainers infestation was high in the second season crop and occurred from the early vegetative stage, while in the first season crop, it started during the flowering period. Cotton stainers disappeared from the crops before the end of the season. Several species of sucking bugs were common during the maturity stages of crop growth. The leafhoppers infested the crop during the first crop season from early vegetative stage when plants had developed dense foliage to the maturity stage. The most leaf damaging pests included the caterpillars (plate 2.3) and leaf miners (fig. 2.3.c). Infestation by caterpillars and leaf miners occurred during the early vegetative stages of crop growth. The population of caterpillars decreased with crop growth while the leaf miners had the highest infestations during the early and late vegetative growth stages, which decreased with crop growth. Leaf miners were more during the second crop than the first crop. Leaf beetles (plate 2.2) fed on the young shoots and were only observed in the reproductive stages of the crop of the first crop season.

The fruit borers (plate 2.4) and flower beetles infested the crop from the reproductive and maturity stages (fig.2.3.d). The second crop had high infestations of the flower beetles and fruit borers than the first crop, which caused substantial damage to the flowers and fruits.

2.3.2 **Effect of the treatments on insect pests of okra**

There were differences observed in the relative severity of infestation by pests among the treatments in both the trials (tables 2.4.a and b.). Among the treatments, which received pesticide applications at different times of plant growth, differences between certain pests at certain stages of plant growth were noted.

Aphid scores in the first crop season were significantly different ($p < 0.05$) between treatments. Treatment one had the highest (1.89) population and at par with treatments two, three and six while the lowest population was observed in treatments five and four during the first season crop. In the second crop, aphid population was high (2.52) in treatment six as compared with treatment three (2.50). The least aphid population was observed in treatment five.

Whiteflies population was significantly different ($p < 0.05$) between treatments. Treatments one, two and three had the highest population and at par with the control while, the lowest populations were in treatments four and five during the first crop. In the second cropping season treatments six and four had the highest comparable populations while treatment five had the lowest population.

Leafhoppers, which were only observed during the first crop season were statistically different ($p < 0.05$) between the treatments with the highest population in treatment six. Treatments two and five recorded the least population. Cotton stainers numbers in the treatments were at par with the control during the two cropping seasons. However, treatment three and six of first and second season recorded the highest (1.02 and 1.23) numbers. Treatment six of the first crop recorded the highest (0.86) number of leaf eating caterpillars while the least (0.71) population was observed in treatments four and five. In the second crop trial, none of the treatments showed significant differences for caterpillar populations though treatment four recorded the highest (0.95) population.

All treatments did not show significant differences with the control in leaf miner populations in the first crop season although treatment two recorded the highest (1.99) and treatment five the least (1.51). In the second crop season, the population of leaf miner was far much higher than in the first crop season. Treatments one, two, three and six were not significantly different within each other but significantly different ($p < 0.05$) from other treatments and with the highest (6.92-7.10) populations of leaf miner. The least (3.01) mean counts were recorded in treatment five.

Population of the sucking bugs in the first crop was not significantly different between the treatments, although treatment six had the highest (0.91) number of observation and five the least (0.71). Treatment two of the second crop recorded the highest (1.52) population and differed significantly ($p < 0.05$) from other treatments. Treatments five and four recorded the least (0.71) population.

Population of fruit borers was not significantly different between the treatments in both trials. The same observations were made with the flower beetles.

Flower thrips in the first crop season were significantly different ($p < 0.05$) between the treatments. The highest number (2.35) was observed in treatment six and the least (1.35 and 1.18) in treatments four and five. Treatments one, two and three were at par with the control. Treatments six, two and three of the second crop season recorded the highest significantly different ($p < 0.05$) population of flower thrips from treatments four and five which, recorded the least populations of thrips.

The red spider mites were only observed during the second cropping season where treatment six recorded the highest (1.41) incidence of the red spider mites as opposed to treatment five with the least (0.97) observations. However there were no significant differences between ($p > 0.05$) the treatments on red spider mites numbers.

2.4 Discussion

Sutherland *et al.*, (1996) and Southwood and Norton (1973) have cited that the development of solutions for the constraints to crop production caused by insects requires, as a precursor, the collection and collation of a wealth of varied and variable data information. Traditionally this has been done by discipline focussed scientists using a range of techniques and formats. It is evident from these studies that okra has a complex pest problem which, infests the crop at different stages of growth.

Observations of pests on okra under different treatment regimes over a period of two cropping seasons provided baseline information on pest dynamics, the critical stage of pest infestation and the appropriate time for crop protection on okra in semi-arid regions. Pests occurred at different times of crop growth and there was a trend of most pests to increase from low infestation levels to high infestation levels before any limiting factor regulated their counts. The hot climatic conditions of the study site favoured the increase of pest populations (Anonymous, 1996) as is common in most hot tropical zones. Weather conditions affect populations build up of insects and most density-independent mortality factors are effective regulatory mechanisms of insect counts (Hill and Waller, 1994).

Aphid counts were highest in the dry and hot conditions of the first crop season before onset of the short rains though they were predominant in both seasons in almost all the growth stages. Melon aphid, *Aphis gossypii* Glover, has been reported as the common aphid on okra and in severe infestation they may debilitate the plant especially in the early growth stages of the crop (Tindall, 1983). Although this was not observed, honeydew secreted by the aphids prompted the growth of fungi on the leaves, which became sooty during the first cropping season.

Whiteflies (*Bemisia tabaci*) were major pests during the first cropping season after the short rains, (Muriungi, personal communication). Although whiteflies are vectors of viral diseases (Vacante, 1989) on chilies for instance, there were no incidences of viral diseases on okra and no indication of any particular growth stage favoured, as they infested the entire plant life in the first cropping season trial. Their disappearance shortly after the rains in the second season was prompted by the indiscriminate application of pesticides on the adjacent commercial plots and the dry weather accompanied by high temperatures. A recent survey of white fly problem in tomato cropping systems in Kenya noted the unusual occurrence of the pest in Kibwezi during the months of November to March 1998 after the short rains (Bob, personal communication).

The green Leafhoppers (*Empoasca* sp) have been observed on this crop and feed principally on leaves, thus inhibiting food translocation. They may also transmit diseases and cause curling of leaves (Hill, 1983). There was no feasible explanation for the appearance of this pest in one season and not in the other. It was evident during the sampling periods that leafhoppers infestation occurred when the plants attained a good percentage of ground cover. Cotton stainer (*Dysdercus* sp) was a common pest of okra. Infestation started during flowering as is common in cotton. They suck sap from cotton bolls (Hill and Waller. 1994) and were observed sucking sap from flower buds and young fruits of okra. However the damage they inflicted on the flower buds and fruits was not noticeable.

Three species of leaf caterpillars (*Ancylolomai* sp, *Helicoverpa armigera* and

Plusia sp) bored into terminal shoots of young plants causing death of the tip and subsequent development of side shoot, this has also been reported by Tindall (1983) on cotton. They may defoliate the leaves and thus inhibit photosynthesis. It was during the early and late vegetative growth stage that the caterpillars preferred feeding on leaves but in rare occasions, they infested the crop at the maturity stage. Their natural enemies as has been reported in Egypt by Zaki (1996) may have brought about their low numbers. Such enemies may include the dipteran parasitoid (Baya, personal communication) and *Campoletis chlorideae* (Hymenoptera; Ichneumonidae) (Sathe and Santhakumar, 1992).

Leaf miner (*Liriomyza* sp.) was a major pest of okra during the early and late vegetative stages. Larvae mined tunnels between the upper epidermis of the first young leaves. This interfered with the process of photosynthesis, and the most affected leaves dried and fell off. The population of leaf miners was high during the second cropping season when favourable hot climate facilitated rapid reproduction (Mueke, 1992 unpublished). Sucking bugs (*Oxycarenus hyalipennis*) were noted during fruit formation and occurred as seed bugs. A number of leaf beetles, the *Leptaulaca fissiocollis*, *Copa delata*, *Lagria villosa*, *Lixus* sp. and *Apion sp.* were identified as pests on okra. They were particularly damaging to the cotyledons as reported by Tindall (1983) and caused defoliation during the late vegetative stages.

Flower beetles (*Coryna apicicornis*), flower thrips (*Frankliniella occidentalis* and *Haplothrips gowdeyi*) and fruit borers (*Helicoverpa armigera*), were serious pests of okra during both cropping seasons at flowering and fruiting stages. The stage at which they infested the crop was critical as any slight infestation resulted in significant damage to the quality and quantity of fruits. Flower beetles were common at the onset of flowering period. They possibly originated from alternative host crops in the commercial plots and their feeding habits interfered with the process of fertilization and fruit setting. Flower thrips feeding in the flowers resulted in deformed fruits and so reduced the quality. The fruit borer, *Earias* sp, has been reported as the most serious pest of okra causing 8.4 to 73.2 percent fruit infestation (Kumar and Urs, 1988). The fruit borer infestation at fruiting stage (about 40 days after sowing) in both trials coincided with that observed by other workers in Asia (Srinivasan and Krishma Kumar, 1988).

The red spider mite infestation at the end of second cropping season suggested their resurgence as a potential pest when weather became favourable for their multiplication. Although they have been identified as pests of okra in the study site (Ogembo, personal communication), it was observed that okra appeared to tolerate their presence due to its vigorous growth and presence of predatory beetles especially coccinellids and carabids which kept their population low.

Treatments, which received insecticide, spray at particular time of the plant growth, had the pests controlled only at that stage. This did not reflect a total pest control in the rest of the other growth stages and pests reappeared on these treatments due to the disappearance of insecticide toxicity. The FAO (1981) yearbook pointed out that experiments comparing sprays applied at different times may be affected by interplot interference (Bainbridge and Jenkyn, 1976). The fully protected plots against insect pests (treatment five), recorded the least pest numbers at any one time that were significantly different ($p < 0.05$) from other treatments. The unprotected plots (treatment six), recorded the highest pest populations in both seasons. The population of pests in the control plots compared in most cases to plots that received chemical insecticides sprays at certain plant growth stages. However, this did not imply absence of pests in the protected plots because insect pests appeared to have developed resistance to pesticides due to continuous use of pesticides (Yu, 1993) as was the case with the farm on which trials were conducted. Some plants escaped pest attack in the unprotected plots and this prevented the expected observations to be made during sampling for pests in the treatment.

The most critical growth stages requiring spray intervention with pesticides against leaf hoppers and aphids have been identified as 21 and 35 days after sowing (Srinivasan and Krishna Kumar, 1988), and 40 days after sowing for fruit borers (Krishna and Srinivasan, 1984). Okra should be protected against leaf miner immediately after emergence, with systemic pesticides and immediately after flowering for flower beetles and flower thrips. Occurrence of one adult of white fly in a leaf is the best time for their intervention (Guharay and Monterrey, 1993 unpublished).

Controlling insect pests at certain intervals of the crop growth may have little impact on pests populations build up. The observations of pests obtained from treatments 1-4 had no significant difference ($p>0.05$) with those obtained from the control treatment. Protection of the crop against pests at reproductive and during the entire growth period significantly reduced the pest populations and more importantly reduced the damage inflicted on the yields.

2.5 Reference

Anonymous, (1996). Kibwezi irrigation project farm reports, pp 5-11. Kibwezi, Kenya

Bournier, A., Lacasa, A. and Pivot Y. (1982). Regime alimentaire d un thrips predateur *Aeolothrips intermidius* (Thys: Aeolothripidae). *Entomophaga* **24**: 353-361.

Brainbridge, A. and Jenkyn, J. F (1976). Mildew re-infection in adjacent and separated plots of sprayed barley. *Annals of Applied Biology* **82**, 477-486. in FAO (1981). Crop Loss Assessment Methods-supplement 3, pp, 35-97. Commonwealth Agricultural Bureaux, UK

Ekipara, E.A. and Muya, E.M. (1991). Detailed soil survey of part of the U. o. N dryland field station Kibwezi. National Agriculture Research Laboratories, Nairobi, Kenya

Guharay and Monterrey (1993). Unpublished data

Hill, D. S and Waller, J. M. (1994). Pests and diseases of tropical crops, pp 233-234, Cambridge University Press, London.

Hill, D.S. (1983). Agricultural Insect Pests of the Tropics and their control, pp 94-123, Cambridge University Press, London

Horticultural Crop Development Authority, HCDA (1996). Export Crop Bulletin: No. 9 June 1996, *KEDS-supported HCDA Export crop manual*. Nairobi, Kenya.

Krishna Kumar, N. K. and Srinivasan, K. (1984). Evaluation of extended spray intervals with synthetic pyrethroids for the control of shoot and fruit borer, *Earias vittella* on okra. *Progressive Horticculture* **17**(3): 254-258.

Kumar, K. K. and Urs, K. C. D. (1988). Population fluctuation of *Earias vittella* Fab. on okra in relation to abiotic factor. *Indian Journal of Plant Protection* **16,** 137-142.

Mote, U. N (1977). Chemical control of chili thrips *Scirtothrips dorsalis* Hood. *Journal of Maharashtra Agricultural university* **2** (1): 71-72.

Mueke, J. M. (1992). Integrated control of coffee pests (unpublished), pp 2-3. Kenyatta University, Nairobi, Kenya

Saika, A. K. and Muniyappa, V (1989). Epidemiology and control of tomato leaf curl in Southern India. *Tropical Agriculture* **66,** 350-354.

Sathe, T.V and Santhakumar, M.V. (1992). Factors responsible for host finding behaviour by *Campoletis chlorideae* Uchida (Hymenoptera; Ichneumonidae), a parasitoid of *Heliothis armigera* (Hubn) (Lepidoptera; Noctuidae). *Rivista di parassitologia journal* **5**:2,233- 40.

Simmonds, N.W (1976) Principles of Crop Improvement. In. Dent, D (1993) Insect pest management, pp 118. CAB International, Wallingford, UK

Southwood, T. R.E. and Norton, G. A. (1973). Economic aspects of pest management strategies and decisions. *Memorus of the Ecological Society of Australia* **1**, 168-84.

Srinvasan, K. and Krishna Kumar, N. K (1988). Timing of scheduled insecticide application for the control of leafhopper, *Amrasca biguttula on okra (Abelmoschus esculentus). Indian Journal of Agricultural Science* **58** (11): 828-831.

Statistical Analysis Systems (1995) *SAS Users Guide. Statistics, Version* 8 edn. SAS Institute Inc., Cary, NC

Sutherland, J. A., Kibata, G. N and Farrell, G. (1996). *Field sampling methods for crop pests and diseases in Kenya,* pp 18-28. KARI/Crop protection project, KARI/NARL, Nairobi

Tindall, H.D. (1983). Vegetables in the tropics, pp 325-36. Oxford university Press, London

Vacante, V. (1989). *Bemisia tabaci* on capsicum. *Applied Entomology and Zoology* **4**: 7

Yu, S.J (1993) Inheritance of insecticide resistance and microsomal oxidase in the diamondback moth (lepidoptera: Yponomeutidae). *Journal of Economic Entomology* **86**: 680-683.

Zaki, F. N. (1996). Field application of *Steinernema feltiae* in the form of baits against the greasy cutworm, *Agrotis ipsilon* in okra field in Egypt. *Anzeiger Fur Schadhngskude, Pfanzenschutz Umweltschutz journal* **69**:4,79-80.

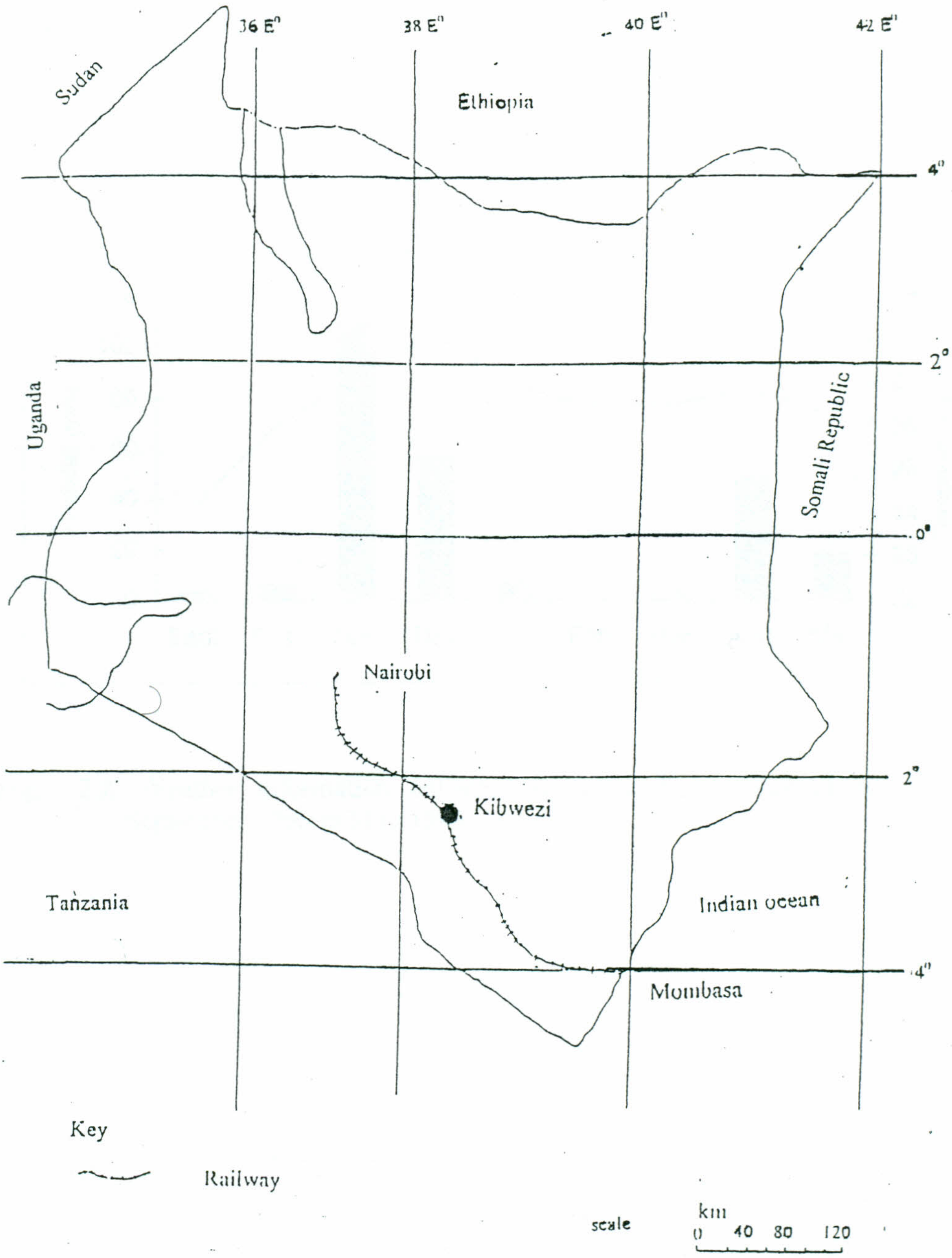

Fig 2.1 The approximate location of the study area of Kibwezi on a map of Kenya.

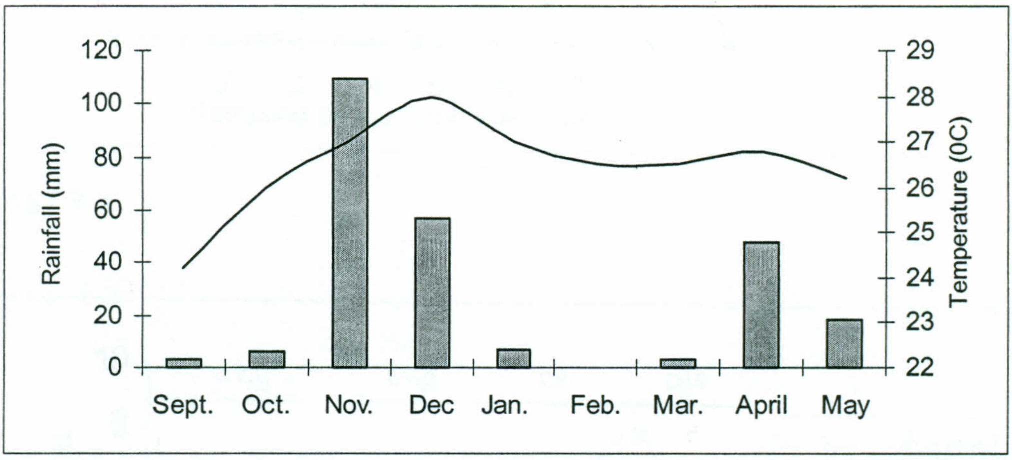

Fig. 2.2. Weather information collected from the farm meteorology station during September 1998 to May 1999.

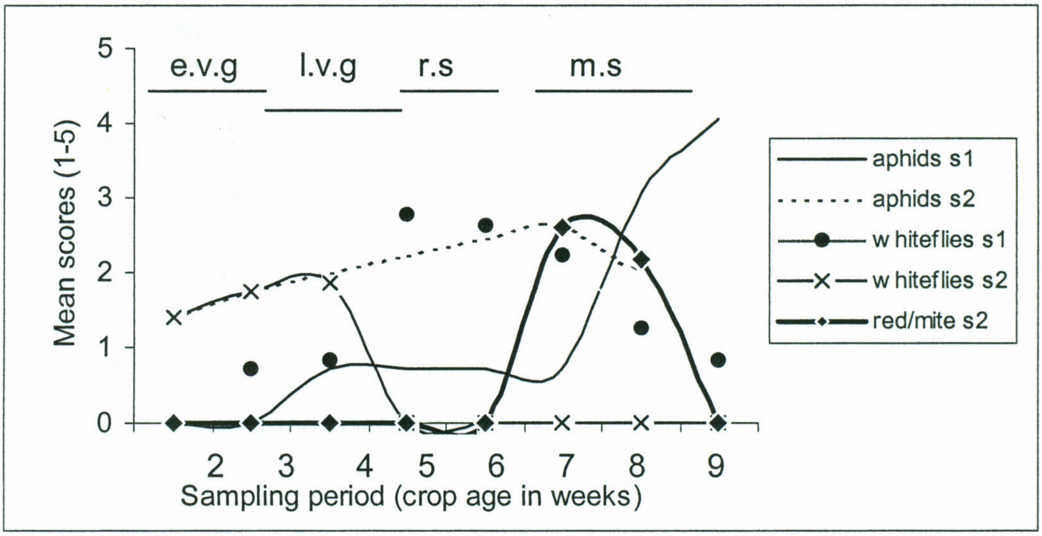

Fig 2.3. a

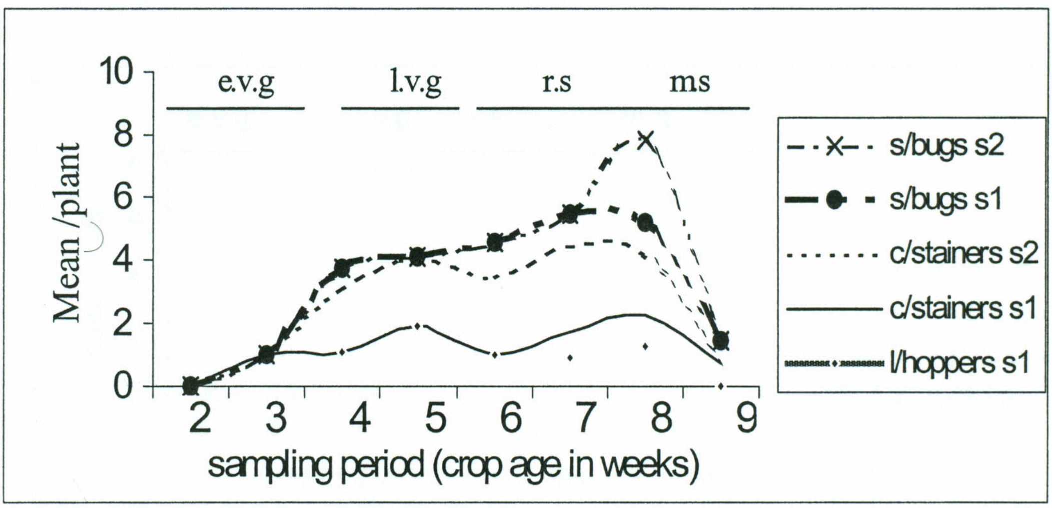

Fig 2.3. b

Figs.2.3 a and b. Relative abundance of pests (aphids, whiteflies, red spider mite (red/mite), sucking bugs (s/bugs), cotton stainers (c/stainers) and leafhoppers (l/hopper) under different plant growth stages of okra (early vegetative growth stage (e.v.g), late vegetative growth stage (l.v.g), reproductive stage (r.s) and maturity stage (m.s). Means represent averages for pooled data (scores) across sampling occasion of the control plots in okra during seasons 1 and 2 (s1, s2). Aphids, whiteflies and red spider mite data are based on 1-5 visual score rating.

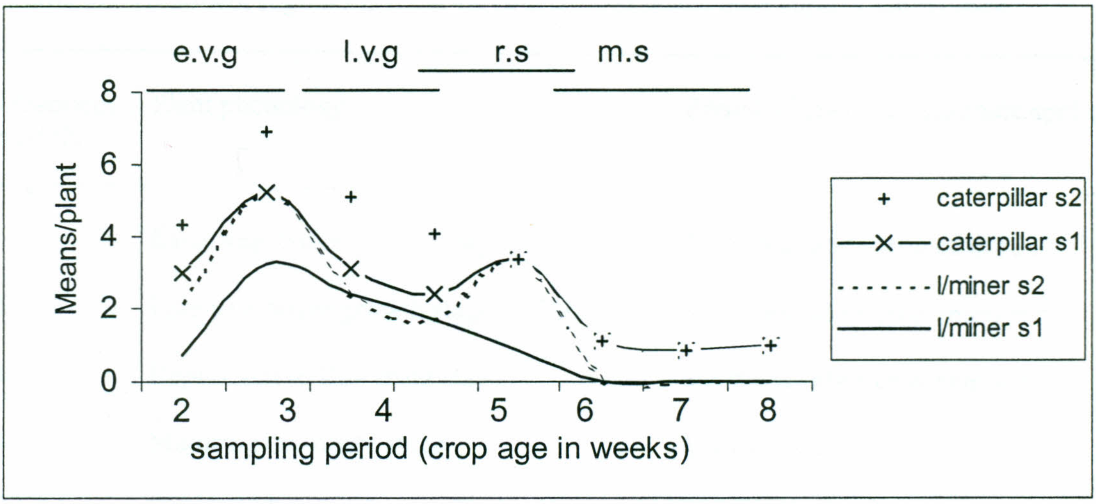

Fig 2.3.c

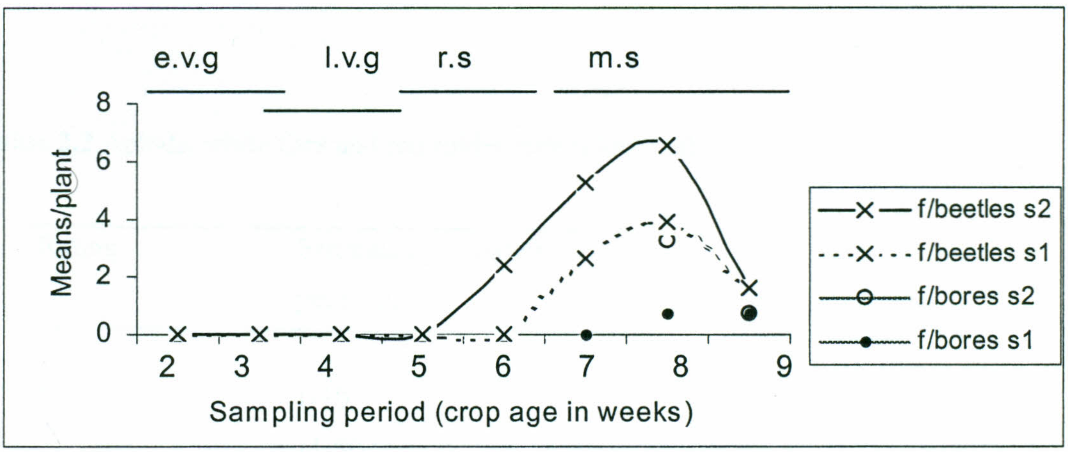

Fig.2.3. d

Figs.2.3 c and d. Relative abundance of caterpillars, leaf miner (l/miner), flower beetles (f/beetles) and fruit borers (f/borers) under different plant growth stages of okra (early vegetative growth stage (e.v.g), late vegetative growth stage (l.v.g), reproductive stage (r.s) and maturity stage (m.s). Means represent averages for pooled data (counts) across sampling occasion of the control plots in okra during seasons 1 and 2 (s1, s2).

Table 2.1 Treatment regimes and period of chemical insecticide application on okra.

Treatment module	Plant phenology	Period of chemical pesticide application.
1.	Early vegetative growth stage (E.V.G.S)	1-2 weeks after crop emergence
2.	Late vegetative growth stage (L.V.G.S)	3-5 weeks after crop emergence
3.	Reproductive/flowering stage	5-6 weeks after crop emergence
4.	Maturing/ maturity stage	6-8 weeks after planting
5.	Sprayed all through	Once every week
6.	Control	No chemical pesticide application

Table 2.2 Aphids, white flies and red spider mite rating scale

Rating	Estimated population per plant
1	1-10
2	11-50
3	51-100
4	101-500
5	> 500

Table 2.3 Insect pests observed on okra during two crop seasons

Reference Name	Order	Family	Species
Aphids	Homoptera	Aphididae	*Aphis gossypii* Glover
White flies	Homoptera	Aleyrodidae	*Bemisia tabaci* Gennadius
Leafhoppers	Homoptera	Cicadellidae	*Empoasca* sp.
Cotton stainers	Heteroptera	Pyrocorrhidae	*Dysdercus* sp.
Leaf caterpillars	Lepidoptera	Pyralidae Noctuidae	1. *Ancylolomai* sp. 2. *Helicoverpa armigera* (Hubner) 3. *Plusia* sp.
Leaf miner	Diptera	Agromyzidae	*Liriomyza* sp.
Leaf beetles	Coleoptera	Chrysomelidae	*Leptaulaca fissiocollis* Blanchard
		Chrysomelidae	*Copa delata* Er
		Lagridae	*Lagria villosa*
		Curculionidae	*Lixus* sp.
		Apionidae	*Apion* sp.
Sucking bugs	Hemiptera	Lygaeidae	*Oxycarenus hyalipennis* Costa
		Pentatomidae	u✳
Flower beetles	Coleoptera	Meloidae	*Coryna apicicornis* (Guer)
Flower thrips	Thysanoptera	Thripidae	1. *Frankliniella occidentalis* (Pergande) 2. *Haplothrips gowdeyi* (Franklin)
Fruit borers	Lepidoptera	Noctuidae	*Helicoverpa armigera* (Hubner)
Red spider mite	Acarina	Tetranychidae	u✳

Bugs have been classified into three orders, Hemiptera, Homoptera and Heteroptera and the latter two orders have been considered as independent orders and not suborder of Hemiptera

u✳ - unidentified species

Table 2.4.a Pest scores/ counts on treatments of the first crop season of okra (counts/scores/ five plants). Kibwezi 1998

Pest group	Sampling factor (score/counts / 5 plant)	protection during Early veg. growth stage	protection during late veg. growth stage	protection during flowering stage	protection during Maturity stage	protection during all the growth stages	No protection
Aphids	scores	1.89± 0.33a	1.73± 0.29a	1.80± 0.27a	1.11± 0.15b	1.06± 0.15b	1.66±0.29a
Whiteflies	scores	1.55± 0.18 a	1.64± 0.17a	1.48± 0.18a	1.18± 0.16b	1.20± 0.15b	1.61±0.17a
Leaf hoppers	counts	0.96± 0.08ab	1.09± 0.11b	0.98± 0.10ab	0.97± 0.11ab	0.88± 0.08b	1.18±0.11a
Cotton stainers	counts	0.89± 0.10	0.94± 0.10	1.02± 0.14	0.75± 0.04	0.87± 0.09	0.82±0.08
Leaf caterpillar	counts	0.77± 0.04ab	0.79± 0.05ab	0.81± 0.05ab	0.71± 0b	0.71± 0b	0.86±0.05a
Leaf miner	counts	1.92± 0.21	1.99± 0.27	1.94± 0.27	1.77± 0.22	1.51± 0.21	1.77±0.24
Other unidentified sucking bugs	counts	0.85± 0.08	0.89± 0.09	0.73± 0.03	0.73± 0.03	0.71± 0	0.91±0.08
Fruit borers	counts	0.71± 0	0.84± 0.08	0.71± 0	0.71± 0	0.71± 0	0.71±0
Flower beetles	counts	0.77± 0.65	0.82± 0.113	0.84± 0.08	0.77± 0.06	0.71± 0	0.82±0.11
Flower thrips	counts	2.09± 0.61ab	2.01± 0.49ab	2.03± 0.61ab	1.34± 0.25b	1.18± 0.18b	2.33±0.60a

Means with the same letter within the same row are not significantly different (SNK) p<0.05. Absence of subscripts indicates indicate lack of significant differences.

Table 2.4.b Pest score/ counts on the treatments of second crop season of okra (counts/scores/ five plants). Kibwezi 1999

Pest group	Sampling factor (score/counts /5 plant)	protection during Early veg. growth stage	protection during late veg. growth stage	protection during flowering stage	protection during Maturity stage	protection during in all the growth stages	No protection
Aphids	scores	1.65± 0.20b	1.91± 0.27b	2.49± 0.26a	1.67± 0.24b	0.84± 0.08c	2.52± 0.26a
White flies	scores	1.71± 0.33ab	1.46± 0.38ab	1.86± 0.27ab	2.19± 0.33a	1.07± 0.19b	2.25± 0.29a
Cotton stainers	counts	0.90± 0.14	0.86± 0.08	0.91± 0.08	0.93± 0.13	0.76± 0.05	1.23± 0.23
Caterpillars	counts	0.77± 0.06	0.71± 0	0.82± 0.11	0.95± 0.12	0.71± 0	0.90± 0.09
Leaf miner	counts	6.61± 3.87a	6.77± 3.22a	7.06± 3.78a	5.26± 1.76ab	3.01± 1.15b	6.91± 3.23a
Other unidentified sucking bugs	counts	1.29± 0.81b	1.52± 0.82a	0.97± 0.26c	0.71± 0c	0.71± 0c	1.29± 0.58b
Fruit borers	counts	0.84± 0.12	0.84± 0.13	0.97± 0.15	0.71± 0	0.71± 0	0.84± 0.13
Flower beetles	counts	0.88± 0.10	0.71± 0	0.97± 0.12	0.79± 0.09	0.71± 0	0.79± 0.09
Flower thrips	counts	4.38± 0.45a	4.53± 0.51a	4.51± 0.45a	1.67± 0.56b	1.62± 0.64b	4.68± 0.56a
Red spider mites	scores	1.38± 0.67	1.13± 0.27	1.17± 0.46	1.06± 0.35	0.97± 0.26	1.41± 0.45

Means with the same letter within the same row are not significantly different (SNK) $p<0.05$. Absence of subscripts indicates indicate lack of significant differences.

Plate 2.1 Aphids under the leaf surface of okra. Some of the aphids are mummified by the parasitic wasps/parasitoids

Plate 2.2 Two species of leaf eating beetles feeding on okra leaves.

Plate 2.3 A heavily defoliated okra leaf by leaf eating caterpillar and beetles.

Plate 2.4 A fruit borer (*Helicoverpa armigera*) feeding on an already deformed okra fruit.

CHAPTER THREE

3.0 INSECT PEST INFESTATION AT DIFFERENT PHENOLOGICAL STAGES OF CHILIES

3.1 Introduction

Critchley (1997) reported that, in Ghana insect pests of pepper are not as important as diseases or weeds. A similar observation has been reported by the National Horticultural Research Center (NHRC) (1994) in Kenya where leaf spots, potato virus Y and powdery mildew diseases are a constraint to capsicum production.

Some of the major pests found on chilies include, aphids, mainly *Aphis gossypii* and *Myzus persicae* (Aphididae), thrips (Thripidae) mainly *Thrips tabaci* and *Scirtothrips dorsalis* which, are the probable vectors of mosaic and leaf-curl virus (Hill and Waller, 1994). Two common lepidopteran pests, *Helicoverpa amigera* and *Spodoptera litura* (Noctuidae) bore into the fruits. The leaf beetles especially striped blister beetle, *Epicauta albovittata* (Meloidae) and *Lema* sp. (Chrysomelidae) are heavy defoliators (Hill, 1983). Whiteflies, especially *Bemisia tabaci* (Aleyrodidae) have been found to infest the foliage of chilies, and they damage the plant by sucking sap and transmitting viral diseases (Vacante, 1989). Other pests of little importance include the leafhoppers (Cicadellidae: Miridae) and the capsicum gall midge, *Asphondylia capsici* (Cecidomyridae) (Hill and Waller, 1994). The yellow tea mite, *Polyphagotarsonemus latus* (Tarsonemidae) (Hill, 1983), the coreid and leaf-footed bugs (Coreidae), termites (Termitidae), grasshoppers and locusts (Acrididae) (Critchley, 1997) are of limited economic importance.

Therefore, a wide range of insect pests infests capsicum in other parts of the world and reduces their potential production. The aim of this study was to establish the pest spectra of chilies at different plant growth stages in a semi arid region of Kenya and also established the critical growth stage for pest attack that would require intervention.

3.2 MATERIALS AND METHODS

3.2.1 Experimental design and plot lay out

The experiment consisted of six treatments (table 3.1) replicated four times in a completely randomized block design (CRBD).

One-month old seedlings of chilies (long pepper, orrhy (anaheim) variety) were transplanted on September 1998 and January 1999 in 4 x 3 sq. m. plots with a spacing of 60 cm between rows and 30 cm within rows with an average plant population of 54 plants/plot. A 1m-wide buffer strip of bare ground separated the plots. Treatments were applied as described in section 2.2.2.

3.2.2 Abundance of insect pests

Sampling of insect pests during the short and long rains cropping seasons of September to December 1998 and January to May 1999 was carried out using the methodology described in section 2.2.3.

3.2.3 Data analysis

Data was analyzed using the methodology described in section 2.2.4.

3.3 RESULTS

3.3.1 Abundance of insect pests

A total of eighteen species of pests were observed on chilies (table 3.2) during the two cropping seasons. However, aphids appeared only during the second crop season presumably because of the overhead irrigation system used in the first season crop while crickets and grasshoppers were observed only in the first crop season.

The two cropping seasons had different sampling periods because the second season crop's growth was reduced by leaf curl disease. Significant differences ($p<0.05$) occurred between pests in the treatments for both seasons. Most of the pests observed on chilies had low infestations (tables 3.3.a and b.) and in most cases few or no pests were observed.

Whitefly and aphid infestations (fig. 3.1.a) were low and they were the probable vectors of the leaf curl disease. Infestation of whiteflies occurred in the maturity stage of the first crop where the initial population was high but drastically dropped as the crop season came to a halt. Infestation in the second season was noted in the early and late vegetative stages of the crop and the whitefly population was relatively low throughout the plant growth. Aphids were observed during the second cropping season and their population remained mostly low in all the plant growth stages.

Abundance of leafhoppers (fig 3.1.b) was noted when the plant attained a 'bush-like' appearance during the late vegetative growth stage in both cropping seasons. However, the first season recorded high populations of leafhoppers that fluctuated at different plant growth stages. Sucking bugs had low populations in both cropping seasons. An unidentified species of cricket was observed in some occasions and laid eggs between leaf epidermis although its population was very low. Grasshoppers were occasionally found on chilies but in very low populations.

The common leaf damaging pests were the leaf caterpillars, leaf beetles (fig 3.1.c) and leaf miners that were noted on few occasions in low numbers. Leaf caterpillars were common during the early vegetative plant growth stage to maturity stage. Leaf beetles had high population during the first crop season where they infested all plant growth stages. The fruit borers were not common during sampling though their damage (plate 3.1 and 3.3) was evident during grading of the fruits. Three species of flower thrips, *Haplothrips gowdeji*, *Megalurothrips sjostedti* and *Frankliniella occidentalis* were serious pests on flowers during the two crop seasons. Both larvae and adult stages of thrips fed on the flowers causing scarifications and deformity of the fruits (plate 3.2).

3.3.2 **Effects of treatments on insect pests**

The numbers of most insect pests did not show significant differences ($p>0.05$) between the various treatments. However, some of the insect pests showed varying differences in number (tables 3.4 a. and b). Aphid showed no significant difference ($p>0.05$) between all treatments (1.03- 1.96) although the fully protected treatment with synthetic insecticides had the least numbers of aphids while the highest was recorded in treatment protected in the late vegetative growth stage. Whitefly population was significantly greater ($p<0.05$) in the unprotected treatment (1.94) while other treatments did not differ significantly during the first season crop. During the second crop season, there was significant differences ($p>0.05$) between treatments on whitefly populations. The unprotected treatment (six), treatments protected in the reproductive stage (three) and maturity stage (four) had higher (2.08, 2.50 and a 2.23 respectively) whitefly numbers than the fully protected treatment (five) which, recorded the least (1.16) population.

The number of leafhoppers during the first crop season were significantly different ($p<0.05$) between treatments. The highest population (1.59) was recorded in the unprotected treatment and the least (1.00) in the fully protected treatment. Treatments protected in the early vegetative growth, reproductive and maturity stages did not show significant difference ($p>0.05$) in leafhopper population. Population of leafhoppers in all treatments during the second crop season were however, at par with the unprotected treatment. Number of leaf caterpillars were only statistically different ($p<0.05$) and higher (0.94) from other treatments in the unprotected treatment (six) during the first crop season. Other treatments did not differ significantly ($p>0.05$) from the control during the second crop season.

Leaf miner population in the first crop season was at par in all treatments, while in the second crop season, treatments protected in the early vegetative growth, reproductive and unprotected treatment had significantly greater ($p<0.05$) populations (2.51, 1.99 and 1.79) than fully protected treatment (1.14). Treatments protected in the late vegetative growth and maturity stages had lower (0.71 and 0.97) leaf miner population. The population of leaf beetles was comparable in all treatments of both crop seasons. However, during the first crop season, all treatments had lower numbers of leaf beetles than the control (0.85). A similar observation was made on the sucking bugs in both seasons, where all treatments were at par with the control. Crickets and grasshoppers were only observed on few occasions in treatments protected in the late vegetative growth and maturity stages.

The numbers of flower thrips were significantly different ($p<0.05$) between the treatments. The lowest numbers of flower thrips were recorded in treatments protected in the maturity stage and the fully protected treatment in both the crop seasons. Treatment protected in the early vegetative growth of the first crop season had slightly higher (3.56) number of thrips than the unprotected (control) treatment (3.35). During the second crop season, populations of thrips were not significantly different ($p>0.05$) between treatments protected in the early vegetative, late and reproductive growth stages with the control.

3.4 Discussion

Majority of pests on chilies were apparently low in numbers and so had probably limited impact on the crop while a few were probably important as vectors of diseases. Critchley (1997) reported in Ghana that insect pests of peppers are not as important as diseases. This may be probably true in other West African countries and especially when the pest population in chilies is low. Insects act as vectors of most viral diseases, for instance aphids are known to be vectors of the mosaic and leaf- curl diseases (Hill and Waller, 1994). Thrips have been known to transmit the leaf- curl disease on chilies in India as reported by Venkatesh *et al*., (1998), and whiteflies especially *Bemisia* (Aleyrodidae) transmit viral diseases (Vacante, 1989) including most vegetable crops in Kenya (Bob, 1998, personal communication). Other insects either defoliate the leaves thus inhibiting the process of photosynthesis, cause leaf scarification, damage the fruits by boring as with the caterpillars.

Different insect pests infested the crop at different growth stages except for the aphids, which infested the crop in all plant growth stages. Insects populations are known to be regulated mostly by the climatic factors (ILACO, 1981). The rapid increase in insect population at Kibwezi have been attributed to the prevailing climatic conditions that favour their rapid reproduction rate (Anonymous, 1996). This on one hand explains the presence or absence of certain pests during the two cropping seasons. The regular spraying of insecticides on the adjacent commercial plots could have caused the disappearance or resurgence of insect pests on the other hand.

Whitefly, *B. tabaci* infestation on chilies started shortly after the onset of the short rains and stopped when the weather turned hot and unfavourable to the whitefly population. Whitefly may have transmitted leaf-curl disease during the second season crop because they are known to transmit chili leaf complex in India (Johnpulle, 1939). The critical stage for chili infestation by whitefly is when one adult is observed in one leaf (Guharay and Monterrey, 1993 unpublished). Aphid infestation on chilies occurred during the second season crop, which received water through furrow system. Their populations were however, relatively low and so may not have caused any economic damage although they are potential vectors of diseases. Overhead irrigation system during the first season crop may have prevented aphid infestation and thus their absence.

Leafhopper (*Empoasca*) infestation started when the crop attained a bush appearance. Despite the toxic saliva they inject into the plant when feeding, there were no indications of damage to the plants. Leaf beetles are known to be minor pest of localized importance on pepper in Ghana (Critchley, 1997) and they were observed defoliating the leaves in few instances. The leaf-eating caterpillars (*Plusia* sp and *H. armigera*) were minor pests before fruiting due to availability of alternative feeding plant parts, the dense foliage. However, they turned out to be a major pest during fruiting when they bored into the developing fruits which, eventually fell off the plant. It was observed that the damaged fruits provided entry points for an unidentified species of dipteran (Phoridae) that facilitated fruit rot. The most appropriate time to protect the crop against caterpillars is from flowering period throughout the fruiting period. Leaf beetles (*L. fissiocollis* and *E. albovittata*) were also of less importance to the crop as they appeared to inflict little damage due to their low numbers.

The leaf miners (*Liriomyza* sp.) were of less importance to the crop due to their low population, which inflicted limited damage to the leaves. The sucking bugs (*N. viridula* and *Tongrina* sp.) occurred in very low counts during the two seasons and no similar damage could have possibly been associated with them. However, their feeding behaviour on developing shoots and fruits led to distortion, poor growth and shoot die-back (Critchley, 1997). The crickets (Orthoptera) and grasshoppers were pests of little importance on chilies. The unidentified species of cricket were however, observed in two separate incidences and laid a mass of eggs between leaf epidermis which, eventually dried up and this made them a potential pest.

Flower thrips (*Haplothrips gowdeji*, *Megalurothrips sjostedti* and *Frankliniella occidentalis*) were common pests of importance to chilies in both seasons. Two species of thrips *Haplothrips gowdeji* and *Megalurothrips sjostedti* have not been associated with flowers anywhere else (Taleka, personal communication). They caused deformation and scarification of fruits lowering their quality. The appropriate time for their intervention with chemical insecticides is during the flowering period.

The treatment that received insecticide application throughout the entire growth period (treatment five) had low pest incidences but not a total absence of pest. Conversely, the treatment that received no insecticides during the entire growth period recorded the highest population of most pests. On the other hand treatments, which received insecticide application at specific growth stages, had pests' population reduced only at that particular period while the rest of the unprotected stages received high pest infestation. This explains the comparisons of pest populations between treatments 1-4. However, treatment one, which, received chemical protection at the very early stage of growth, had comparable pests infestations with treatment six (control). This perhaps resulted from the absence of pest in the early vegetative stage and hence chemical insecticides applied at this time may have been of no use to subsequent infesting pests.

The FAO yearbook (1981) indicates that experiments comparing sprays applied at different times may be affected by interplot interference (Brainbridge and Jenkyn, 1976). Insect pests develop resistance to pesticides after a continuous use of pesticides (Yu, 1993). Plants may have escaped pest attack or tolerated the injury by vigour growth. This explains the indiscriminate presence or absence of pests in the treatments where they are least expected.

Controlling insect pests of chilies at certain intervals of the crop growth may have little impact on pests populations build up. The observations of pests obtained from treatments protected from the early, late vegetative growth stage, reproductive and maturity stages did not differ significantly ($p>0.05$) with those obtained from the unprotected treatment. Protection of the crop against pests from the reproductive period and during the entire growth period significantly reduced the pest's population and more importantly reduced the damage inflicted on the yields.

3.5 Reference

Anonymous, (1996). Kibwezi Irrigation Project farm Report, pp 1-10 Kibwezi, Kenya.

Brainbridge, A. and Jenkyn, J. F (1976). Mildew re-infection in adjacent and separated plots of sprayed barley. *Annals of Applied Biology* **82**: 477-486.

Critchley, B. R (1997). Pests of vegetables: Their identification and control in Ghana, pp 49-112. Natural Resource Institute. U.K

FAO (1981). Crop Loss Assessment Methods-supplement 3, pp 35-97 Commonwealth Agricultural Bureaux, UK.

Guharay and Monterrey, (1993) unpublished data.

Hill, D. S and Waller, J. M. (1994). Pests and diseases of tropical crops, pp 69-78. Cambridge University Press, London.

Hill, D. S. (1983). Agricultural insect pests of the tropics and their control, pp 69-89. Cambridge University Press, London.

ILACO (1981). Agricultural Compendium for Rural Development in the Tropics and subtropics. Elsevier Scientific Publishing Company, Amsterdam.

Johnpulle, A. L. (1939). Chili leaf curl experiment-1-preliminary infection tests. *Tropical Agriculturist* **92**: 28-30.

National Horticultural Research Center, Thika (1994) Horticultural crops protection Handbook, pp 69-80. Ministry of Agricultural and Livestock development, Nairobi, Kenya

Vacante, V. (1989). *Bemisia tabaci* on capsicum. *Applied Entomology and Zoology* **4**: 7.

Venkatesh, H. M., Muyanippa V., Ravi K. S and Krishnaprasad, P.R (1998) Management of chili leaf curls complex. *Proceedings of National Symposium. Pest Management Horticultural Crops, Bangalore.* India

Yu, S.J (1993) Inheritance of insecticide resistance and microsomal oxidase in the diamondback moth (lepidoptera: Yponomeutidae). *Journal of Economic Entomology* **86**: 680-683.

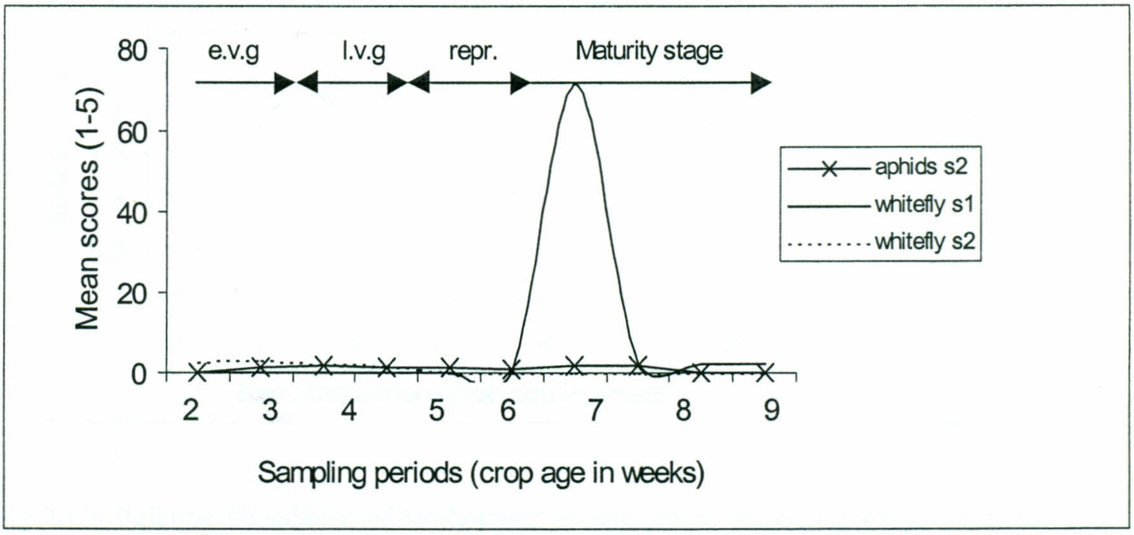

Fig. 3.1.a Relative abundance of white flies and aphids in relation to plant phenology of chilies (early vegetative growth stage (e.v.g), late vegetative growth stage (l.v.g), reproductive stage (repr) and maturity stage) at Kibwezi, September 1998 to May 1999.

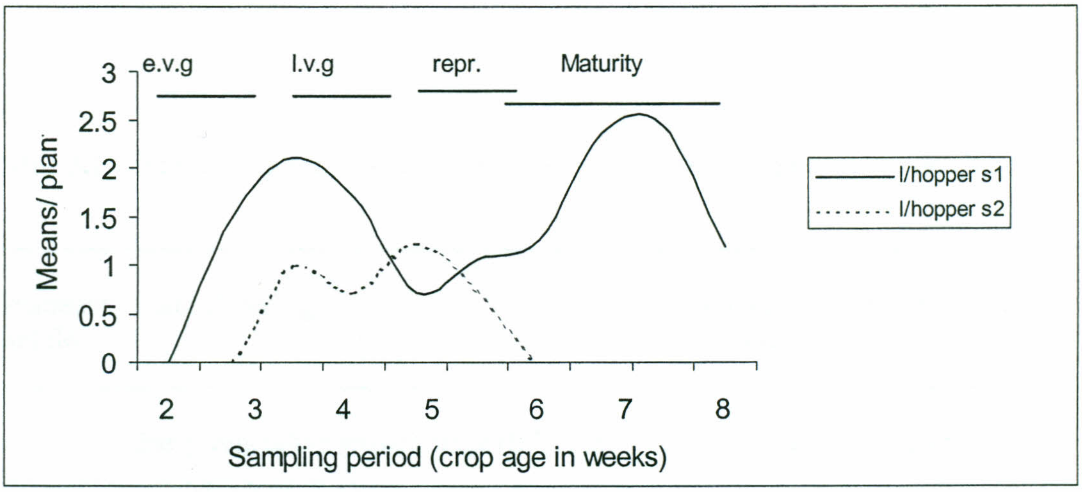

Fig 3.1.b Relative abundance of leafhoppers in relation to plant phenology of chilies (early vegetative growth stage (e.v.g), late vegetative growth stage (l.v.g), reproductive stage (repr) and maturity stage) at Kibwezi, September 1998 to May 1999.

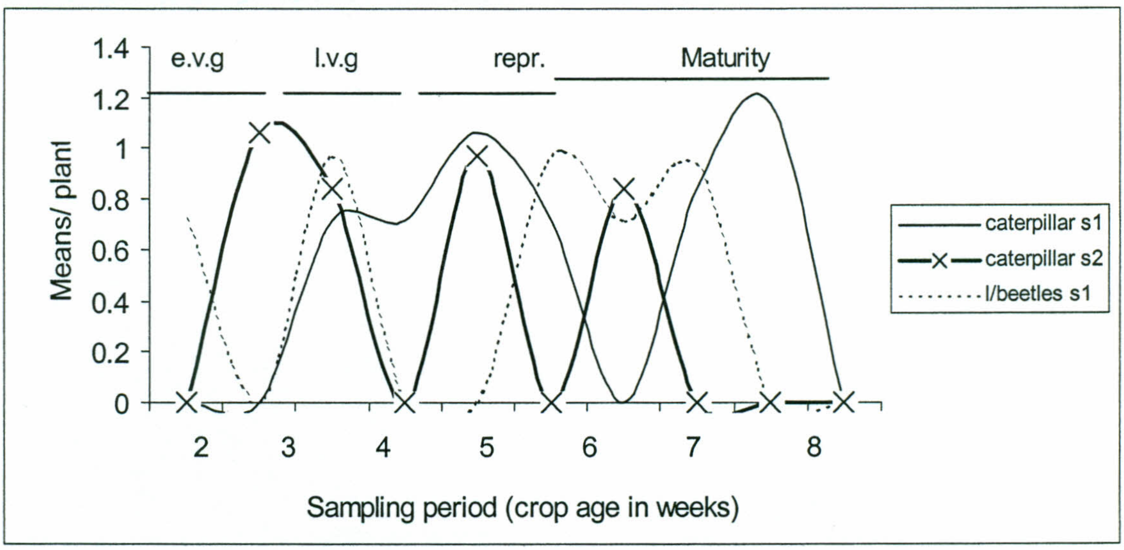

Fig 3.1.c Relative abundance of caterpillars and leaf beetles in relation to plant phenology of chilies (early vegetative growth stage (e.v.g), late vegetative growth stage (l.v.g), eproductive stage (repr) and maturity stage) at Kibwezi, September 1998 to May 1999.

Table 3.1 Treatment regimes and period of chemical insecticide applications on chilies.

Treatment module	Plant phenology	Period of chemical pesticide Application.
1.	Early vegetative growth stage (E.V.G.S)	1-2 weeks after transplanting
2.	Late vegetative growth stage (L.V.G.S)	3-5 weeks after transplanting
3.	Reproductive/flowering stage	5-7 weeks after crop emergence
4.	Maturing/ maturity stage	7-9/ 10 weeks after transplanting
5.	Sprayed al l through	Starting one week after transplanting
6.	Control	No chemical pesticide application

Table. 3.2 Pests collected from chilies over the two season trials and identified by the biosystematic unit at I.C.I.P.E and KEPHIS

Common name	Order	Family	Species
Aphids	Homoptera	Aphididae	u
Whiteflies	Homoptera	Aleyrodideae	*Bemisia tabaci* Gennadius
Leafhoppers	Homoptera	Cicadellidae	*Empoasca* sp.
Caterpillars	Lepidoptera	Noctuidae	*Plusia* sp.
Leaf miner	Diptera	Agromyzidae	*Liriomyza* sp.
Leaf beetles	Coleoptera	Chrysomelidae Meloidae	*Leptaulaca fissiocollis* *Epicauta albovittata* Gerst.
Sucking bugs	Hemiptera	Pentatomidae Pyrrocoridae	*Nezara viridula* (Linnaeus) *Tongrina* sp.
Fruit borers	Lepidoptera	Noctuidae	*Plusia* sp. *Helicoverpa armigera* Hubner
Flower beetles	Coleoptera	Meloidae Curculionidae	*Coryna apicicornis* (Guer) *Lixus* sp.
Flower thrips	Thysanoptera	Thripidae	1. *Haplothrips gowdeyi* (Franklin) 2. *Megalurothrips sjostedti* 3.*Frankliniella occidentalis* (Pergande)
Crickets	Orthoptera	u★	u
Grass hoppers	Orthoptera	u★	u

u★ – unidentified family, u- unidentified species

Table 3.3 .a Mean counts or scores/ five plants of pests occurring on the control plots of chilies during the different sampling periods of the first season crop (Kibwezi, September 1998 to January 1999)

Pest group	Samplings factor /five	Sampling period (weeks)									
		1	2	3	4	5	6	7	8	9	10
White flies	scores	-	-	-	-	-	-	0.71c	2.67a	2.39ab	198b
Leaf hoppers	counts	-	1.48cd	2.20ab	1.7abc	0.71d	1.05cd	1.26cd	2.35a	2.44a	1.19cd
Caterpillars	counts	-	-	0.71	0.71	1.06	0.71	-	0.84	1.18	-
Leaf miner	counts	-	1.18a	0.71b	-	-	-	-	-	-	-
Leaf beetles	counts	0.71	-	0.97	-	-	0.97	0.71	0.93	-	-
Sucking bugs	counts	-	0.71	-	0.71	-	-	-	-	-	0.71
Crickets	counts	0.71	-	-	-	-	-	-	-	-	-
Grass hoppers	counts	0.71	-	-	-	-	-	-	-	-	-

Means with same letter within a row are not significantly different (SNK) p< 0.005, - indicate absence of pest during sampling.

Table 3.3. b Mean counts or scores/ five plants of pests occurring on the control plots of chilies during different sampling periods of the second season crop (Kibwezi, January to May 1999).

pest group	Sampling factor /five plants	Sampling period (weeks)							
		1	2	3	4	5	6	7	8
Aphids	scores	-	1.43	1.63	1.27	1.18	1.06	1.73	1.58
White flies	scores	2.6b	3.15a	2.1c	1.7c	-	-	-	-
Leaf hoppers	counts	-	-	0.99	0.71	1.22	0.71	-	-
Caterpillars	counts	-	1.06	0.84	-	0.97	-	0.84	-
Leaf miner	counts	-	-	-	1.83	-	-	-	-
Leaf beetles	counts	-	-	0.71	-	-	-	-	-
Sucking bugs	counts	-	-	-	0.71	0.71	-	-	-

Means with same letter within a row are not significantly different (SNK) $p < 0.005$,
-indicates absence of pest during sampling

Table 3.4.a Pest scores and counts/ five plants under different treatments, first crop season of chilies (Kibwezi, September 1998 to January 1999).

Treatment Means ±SE	Protection during E.V.G	Protection during L.V.G	Protection during Reproductive stage	Protection during Maturity stage	Protection during all growth stages	No protection
Whiteflies	1.59± 0.18b	1.68± 0.19b	1.64± 0.15b	1.10± 0.11c	1.12± 0.11c	1.94± 0.20d
Leaf hoppers	1.21± 0.10bc	1.28± 0.10b	1.17± 0.10bc	1.13± 0.08bc	1.00± 0.08b	1.59± 0.11a
Caterpillars	0.79± 0.06b	0.73± 0.02b	0.75± 0.03b	0.73± 0.02b	0.71± 0b	0.94± 0.11a
Leaf miner	1.12± 0.13	1.08± 0.12	1.09± 0.21	0.97± 0.10	0.95± 0.09	0.90± 0.12
Leaf beetles	0.85± 0.10	0.80± 0.05	0.78± 0.05	0.76± 0.04	0.71± 0	0.85± 0.06
Sucking bugs	0.75± 0.04	0.71± 0	0.75± 0.04	0.71± 0	0.75± 0.04	0.71± 0
Crickets	0.71± 0b	1.06± 0.35a	0.71± 0b	0.71± 0b	0.71± 0b	0.71± 0b
Grass hoppers	0.71± 0b	0.71± 0b	0.71± 0b	0.84± 0.13a	0.71± 0b	0.71± 0b
Flower thrips	3.56± 0.56a	3.28± 0.23ab	2.49± 0.43bc	1.91± 0.37cd	1.37± 0.19d	3.35± 0.33a

Means with same letter within a row are not significantly different (SNK), $p<0.05$, absence of subscripts indicate lack of significance differences, E.V.G – early vegetative growth stage, L.V.G – late vegetative growth stage

Table 3.4.b Pest scores and counts/ five plants under different treatments, second season crop, chilies (Kibwezi, January to May 1999)

Treatment Means±SE	Protection during E.V.G	Protection during L.V.G	Protection during Repro-ductive stage	Protection during Maturity stage	Protection during all growth stages	No protection
Aphids	1.36± 0.18	1.96± 0.21	1.18± 0.12	1.10± 0.13	1.03± 0.11	1.41± 0.15
Whiteflies	1.69± 0.14b	1.55± 0.39b	2.08± 0.37a	2.23± 0.27a	1.16± 0.14c	2.50± 0.19a
Leaf hoppers	1.26± 0.20	0.92± 0.15	1.16± 0.15	1.13± 0.18	0.95± 0.12	1.00± 0.19
Caterpillars	0.71± 0	0.84± 0.08	0.71± 0	0.77± 0.06	0.71± 0	0.84± 0.08
Leaf miner	2.15± 0.93a	0.71± 0c	2.00± 0.13a	0.97± 0.26c	1.14± 0.44b	1.79± 0.56a
Leaf beetles	0.71± 0	0.71± 0	0.71± 0	0.71± 0	0.71± 0	0.71± 0
Sucking bugs	0.84± 0.13	1.13± 0.28	0.84± 0.13	0.84± 0.13	0.93± 0.22	0.71± 0
Flower thrips	5.38± 0.43a	5.43± 0.87a	5.86± 0.71a	2.70± 0.44b	1.80± 0.40b	5.77± 0.60a

Means with same letter within a row are not significantly different (SNK), $p<0.05$, absence of subscripts indicate lack of significant differences, E.V.G – early vegetative growth stage, L.V.G – late vegetative growth stage

Plate 3.1. A fruit borer (*Helicoverpa armigera*) feeding inside a chili fruit

Plate3.2. Effect of flower thrips on chili fruits (left) and Damage free fruits (right)

Plate 3.3. Insect-damaged chili fruits by fruit borers

CHAPTER FOUR

4.0 DIVERSITY AND IMPACT OF NATURAL ENEMIES ON INSECT PESTS OF OKRA AND CHILIES

4.1 Introduction

Natural enemies have been grouped as parasites, predators or pathogens (Debach and Rosen, 1991) and have the quality of being able to interact with the prey or host populations and maintain them at low levels than would occur. Some natural enemies are effective at extremely low levels while others at high levels (Debach and Rosen, 1991). There is no accurate estimate available of the total number of insect natural enemies to other insects, but they are probably as many as there are insect preys or hosts. However, Debach and Rosen (1991) estimates that only 15% of the insect natural enemies in existence have been discovered and named.

In insect pest population dynamics, natural enemies affect the average population density, induce fluctuations in counts and regulate population levels. Murdoch and Walde (1989) point out that the factors which regulate population levels can act either by; returning populations towards an equilibrium level after some perturbations i.e. stabilizing population counts, or restricting population counts within certain limits but allowing fluctuations in counts (e.g cycles) within those limits. The extent to which a pest population suffers predation or parasitism hinges both upon the number of predators or hosts present and on the ability to find and consume preys or lay eggs on the host. Solomon (1949) considered prey density to be the crucial factor determining the response of the predators.

When classical biological control is successfully utilized, it has several advantages over other control measures; it is inexpensive, non-hazardous and maintains pest populations at often permanently, well below the economic injury levels (Debach and Rosen, 1991). The main objective of this study was to observe and establish the abundance and impact of natural enemies on pest populations of okra and chilies.

4.2 MATERIALS AND METHODS

The study was conducted in the same site as the previous studies on insect pest infestations of okra and chilies described in section 2.2.1.

4.2.1 Experimental design and plot lay out

The same experimental plots used for studies on insect pest infestations of okra and chilies were used for these studies (section 2.2.2). The treatment regimes described in table 2.1 were also used.

4.2.2 Sampling for natural enemies on okra and chilies

During the short and long rain cropping seasons of October 1998 to January 1999 and January to May 1999, a week after crop emergence and three days after chemical insecticide application, sampling of natural enemies commenced. Within a row of each plot, a plant was randomly selected for sampling and the observations made in the field.

Numbers of coccinellid beetles (ladybirds) predating on aphids was obtained by actual counts. Visual observations of both coccinellid adults and nymphs from leaves of each of the randomly selected plant were made. The predatory larvae of syrphid flies on aphids were counted from the leaves on all randomly selected plants and some larvae collected in petri dishes and reared on aphids to recover their parasitoids. The parasitoids were preserved in 70% alcohol for identification. Parasitism on aphids was established by counting the aphid mummies on top and middle leaves of the randomly selected plants. Some of the mummified aphids were collected in glass vials and maintained in the laboratory to recover the parasitoid. Other rare insect predators on the five sampling plants were counted. Sample specimens of natural enemies were preserved in 70% alcohol and submitted to Biosystematics unit, I.C.I.P.E for identification.

4.2.3 **Data analysis**

Data collected during the two cropping seasons were summed for each individual treatment and subjected to Square root transformation for standardization. The data was analyzed using repeated-measures two way analysis of variance, ANOVA, (PROC GLM, SAS, 1995) was performed. The means were separated using the Student-Newman-Keuls (SNK) test. Population patterns of natural enemies and pests over time was illustrated by plotting the data collected against each plant growth stage using Microsoft Excel 97 software.

4.3 RESULTS

4.3.1 Natural enemies of insect pests of okra and chilies

Several species of predators and parasitoids (table 4.1a and b) were found associated with some of the insect pests in both crops.

Aphids were found to be predated by both adult and nymphal stages of five coccinellid beetle species (*Cheilomenes propinqua*, *C. lunata*, *C. sulpurea,* and two unidentified *Cheilomenes* sp.), larval stage (unidentified species) of syrphid fly and *Chrysoperla carnea* (Neuroptera). Aphids were also found to be parasitised by parasitic wasps (table 4.1.b) belonging to three different families (Encyrtidae, Aphidiidae and Scelionidae) and most of them could not be identified upto species level. Red spider mites were found to be predated upon by two species of predatory beetles, *Casnoidae* sp. (Carabidae) and *Scymnus lavaillanti* (Coccinelidae). Cricket eggs were parasitized by an unidentified hymenoptera parasitoid. Rove beetles (*Paedarus sabaeus*) and *Phonoctonus grandis*, knowns to be predacious were observed on chilies although not observed predating on any particular insect pest.

During the rearing of hover (syrphid) flies on aphids, it was established that the larval stages were parasitized by a hymenopteran (*Charops* sp; Icheneumonidae) that emerged from the pupal case. No parasitoids were obtained from the leaf feeding caterpillars that were reared.

A comparison of relative abundance of natural enemies in both seasons reveals that there were significant differences ($p<0.05$) between treatments in their numbers. Parasitoids and syrphid flies were abundant in the first crop season than the second season, while the coccinellids occurrence in both seasons was similar (table 4.2).

4.3.2 Dynamics of natural enemies in relation to aphids numbers on okra

The coccinellid beetles (*Cheilomenes propinqua*, *C. lunata*, *C. sulpurea* and *Cheilomenes* sp.), an unidentified species of syrphid fly and hymenopteran parasitoids in the families Encyrtidae and Aphidiidae were the predominant natural enemies of aphids on okra. However, on chilies the occurrence of coccinellids (*C. propinqua* and *Cheilomenes* sp.) and unidentified species of hymenoptera parasitoids in the families Encyrtidae and Scelionidae were very low for quantification.

The occurrence of parasitoids increased substantially in the maturity stage of the first crop season of okra (fig 4.1.a) relative to aphid numbers. The numbers of predatory insects observed on aphids, the coccinellids and syrphid flies were low in the early stage of plant growth but increased in the early maturity stage, while they decreased towards the end of the first crop season. However, during the second crop season, the number of the natural enemies followed a different trend (fig 4.1.b). Parasitoids occurred in low numbers in the early growth stage and reached higher levels during flowering stages but decreased gradually towards the end of the crop season. Coccinellids and syrphid flies apparently increased from low numbers in the early growth stage and stabilized through the rest of the plant growth. However, syrphid flies decreased to low levels in the maturity stage.

Aphid numbers appeared to relate to the occurrence of predators like the coccinelids and syrphid flies besides the parasitoids (fig.4.1.a and b.). Syrphid flies and coccinellids apparently fluctuated with the aphid numbers. The parasitoid numbers tended to increase with increase in aphid numbers but when the aphid population decreased they did not seem to decrease during the first crop season.

4.3.3 **Occurrence of natural enemy groups among different treatments on okra**

The use of synthetic insecticides at various crop growth stages affected the number of natural enemies differently (table 4.3.a). The number of coccinellids showed no significant difference between treatments of the first crop season. However, treatments differed significantly ($p< 0.05$) in the second crop season where protection during late vegetative stage and full protection recorded the least number of coccinelids. The number of parasitoids (parasitic wasps) did not differ significantly ($p>0.05$) in all the treatments during the first crop season (1.20-2.50) but differed significantly ($p<0.05$) between treatments in the second crop season. Parasitoids were

more (1.14) in treatment that received insecticide application in the late vegetative stage and least (0.71) in the unprotected treatment. The number of syrphid flies was significantly different ($p<0.05$) between treatments in both crop seasons. Their numbers were high (1.60 and 1.00) in the treatment protected during reproduction of both crop seasons. The lowest incidences of the predatory syrphid flies were noted in the fully protected treatment of both seasons.

4.3.4. **Dynamics of natural enemies in relation to aphid numbers of chilies**

Natural enemies of pests of chilies were not observed during the first season crop (Oct 1998 to Jan 1999). However, during the second season crop (Jan to May 1999), aphids were found to be predated upon by three species of coccinellids (*C.*

lunata, C. propinqua and *C. sulpurea*) mentioned in table 4.1a and parasitised by two species of unidentified hymenoptera parasitoids in the families Scelionidae and Encyrtidae also mentioned in table 4.1b. Coccinellids number was apparently low when the numbers of aphids were few and tended to increase or decrease relative to the aphid numbers (fig.4.2). The occurrence of parasitoids was low at first despite the increase in aphid numbers and only increased when the aphid numbers were low.

The number of parasitoids was significantly different between treatments (table 4.3.b). A higher (1.06) occurrence of parasitoids was recorded in treatment that received protection during late vegetative stage while the rest of the treatments had similar low incidences of parasitoids (0.71). Coccinellids were not significantly different ($p>0.05$) between treatments.

4.4 **Discussion**

Various natural enemies of aphids were found and included the coccinellids, hover flies, which have been reported by Jervis and Kidd (1997) and hymenopteran parasitoids. The natural enemies of aphids can occasionally reduce their rate of increase dramatically. The use of hymenopterous parasites and ladybird beetles in the biological control of aphids has been successful (Dixon, 1998). The relative abundance of the natural enemies (coccinellids, hover flies and hymenopterous parasitoids) was apparently linked to the population dynamics of aphids. Their numbers tended to increase when the aphid numbers were higher and reduced when the population of aphids decreased. This was however, more evident with the predators which are less specific in their choice of prey than parasitoids, although some predators show a preference for larger prey or certain instars (Griffiths, 1982; Thompson, 1978; Cock, 1978). However, it has also been reported that ladybirds may not be effective biological control agents of aphids (Hodek, 1973) due to dynamics of the aphid-lady bird interaction and it's consequences for ladybird fitness (Kindlmann and Dixon, 1993). Predators exploit aphid colonies, which are patchily distributed and in relation to the duration of their larval development and short lived. The larvae risk starvation if the abundance of the aphids in the patch they are exploiting declines to a low level before they can complete their larval development.

The predatory syrphid flies were effective in regulating the aphid numbers although they were parasitized by *Charops* sp. (Icheneumonidae; Campopleginae) which may have reduced their numbers. Hymenopterous parasitoids on the other hand increased with increasing aphid populations on okra but did not fluctuate with the aphid population patterns. Parasitoids can complete their larval development in one aphid and thus are more likely to regulate aphid populations. However, their effectiveness is reduced by their longer developmental period relative to their hosts and the risks of hyperparasitism (Holler *et al.*, 1993; Mackauer and Volkl, 1993). Jervis and Kidd (1997) have also reported that parasitoids spend significant proportion of their adult lives searching for places where hosts can potentially be found.

Elsewhere, aphids mainly *Myzus persicae* (Aphididae) has been successfully controlled by the parasitoid, *Aphidius matricariae* (Braconidae) in the USSR (Zabudskaya, 1989). Another chili aphid, *Aulacorthum solani* in the Tula region of Russia was found to be suppressed by parasitoid the *Lysiphlebus fabarum* (Braconidae) (Lyashova, 1992).

No predators or parasitoids were observed regulating flower thrip population. However, a predatory mite *Amblyseius cucumeris*, is known to effectively control the western flower thrips, *Frankliniella* sp. (Veire *et al.*, 1993). Similarly, natural enemies of whiteflies were not observed during the study period. However, the parasitoid *Encarsia* sp. and predator *Macrolophus caliginosus* has been encountered in Kibwezi during a field survey (Bob, personal communication). In Italy *Bemisia tabaci* was reported to be parasitized by *Evertmocerus mundus* (Hymenopteran; Aphilinidae) (Vacante *et al.*, 1989).

A hymenopteran parasitoid *Eulophus pennicornis* (Eulophidae) has been known to successfully control the lepidopteran population on chilies in Belgium (Veire *et al.,* 1993). *Campoletis chlorideae* (Hymenoptera; Ichneumonidae) can effectively reduce the population of *Heliothis armigera* by parasitising the larvae (Sathe and Santhakumar, 1992). The greasy cutworm, *Agrotis ipsilon*, a common pest of okra in Egypt was found to be effectively reduced by entomogenous nematode, *Steinernema feltiae* (Zaki, 1996). In India, *Empoasca* sp. eggs were found to be parasitized by *Anagarus* sp (Hymenoptera) (Sighn *et al.*, 1993). Several species of insect are known to prey upon mites and they belong to Coleoptera (Coccinellidea, Staphylinidae), Thysanoptera, Hemiptera, Diptera, Neuroptera and Dermaptera. Phytoseiid mites are natural enemies of spider mites, although only a limited number of phytoseiid species are of value for spider mites control (Mcmurtry *et al.*, 1970).

The phenomenon of pest resurgence brought about by the application of insecticides and inadvertent elimination of pest's natural enemies reveals dramatically the significant impact the latter normally have (Debach and Rosen, 1991; Shepard and Ooi, 1991). Insecticides have been noted to have an impact on parasitoids and predators as well as upon populations of aphids (Bartlett, 1968), spider mites and also to other natural enemies of other pests (Kenmore *et al.*, 1985; Ooi, 1986; Plaut, 1965; Readshaw, 1973).

Aphids were apparently the major host or prey to many of the natural enemies observed on okra and chilies. The changes in numbers of prey/ host with numbers of natural enemies are perhaps or apparently related or linked to one another.

4.5 Reference

Bartlett, B.R (1968). Outbreaks of two-spotted spider mites and cotton aphids following pesticide treatment. 1. Pest stimulation vs. natural enemy destruction as the cause of outbreaks, *Journal of Economic Entomology* **61**: 279-303.

Cock, M.J.W. (1978). The assessment of preference. *Journal of Animal Ecology* **47**: 805-16.

Debach, P. and Rosen, D. (1991). Biological control by natural enemies, 2nd edn, pp 5-113. Cambridge University press, Cambridge

Dixon, A. F.G (1998). Aphid ecology (2nd edn.), pp 200-203.Chapman and Hall, London, UK

Griffiths, D. (1982). Tests of alternative models of prey consumption by predators using anti-lion larvae. *Journal of Animal Ecology* **52**: 363-73.

Hodek, I (1973). Biology of coccinellidae. *Prague: Academia*. In Debach, P. and Rosen, D. (1991). Biological control by natural enemies, 2nd edn, pp 5-113. Cambridge University press, Cambridge

Holler, C., Borgemeister C., Haardt, H and Powell, W. (1993). The relationship between primary parasitoids and hyperparasitoids of cereal aphids: an analysis of field data. *Journal of Animal Ecology* **62**: 12-21.

Jervis, M. and Kidd, N. (1997). Insect natural enemies: practical approaches to their study and evaluation, pp 293-360. Chapman and Hall, London, UK

Kenmore, P.E., Carino F.O., Perez, C.A., Dyck, V.A and Gutierrez, A.P (1985). Population regulation of the rice brown plant hopper (*Nilaparvata lugens* Stal) within rice fields in the Philippines. *Journal of Plant Protection in the Tropics* **1**: 19-37.

Kindlmann, P. and Dixon, A.F.G (1993). Optimum foraging in lady bird beetles (Coleoptera: Coccinellidae) and it's consequences for their use in biological control. *European Journal of Entomology* **90**: 443-450.

Lyashova, L. V (1992. Lysiphlebus against aphid on vegetable crops. *Zashhchtika Rastenii Moskava* **7**: 27.

Mackauer, M and Volkl, W (1993). Regulation of aphid population by aphidiid wasps: does parasitoid foraging behaviour or hyperparasitism limit impactu *Oecologia* (Berlin) **94**: 339-350.

Mcmurtry, J. A., Huffaker C. B and Van de Vrie M. (1970). Ecology of tetranychid mites and their natural enemies: A review. 1. Tetranychid enemies: their biological characters and the impact of spray practices. *Hilgardia* **40**: 331-390.

Murdoch, W.W and Walde, S.J (1989). Analysis of insect population dynamics, pp 113-40, in *Towards a more Exact Ecology* (eds P.J Grubb and J.P Whittaker) Backwell, Oxford

Ooi, P.A.C (1986). Insecticides disrupt natural biological control of *Nilaparvata lugens* in Sekinchan, Malaysia, pp 109-20 .In. *Biological control in the Tropics* (eds. M.Y Hussein and A.G Ibrahim). Universiti Pertanian Malaysia, Serdang

Plaut, H.N (1965). On the phenology and control value of *Stethorus punctillum* Weise as a predator of *Tetranychus cinnabarinus* Boid. in Israel. *Entomophaga* **97**: 141-66.

Readshaw, J. L (973). The numerical response of predators to prey density. *Journal of Applied Ecology* **10**: 342-51.

Sathe, T.V and Santhakumar, M.V. (1992). Factors responsible for host finding behaviour by *Campoletis chlorideae* Uchida (Hymenoptera; Ichneumonidae), a parasitoid of *Heliothis* amigera (Hubn) (Lepidoptera; Noctuidae). *Rivista di parassitologia* **5**: 2233- 40.

Shepard, B.M and Ooi, P.A.C (1991). Techniques for evaluating predators and parasitoids in rice, pp 197-214. In *Rice Insects: Management Strategies* (eds E.A, Heinrichs and T.A Miller). Springer- Verlag. NewYork

Sighn, S.P., Rao, N.S and Hennberry, T.J (1993). Leafhoppers and their natural enemies. *Technical Bulletin Project Directorate of Biological Control ICAR* **6**: 65; 24.

Solomon, M. E (1949). The natural control of animal populations. *Journal of Animal Ecology* **18**: 1-35.

Statistical Analysis Systems (1995). *SAS Users Guide. Statistics, Version* 8 edn. SAS Institute Inc., Cary, NC

Thompson, D.J (1978). Prey size selection by larvae of the damselfly *Ishnura elegans* (Odonata). *Journal of Animal Ecology* **47**: 786-96.

Vacante, V. (1989). *Bemisia tabaci* on capsicum. *Applied Entomology and Zoology* **4**: 7.

Veire M. van de., van de Veire M. and De Veire M. van (1993). Observation in glasshouse sweet peppers in Belgium and laboratory rearing of the parasitic wasp *Eulophus pennicornis* (Hym. Eulophidae). *Entomophaga* **38**: 1,61-62.

Zabudskaya, I.A .(1989). Biological control of the green house white fly, *Trialeurodes vaporariorum* (Homoptera; Aleyrodidae). *Acta Entomologica Fennica* **53**: 73-76.

Zaki, F.N. (1996). Field application of Steinernema feltiae in the form of baits against the greasy cutworm, *Agrotis ipsilon* in Okra field in Egypt. *Anzeiger Fur Schadhngskude, Pfanzenschutz Umweltschutz* **69**: 4,79-80.

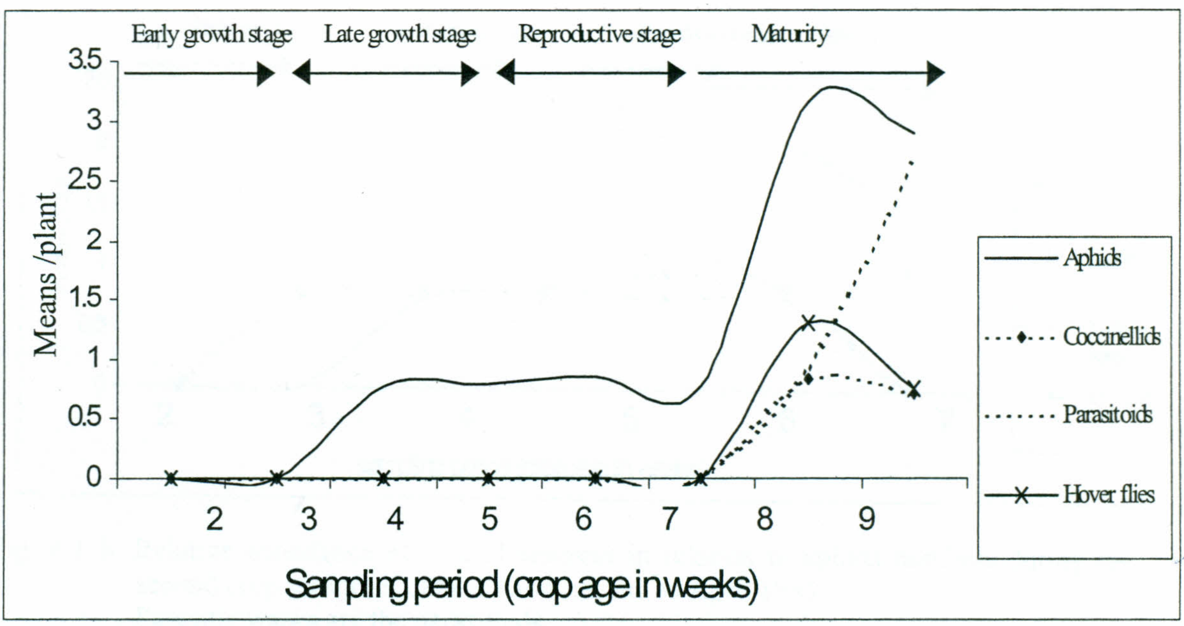

Fig. 4.1 a. Relative abundance of natural enemies in relation to aphids numbers during the first crop season of okra at Kibwezi, Oct 1998 to Dec 1998. Parasitoids are the parasitic wasps.

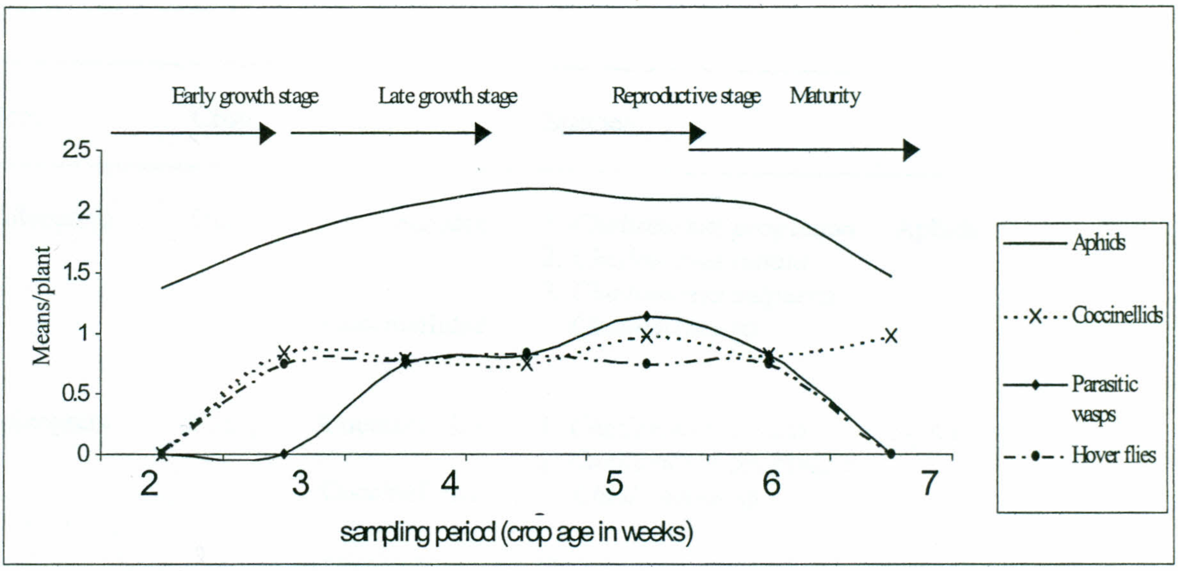

Fig. 4.1 b. Relative abundance of natural enemies in relation to aphids numbers during the second crop season of okra at Kibwezi, Jan to April 1999. Parasitic wasps are the parasitoids

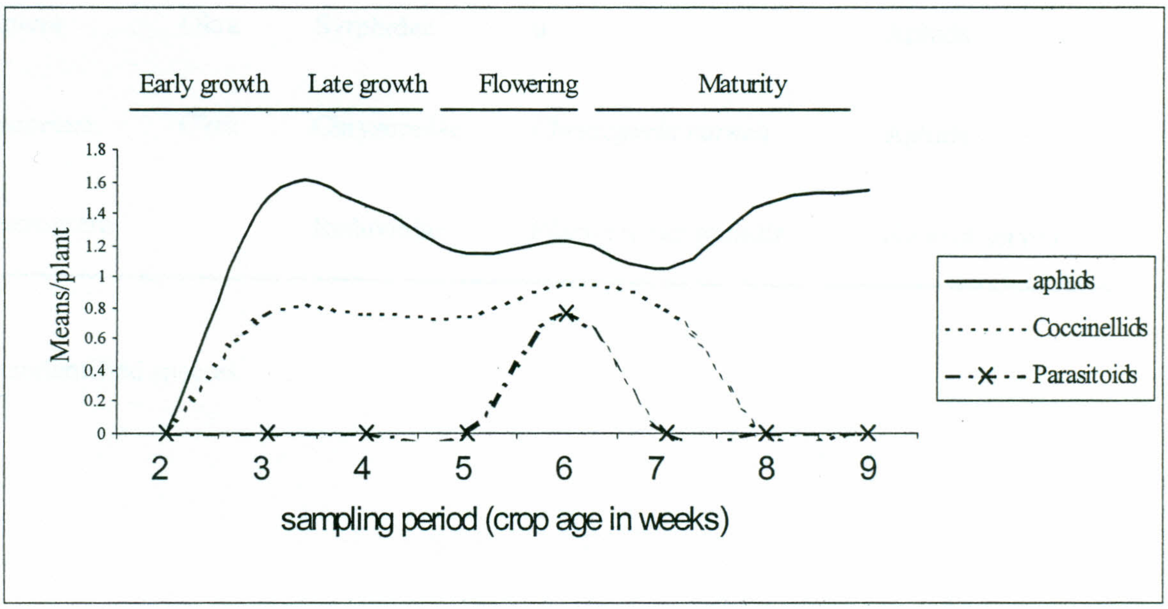

Fig 4.2 Relative abundance of natural enemies in relation to aphid numbers during the second crop on chili crop at Kibwezi, Jan to may 1999.

Table 4.1a Natural predators observed on pests of okra and chilies

Order	Crop	Family	Species	Prey
Coleoptera	Okra	Coccinellidae	1. *Cheilomenes propinqua* 2. *Cheilomenes lunata* 3. *Cheilomenes sulpurea*	Aphids
		Coccinellidae	*Cheilomenes* sp.	
Coleoptera	Chilies	Coccinellidae	1. *Cheilomenes lunata* 2. *Cheilomenes propinqua*	Aphids
		Coccinellidae	*Cheilomenes* sp.	
Coleoptera	Okra	Carabidae	*Casnoidae* sp.	Red spider mites
		Coccinellidae	*Scymnus lavaillanti*	
Coleoptera	Chilies	Staphylinidae	*Paedarus sabaeus*	None observed
Diptera	Okra	Syrphidae	u	Aphids
Neuroptera	Okra	Chrysopidae	*Chrysoperla carnea*	Aphids
Heteroptera		Reduviidae	*Phonoctonus grandis*	None observed

u- unidentified species

Table 4.1.b. Natural hymenopteran parasitoids observed on pests of okra and chilies

Order	Crop	Family	Species	Host of the parasitoid
Hymenoptera	Okra	Encyrtidae	u	Aphids on okra
Hymenoptera	Okra	Aphidiidae	*Diaretiella rapae*	Aphids on okra
Hymenoptera	Chilies	Scelionidae	u	Aphids on chilies
Hymenoptera	Chilies	Encyrtidae	u	Aphids on chilies
Hymenoptera	Chilies	u★	u	Cricket on chilies
Hymenoptera		Icheneumonidae	*Charops sp.*	Syrphid flies

u★- unidentified family
u- unidentified species

Table 4.2. Incidences of common natural enemies of aphids on okra at Kibwezi Oct 1998 to may 1999

Natural enemy	Coccinellids	Parasitoids (parasitic wasps)	Syrphid flies
Season 1	0.77	1.81a	1.03a
Season 2	0.87	0.87b	0.77b

Means with the different subscripts within a column are significant and lack of subscripts signifies non-significance, $p < 0.05$.

Table 4.3.a Occurrence of natural enemy groups under different treatments on okra at Kibwezi Oct 1998- April 1999.

Treatment Means ±SE	Seasons (S1,S2)	Numbers per five plants (mean) Protection during early growth	Protection during late growth	Protection during Repro-ductive stage	Protection During Maturity stage	Protection During all growth stages	No protection
Coccinellids	S1	0.88± 0.12	0.71± 0	0.77± 0.06	0.77± 0.06	0.77± 0.06	0.71± 0
	S2	0.94± 0.10a	0.71± 0b	1.07± 0.13a	0.71± 0b	0.71± 0b	1.05± 0.14a
Parasitoids	S1	2.50± 0.32	1.55± 0.35	1.87± 0.66	1.82± 0.66	1.20± 0.39	1.90± 0.72
	S2	0.92± 0.15ab	1.14± 0.22a	1.01± 0.12ab	0.77± 0.06b	0.77± 0.06b	0.71± 0b
Syrphid flies	S1	1.19± 0.22ab	1.14± 0.22ab	1.60± 0.42a	0.77± 0.06b	0.71± 0b	0.84± 0.08b
	S2	0.71± 0b	0.71± 0b	1.00± 0.10a	0.76± 0.05b	0.71± 0b	0.76± 0.05b

Means with the same letter within a row are not significantly different (SNK), $p<0.05$ and Means without subscripts are not significantly different.

Table 4.3.b Occurrence of natural enemies among different treatments on chilies at Kibwezi Jan –May 1999

Treatment Means ±SE	Numbers per five plants (mean) Protection during early growth	Protection during late growth	Protection during Repro-ductive stage	Protection during Maturity stage	Protection during all growth stages	No protection
Coccinellids	0.82± 0.07	0.83± 0.06	0.84± 0.05	0.73± 0.03	0.75± 0.04	0.87± 0.07
Parasitoids	0.71± 0b	1.06± 0.21a	0.71± 0b	0.71± 0b	0.71± 0b	0.71± 0b

Means with the same letter within a row are not significantly different (SNK), $p<0.05$ and Means without subscripts are not significantly different.

CHAPTER FIVE

5.0 INSECT DAMAGE AND ITS IMPACT ON THE YIELD OF OKRA AND CHILIES

5.1 Introduction

Zadoks and Schein (1979) have defined crop loss as the reduction in either quantity and/ or quality of yield. In quantitative terms, crop loss is the difference between actual yield and attainable yield. Zadoks (1967) has proposed a typology of losses, which uses contrasting pairs of antitheses to categorize crop loss caused by biotic agents. Field experiments/ survey is one of the typology where crop loss data are gathered using a two-phase strategy (James and Teng, 1979). The relationship between pest intensity and loss is quantified by means of field experiments conducted over several seasons. The quantified relationships are then integrated with field survey data to give a regional loss statistic with known precision.

Crop loss data may result from the proportion of parts lost in a crop, for instance, occurrence of diseases at certain stages of development with no ability to compensate. In such a case the disease intensity is measured and used to predict the loss in yield (FAO, 1981). The agricultural importance of a pest or A disease of crop plants is that the damage they cause reduces the quality and quantity of the yields. As mentioned by Hill and Waller (1994), there may be several causes of damage to plant and it is imperative for a crop protection worker to recognize the cause of damage. Insects may physically damage the plant, spread viral diseases or create wounds through which pathogens may infect the plant. Assessments of injury, damage or other effects of pest attack are often used to quantify pest intensity. This can be done by estimating damage of the whole plant such as number of plants killed, die back, wilting by stem borers, aphids, soil larvae (FAO, 1981), damage to leaves through windowing and uniform or irregular mining of areas. Both okra and chilies are infested by various insect pests, which may cause significant damage to the plant and subsequently reduce the yields. The aim of this study was to establish the damage caused to the crops by insects and the loss in yield resulting from the insect pest infestations.

5.2 MATERIALS AND METHODS

The same experimental plots used for studies on insect pest infestations of okra and chilies were used for these studies (section 2.2.2). The treatment regimes described in table 2.1 were also used.

Five plants were selected randomly from each plot to obtain data on physical damage caused on the leaves by defoliating insects. Damage to each plot was rated weekly between the early growth stage and maturity of the crops using a modified empirical scale of 1-5 of Ogol and Spence (1997) (table 5.1). The overall damage rating for each treatment was calculated by averaging the ratings of all plots for all the plant growth stages.

Fruits were graded into three categories upon harvesting (table 5.2) and the weighted mean (kg/plot) of each grade was recorded. The overall percentage weight of insect-damaged fruits for each treatment was estimated.

The avoidable yield loss in both crops was evaluated using the paired-treatment experiment (Bernard, 1985; Cole *et al.*, 1984 and Fisher and Wright, 1981). A comparison of the percentage fruit gain of the undamaged yield in the unprotected plot (treatment 6) with the yield from plots protected at certain growth stages (treatments 1-4) was made. The overall avoidable yield loss was estimated by subtracting the weight of damage free fruits in the unprotected plot (treatment 6) from the fully protected plot (treatment 5) and the data was expressed as percentage yield gain or loss.

5.3 Data analysis

Data collected on scores (as percentage of damage) on foliar damage and fruit drop (as counts) on chilies was subjected to square root transformation and analyzed using two way factor ANOVA and means were separated using the student Newman Keuls' (SNK) test (PROC GLM, SAS, 1995). Weight of the three grades of fruits from the six treatments was subjected to square root transformation and analysed using one way factor ANOVA. Means were separated using the student Newman Keuls' (SNK) test (PRO, GLM, SAS, 1995).

5.4 RESULTS

5.4.1 Foliar damage and impact on yield caused by insect pest infestations on okra

5.4.1.1 Foliar damage

Foliar damage on okra was caused by feeding by leaf-eating caterpillars and leaf beetles at certain stages of the plant growth. The damage inflicted by the leaf miner larvae was cumulative. However, foliar damage on chilies to a lesser extent, was as a result of the feeding habits leaf-eating caterpillars and leaf beetles whereas to a larger extent it was as a result of the effect of both bacterial and viral diseases.

Foliar damage on okra was statistically different ($p<0.05$) between the plant growth stages (table 5.3) during the two cropping seasons. Foliar damage was highest (1.19) during the late vegetative stage and lowest (0.78 and 0.92) during the late maturing stage of the first crop season (Oct to Dec 1998). In the second crop season (Jan to May 1999), maturity stage had the highest defoliation (3.33). There were no significant difference ($p>0.05$) between the other plant growth stages on the amount of defoliation.

There were significance differences ($p<0.05$) in foliar damage between the treatments (table 5.4). During the first crop season, the highest (1.53-1.62) foliar damage was recorded in treatments protected in the reproductive stage, in the maturity stage and unprotected in that order. The lowest (1.10 and 0.94) defoliation was recorded in the fully protected treatments and the treatment protected in the early vegetative stage. Whereas in the second crop season, the highest (1.63-1.71) defoliation was observed in treatment protected in the maturity stage, unprotected treatment and treatment protected in the late vegetative stage in that order. The fully prótected treatment had least (1.08) defoliation, although it did not show significant difference ($p>0.05$) to the levels in treatments protected in the early and late vegetative stages.

5.4.1.2 **Impact of insect pest infestations on yield**

There were no significance differences ($p<0.05$) between the treatments in the three grades of fruits (table 5.5) harvested in both of the two cropping seasons. The weight of each of the three grades did not differ significantly ($p>0.05$) between the treatments in any of the two seasons (table5.6.a). However, the protected plots during the fruiting and maturity stage (treatments 4 and 5) of both crop seasons recorded lower mean weight of insect-damaged fruits (17.24, 16.16 kg/plot for season one and 13.29, 10.86 kg/plot for season two respectively).

The untreated plots during fruiting and maturing stages (treatments 1, 2, 3 and 6) for both seasons had greater mean weight of insect-damaged fruits (17.80, 18.87, 17.40 kg/plot for season one and 19.90 and 16.00, 13.04, 14.07, 15.98 kg/plot for season two respectively).

Insect-damaged fruits accounted for 22% and 16.4% of the total fruit yields for season 1 and 2 (table 5.6.b). The lowest percentages of the insect-damaged fruits were recorded in the treatments, which received chemical insecticides during the maturity stage (treatments 4 and 5), and the higher percentages were also obtained from the treatments, which received chemical spraying before fruiting. Diseases and other injuries during harvesting contributed to the overall yield loss (fig. 5.1). However, the proportion of yield loss from this was far less than that caused by insects.

5.4.2 Foliar damage and impact on yield caused by insect pest infestations on chilies

5.4.2.1 Foliar damage

Insects appeared to cause little foliar damage on chilies but apparently infections of both bacterial and viral diseases caused substantial foliar damage.

5.4.2.2 Impact of insect pest infestations on yield

The weight of insect-damaged fruits was significantly different ($p<0.05$) between treatments in the first crop season (table 5.7). However, other grades in both seasons did not show significant difference ($p>0.05$) between the treatments (table 5.8.a). A high amount of the insect-damaged fruits (16.71-18.13 kg) was obtained from treatments protected in the early, late, reproductive growth stages and unprotected treatment, while the lowest (10.46 and 11.50 kg) were obtained from treatments protected in the maturity stages (4 and 5) in the first crop season. Similarly, the highest weight of insect-damaged fruits (16.89-20.97 kg) during the second crop season was obtained from treatments protected in the early, late, reproductive growth stages and unprotected treatment, while treatments 4 and 5 recorded the lowest (14.82 and 15.98 kg) mean weight.

Insect-damaged fruits accounted for 16.2% and 30.7% of the total yield weight in the first and second season crop (table 5.8.b). The first crop had high percentage of insect-damaged fruits than the second season. Equally, high percentages of diseased fruits were recorded in the first season (fig. 5.2).

5.4.2.3 Avoidable yield loss on okra and chilies

During the trials on okra, 6.3 % and 7.7 % of the total yield loss was avoided due to protection against insect pests in the first and second season crops (table 5.9.a).

However, protecting okra against pest from the early vegetative stage to maturity in the first and second crop season respectively, resulted in varied gain in damage free fruits (table 5.9.b). Protecting the crops against insect pests during the maturity and the entire plant growth period appeared to result in high yield gain of the undamaged fruits (9.0%, 24.3% and 5%, 10.7% in season 1 and 2 respectively).

10.7 % and 16.6% of marketable fruits of chilies in season one and two was the gain as a result of protection. Protecting the crop in different growth stages had varied yield gain of the damage free fruits. However, protection during the maturity stages and the entire growth period resulted to higher yield gain of the damage free fruits (5.10). Protection of the crop during the fruiting and through out the growth period of the crop gave the highest gain of insect damage free fruits (5.3 %, 8.4 and 10.45, 9.7% in season 1 and 2 respectively).

5.5 **Discussion**

According to Taylor and Bardner (1968), chewing insects cause different types of damage. Leaf-eating caterpillars, leaf miners and leaf beetles, caused foliar damage on okra at certain stages of the plant growth. However, foliar damage on chilies to a lesser extent, was as a result of the feeding habits leaf-eating caterpillars and leaf beetles whereas to a larger extent it was as a result of the effect of both bacterial and viral diseases. The consumption of leaf tissues reduced the area of photosynthetic material available to plant.

Insect pests feeding on leaf epidermis (some forms of caterpillars) may have caused less damage than those feeding on the leaf veins. The damage by insects that bore in plant tissue (leaf miner) and sap suckers (aphids, white flies, leafhoppers, and other sucking bugs) interfered with translocation of nutrients and water within the plant tissues and reduced the photosynthetic material available to plants as pointed by Bardner and Fletcher (1974). However, the loss of leaf area does not necessarily result in a concomitant loss in plant yield (Dent, 1993).

Plants tolerated certain amounts of defoliation probably without any effect on yields and it has been shown in a number of cases that plants can compensate for damaged tissue by enhanced growth (Capinera *et al.*, 1986). The maturity stages of the crops in both crop seasons had low percentages of damage than the early growth stages due to the preference for soft tissues by insects. Plant phenology, environmental conditions and the level of injury may have influenced this compensation (Bardner and Fletcher, 1974; McNaughton, 1983).

Insects associated with disease transmission such as thrips, aphids and white flies were the probable cause of foliar damage and yield loss in the second season of chilies.

The leaf curl disease observed on chilies caused deep coloured blotches on fruits in addition to the leaf curling. Other forms of diseases (powdery mildew and leaf spots in both crops) reduced the photosynthetic material and area available to the plant. The leaf curl disease (PVY), leaf spots {*Cercospora unamunoi* (syn. *Phaeoramularia capsiciola*) (Vassil.)} Deighton. and Powdery mildew (*Leveillula taurica* (Lev.) Arnaud. have been noted to be the common diseases affecting most capsicum crops in Kenya all year round (NARC, 1994).

Consumption of the harvestable plant parts by insects (fruit borers and thrips) or damage by diseases (flower drop and fruit rot) was a direct measure of yield loss since the damaged fruits were rendered unfit for sale (Southwood and Norton, 1973). Insects caused yield losses in okra estimated at 22% for the first season and 16.4% for the second season. In chilies it was estimated as 16.2% and 30.7% for the two seasons respectively. The resultant effect of plant death during growth was a reduction of the attainable yield. The major causes of plant death were the root-rot disease, which affected the young plants of okra and the root-knot nematodes common in all plots but with localized 'hot spots'. Okra was more affected by root-knot nematodes than chilies and the plants died before maturing.

The study of different components of yield loss is apparently a complex subject and requires further research. The relationship between damage and yield loss caused by chewing insects may be complex than simple association with the area defoliated. It was assumed that each type of insect contributed to the total yield loss in the crop when counts of insects were made and used as a measure of pest intensity. However, different insect developmental stages may have had different effects on plant yield and may have affected different plant parts (Dent, 1993). Furthermore, insects caused direct yield loss on both crops.

It is worth mentioning that the use of chemical insecticides to suppress insect pests may have created problems on plant physiology and pest counts. FAO (1981) reported that pesticides may stimulate plant part to give more yields or may reduce their yield. However, protecting okra and chilies from the reproductive stage and maturity stage may avoid yield loss due to insect pest infestations.

5.6 **Reference**

Bardner, R. and Fletcher, K.E. (1974). Insect infestations and their effects on the growth and yields of field crops: a review. *Bulletin of Entomological Research* **64**: 141-60.

Bernard, D. R. (1985). Injury thresholds and production loss functions for the lone star tick, *Amblyomma americanum* (Acari: Ixodidae) on pastured, pre-weaner beef cattle, *bos taurus*. *Journal of Economic Entomology* **78**: 852-5.

Capinera, J.L., Epsky, N.D. and Thompson, D.C. (1986). Effects of adult western corn root worm (Coleoptera; Chrysomelidae) ear feeding on irrigated field corn in Colorado. *Journal of Economic Entomology* **79**: 1609-12.

Cole, N. A., Guillot, F. S. and Purdy, C.W. (1984). Influence of *Psoroptes ovis* (Hering) (Acari: Psoroptidae) on the performance of beef steers. *Journal of Economic Entomology* **77**: 390-3.

Dent, D. (1993). Insect pest management, pp 82-130. CAB International, Wallingford. UK

Fisher, W.F. and Wright, F.C. (1981). Effects of the sheep scab mite on cumulative weight gains in cattle. *Journal of Economic Entomology* **74**: 234-7.

Food and Agriculture Organization (FAO) (1981) Crop Loss Assessment Methods-Supplement 3, pp 35-97. Commonwealth Agricultural Bureaux, Rome

Hill, D. S and Waller, J. M. (1994). Pests and diseases of tropical crops, pp 1-16. Cambridge University Press, London

James, W. C. and Teng, P. S. (1979). The Quantification of production Constraints associated with Plant diseases: In. Coaker, T. H. (ed.) Applied Biology, vol., pp. 201-267. Academic press, New York

McNaughton, S.J. (1983). Compensatory plants growth as a response to herbivory. *Oikos* **40**: 329-36.

National Horticultural Research Center, Thika (1994). Horticultural crops protection hand book, pp. 60-79. Ministry of Agriculture and Livestock development. Nairobi, Kenya

Ogol C. K. P .O and Spence J. R. (1997). Abundance, population dynamics and impact of the Leucaena psyllid *Heteropsylla cubana* Crawford in a maize-leucaena agroforestry system in Kenya. *Insect Science and its Application* **17**(2): 183-192.

Southwood, T.R.E and Norton, G.A. (1973). Economic aspects of pest management strategies and decisions. *Memirus of the Ecological Society of Australia* **1**: 168-84.

Statistical Analysis Systems (1995). *SAS Users Guide. Statistics, Version* 8 edn. SAS Institute Inc., Cary, NC

Taylor, W.E. and Bardner, R. (1968). Leaf injury and food consumption by larvae of *Phaedon coditera* (Coleoptera; chrysomelidae) and *Plutella maculipennis* (Lepidoptera; Plutellidae) feeding on turnip and radish. *Entomologia Experimentalis et Applicata* **11**: 177-84.

Zadoks, J. C. (1967). Types of Losses caused by Plant Diseases. In Papers Presented at the FAO Symposium on Crop Losses, Rome, 1967, pp 149-158. Rome, FAO, UN

Zadoks, J. C. and Schein, R. D. (1979). Epidemiology and plant diseases management, pp 123-45. New York, Oxford University press.

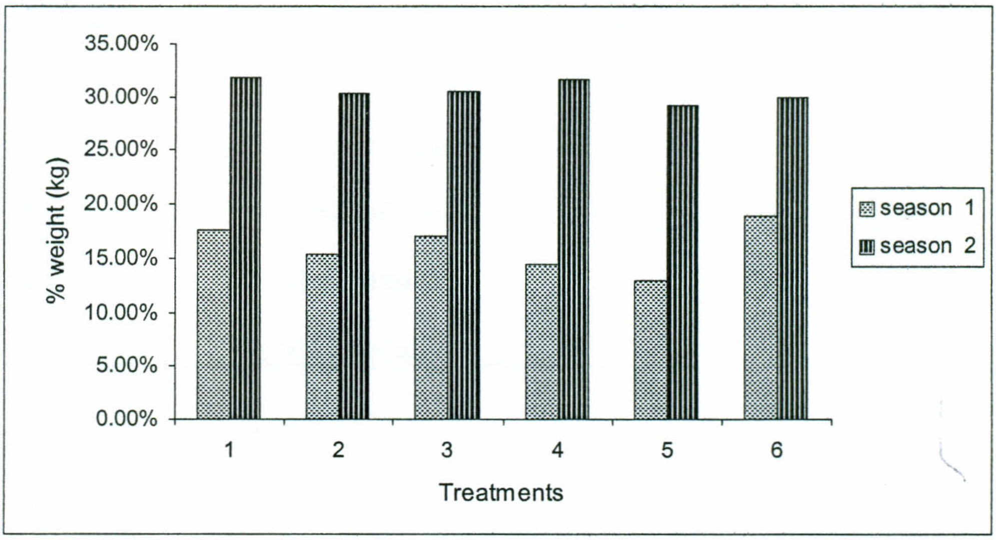

Fig 5.1 Percentage of other damaged fruits in the treatments of okra during the two cropping seasons at Kibwezi, Oct 1998- April 1999.

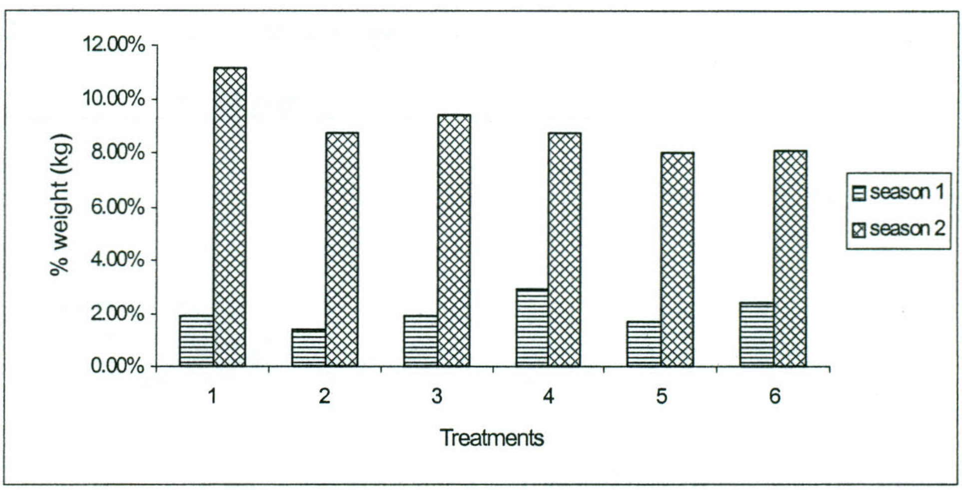

Fig 5.2 Percentage of other damaged fruits in the treatments of chilies during the two cropping seasons at Kibwezi, Oct 1998- may 1999.

Table 5.1 Insect damage rating scale

Rating	Damage category
1	1-10 % plant defoliation
2	11-25% plant defoliation
3	26-50% plant defoliation
4	51-75% plant defoliation
5	>76% plant defoliation.

Table 5.2 Fruits grading system

Grade	Criterion of grading
1	Insect-damaged fruits
2	Any other damaged fruits
3	Undamaged fruits

Table 5.3. Mean scores of leaf defoliation 5 $plants^{-1}$ on okra during the crop's growth at Kibwezi, Oct 1998- May 1999.

	Early growth stage		Late growth stage		Reproductive stage		Maturity stage	
Sampling Period (week)	1	2	3	4	5	6	7	8
Season 1	1.19cde	1.77ab	1.30bcd	1.89a	1.33bcd	1.56abc	0.78e	0.92de
Season 2	1.21bc	1.54b	1.27bc	1.23bc	1.13bc	0.78c	3.34a	_

Means with the same letter within a row are not significantly different (SNK), $p<0.05$

Table 5.4 Percentage leaf defoliation from the different treatments of okra at Kibwezi, Oct 1998- May 1999.

Season	Protection during early growth	Protection during late growth	Protection during Reproductive stage	Protection during Maturity stage	Protection during all growth stages	No protection
Season 1	0.94 ±0.09b	1.21 ±0.16ab	1.62 ±0.13a	1.59 ±0.16a	1.10 ±0.12b	1.53 ±0.17a
Season 2	1.45 ±0.24ab	1.14 ±0.29ab	1.63 ±0.27a	1.71 ±0.20a	1.08 ±0.22b	1.67 ±0.23a

Means with the same letter within a row are not significantly different (SNK), $p<0.05$.

Table 5.5. Anova table of yields on okra at $p < 0.05$

Grade	Seasons	Source of Variation	Degrees of freedom	Sum of Squares	Mean square	F value	Pr < F
Grade 1	seasons 1	Treatment	5	208.372	41.674	1.90	0.0976
	seasons 2	Treatment	5	458.987	91.797	2.17	0.0609
Grade 2	seasons 1	Treatment	5	91.702	18.341	0.47	0.796
	seasons 2	Treatment	5	66.348	13.269	0.93	0.461
Grade 3	seasons 1	Treatment	5	352.480	70.496	0.59	0.710
	seasons 1	Treatment	5	430.556	86.111	0.59	0.711

G1- weight of the insect damaged fruits, G2- weight of the diseased fruits and G3- weight of the other damaged fruits.

Table 5.6.a Weighted means of fruit grades per plot in the different treatments of okra in Kibwezi between Oct 1998 and May 1999.

Fruit category	Seasons	Protection during early growth	Protection during late growth	Protection during Repro-ductive stage	Protection during Maturity stage	Protection during all growth stages	No protection
Grade 1	season 1	17.8 ±0.98	18.87 ±0.93	17.40 ±0.89	17.24 ±0.98	16.16 ±0.98	19.90 ±0.98
	season 2	16.01 ±1.29	13.04 ±1.21	14.07 ±1.39	13.29 ±1.39	10.86 ±1.39	15.98 ±1.35
Grade 2	season 1	13.65 ±1.22	12.28 ±1.19	12.77 ±1.3	11.38 ±1.49	12.15 ±1.17	13.54 ±1.23
	season 2	4.38 ±0.76	2.93 ±0.64	4.11 ±0.67	4.66 ±0.91	3.09 ±0.71	4.47 ±0.88
Grade 3	season 1	28.70 ±2.43	29.79 ±2.08	28.18 ±2.05	33.09 ±2.33	30.21 ±2.51	30.17 ±1.97
	season 2	35.29 ±2.1.22	30.28 ±2.74	31.94 ±2.42	31.43 ±2.69	30.28 ±2.38	33.19 ±2.46

Means without subscripts within a row are not significantly different (SNK), $p<0.05$
Grade 1- weight of the insect damaged fruits, Grade 2- weight of the diseased fruits and Grade 3- weight of the other damaged fruits

Table 5.6.b Percentage of insect-damaged fruit of okra under different treatments (weight (kg/ plot) in Kibwezi between Oct 1998 and May 1999.

Season	Protection during early growth	Protection during late growth	Protection during Repro-ductive stage	Protection during Maturity stage	Protection during all growth stages	No protection	Total weight
Season 1	22.3	24.3	22.7	18.6	18.6	25.5	22
Season 2	21.8	15.4	17.0	15.6	12.9	18.9	16.4

The percentage (%) of each grade is in relation to the total weight of that grade in that particular treatment.

Table 5.7. Anova table of yields of chilies at $p < 0.05$

Grades	Seasons	Source of Variation	Degrees of freedom	Sum of squares	Mean square	F value	Pr > F
Grade 1	season 1	Treatment	5	1312.60	266.52	3.09	0.0113 *
			5	766.01	153.20	1.87	0.1029
Grade 2	season 1	Treatment	5	106.35	21.27	0.10	0.9917
			5	207.98	41.60	0.68	0.6397
Grade 3	season 1	Treatment	5	714.19	142.84	0.28	0.9242
			5	949.72	189.94	1.16	0.3295

Grade 1- weight of insect damaged fruits, Grade 2- weight of diseased fruits and Grade 3- weight o other damaged fruits

Table 5.8.a Weighted means of chili fruits grades per treatment during the two crop seasons in Kibwezi between Oct 1998 and May1999.

Treatment Means	Season (S1,S2)	Protection during early growth	Protection During late growth	Protection during Reproductive stage	Protection during Maturity stage	Protection during all growth stages	No protection
Grade 1	S1	16.99 ±2.1	17.53 ±2.26	16.71 ±2.20	11.50 ±1.25	10.48 ±1.02	18.13 ±2.18
	S2	20.973 ±1.56	19.84 ±1.48	16.89 ±1.83	15.98 ±1.82	14.82 ±1.73	18.08 ±1.82
Grade 2	S1	20.93 ±2.45	21.09 ±3.14	19.79 ±2.73	19.89 ±3.15	21.63 ±3.20	19.16 ±2.99
	S2	9.85 ±1.72	7.77 ±1.60	6.87 ±1.59	6.82 ±1.34	6.57 ±1.22	7.96 ±1.35
Grade 3	S1	37.57 ±4.34	35.83 ±5.62	38.33 ±4.32	39.51 ±5.06	42.87 ±4.33	40.43 ±3.85
	S2	27.56 ±2.31	28.19 ±2.03	23.19 ±2.71	22.88 ±2.189	21.97 ±2.44	25.69 ±2.73

Means without subscripts within a row are not significantly different (SNK), $p<0.05$

Grade 1- weight of the insect damaged fruits, Grade 2- weight of the diseased fruits and Grade 3- weight of the other damaged fruits

Table 5.8.b Percentage weight of the insect-damaged chili fruits in the treatments in Kibwezi 1998-1999.

Season	Protection during early growth	Protection during late growth	Protection during Repro-ductive stage	Protection during Maturity stage	Protection during all growth stages	No protection	Total % weight
Season 1	17.6	15.4	17.0	14.5	12.9	18.9	16.2
Season 2	31.9	30.4	30.6	31.6	29.2	30.0	30.7

Percentages within a row are in relation to the total weight of that grade in that particular treatment.

Table 5.9.a. Overall avoidable yield loss by % in okra and chilies in two cropping seasons at Kibwezi, Oct 1998- May 1999.

Okra		Chilies	
Season 1	Season 2	Season 1	Season 2
6.3	7.7	10.7	16.6

Table 5.9.b. Yield of okra and pest damage under different protection regimes in Kibwezi between Oct 1998 and May1999.

Treatment module	Insect damaged fruits/ treatment (kg/plot)		% of insect damaged fruits/ treatment (kg/plot)		Damage free fruits/ treatment (kg/ plot)		% of damage free fruits/ treatment		% gain in yield of damage free fruits due to protection in different stages	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
T1	8.13	7.07	22.3	21.8	23.2	26.4	63.2	77.1	2.1	0.6
T2	9.01	4.90	24.3	15.4	23.67	26.36	63.9	83.2	2.8	6.7
T3	7.68	5.83	22.7	17.0	21.36	27.73	63	81.1	1.9	4.6
T4	6.9	5.30	18.3	15.6	26.3	27.69	70.1	81.5	9.0	5.0
T5	6.79	3.79	18.6	12.9	25.38	29.13	69.6	87.2	24.3	10.7
T6	10.02	7.14	25.5	18.9	23.98	26.2	61.1	76.5	NA	NA

Table 5.10 .Yield of chilies and pest damage under different protection regimes in Kibwezi between Oct 1998 and May 1999

Treatment module	Insect damaged fruits/ treatment (kg/ plot)		% of insect damaged fruits/ treatment (kg/plot)		Damage free fruits/ treatment (kg/plot)		% of damage free fruits/ treatment		% gain in damage free fruits due to protection in different stages	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
T1	7.96	9.3	31.5	13.8	15.3	44.24	58.4	65.7	1.5	2.3
T2	7.97	8.5	28.8	12.8	16.7	44.19	60.2	66.6	3.3	3.2
T3	7.7	9.4	31.3	13.7	14.5	45.6	59.6	66.6	2.7	3.2
T4	7.3	3.1	29.5	5.0	15.4	46.2	62.2	73.8	5.3	10.4
T5	7.3	3.2	26.3	4.3	18.03	54.43	65.3	73.1	8.4	9.7
T6	9.2	10.5	32.5	17.4	16.1	45.38	56.9	63.4	NA	NA

CHAPTER SIX

6.0 EFFECTS OF NEEM FORMULATIONS ON THE POPULATION OF INSECT PESTS AND NATURAL ENEMIES AND YIELD OF OKRA AND CHILIES

6.1 Introduction

Overuse and misuse of highly toxic, persistent, and broad-spectrum insecticides at short intervals is a common practice among vegetable growers. The fruits harvested from such treated plots contain insecticide residues over and above the tolerance limits and hence pose unwarranted health hazards to the consumer (Narasimha Rao, 1990). Although a good number of chemical insecticides are known to be effective against insect pests on vegetables (Saxena, 1978, 1981; Samalo and Patnaik, 1986; Bhalani and Parsana, 1987), neem has been reported to possess insecticidal, antifeedant and antiviral properties (Ketkar, 1976). However, in Kenya little work seems to have been done on the management of insect pest complex found in okra and chilies using botanical products.

Use of insecticides obtained from neem is becoming an alternative to use of chemical control for the management of pests of vegetable crops grown by small-scale farmers due to its effectiveness and low cost. Non-Governmental Organizations and research institutions in Kenya are enhancing and creating awareness and accessibility on use of neem products. These factors led to a low-risk pest management preferred by small-scale growers in Nicaragua (Gomez *et al.*, 1993). The use of much safer botanical insecticides for containing pest problems in okra will help overcome problems associated with to harmful chemical insecticide residues, environmental pollution, and the conservation of beneficial insects. In view of the ecological implications as well as costs of chemical insecticides, plant products need to be exploited. The present study was therefore undertaken to evaluate the field efficacy of three neem products [seed neem oil, kernel neem powder and neem seed kernel extracts (NSKE)] against the pest complex of okra and chilies.

6.2 MATERIALS AND METHODS

The trials were conducted at the University of Nairobi (U.o.N) Kibwezi irrigation project (K.I.P), field station at Kibwezi, in Eastern province of Kenya, (2°21-5'S, 38°2-5'E and 700m above the sea level) (Fig. 2.1). This study was carried out over two cropping seasons for okra and one season for chillies during the long and short rains from September 1998 to May 1999.

6.2.1 Experimental design and plot lay out

The experimental plots were laid out on a completely randomized block design (Simmonds, 1976) with six treatments (table 6.1) replicated four times. Okra seeds (Pusa sawani variety) were sown on October 1998 and February 1999 in 4 x 3 sq. m. plots at a spacing of 60 cm between rows and 15 cm within rows and with a population of 100 plants/plot. 40-day old chili seedlings were transplanted on September 1998 in similar plots with a spacing of 60 cm between rows and 30 cm within rows with a plant population of 54 plants/plot. A 1m-wide buffer strip of bare ground separated the plots with the normal agrotechniques adopted on all the plots.

Treatment applications commenced after crop emergence and establishment and were applied on weekly basis for a period of eight and ten weeks for okra and chilies respectively. Systemic and knock down chemical insecticide applications were alternated to avoid development of resistance. Few drops of teepol were added to the treatment modules before application to enable them stick to the plant surface.

Preliminary trials on neem oil had indicated that 15ml/l of neem oil and 25g/l of neem powder were effective to insects and least phytotoxic to plants (Roychoudhury and Jain, 1991). Neem oil was mixed directly with water and sprayed, neem powder was soaked over night and sieved before spraying, while neem seeds were crushed and soaked in water overnight and sieved to obtain the (NSKE) before application. The chemical insecticides were used directly as recommended by the manufacturers. All treatment modules were applied to the crops as foliar application.

6.2.2 **Sampling for Insect pests**

Sampling for insects commenced three days after treatment application on five randomly selected plants per plot. Aphids, white flies and red spider mites populations were determined using a modified empirical scale of 1-5 (table 6.2) of Saika and Muniyappa (1989). The under surface of each leaf was closely examined for the minute red spider mites. Rating of white flies was done during the early morning hours (from 6-8 hrs) when they are inactive.

Leaf hopper nymphs and adults, leaf beetles, cotton stainers and other sucking bugs, flower beetles, flower thrips, leaf miner, leaf eating caterpillars and fruit borers were counted directly from the five randomly selected plants per plot without disturbing the plant. Flower thrips were picked in five flowers per plot and preserved in 70% alcohol for 2-3 hours (Bournier *et al.*, 1982) before counting them. The leaf miners were counted on the freshly mined tunnels by the larvae from the four upper most leaves. Data obtained was expressed as the number of insect pest per five plants. Insect pest sample specimens were collected and preserved in 70% alcohol or dry mounted and sent to the Biosystematics department (I.C.I.P.E) for identification.

6.2.3 **Sampling for beneficial insects and natural enemies**

During the cropping seasons of short and long rains of October to January 1998 and January to May 1999, starting a week after crop emergence and establishment and three days after chemical insecticides application, five plants from both crops were randomly selected from each plot for sampling.

Coccinellid beetles (ladybirds), both adults and nymphs predating on aphids and red spider mites were counted from the five randomly selected plants. Similarly, predatory ladybird beetles of red spider mites were visually observed and counted. The population of syrphid fly larvae predatory on aphids was established from the leaves of the five randomly selected plants by actual counts. Some of the larvae were placed in petri dishes and reared on aphids until adult emergence. Parasitism on aphids was established by counting the aphid mummies on all leaves of the five randomly selected plants. Some of the mummified aphids were placed in glass vials and maintained in the laboratory to recover the parasitoid (parasitic wasps). Sample specimens of natural enemies were preserved in 70% alcohol and sent to I.C.I.P.E for identification.

Bees and wasps were observed from the plants in each plot three days after application of neem treatments.

6.2.4 **Damage assessment**

Five plants were selected randomly from each plot to obtain data on physical damage caused on the leaves by defoliating insects. Damage to each plot was rated weekly between the early growth stage and maturity of the crops using a modification of Ogol and Spence, (1997) empirical scale of 1-5 (table 6.3). The overall damage rating for each treatment was calculated by averaging the ratings of all plots.

Fruits were graded into three categories upon harvesting (table 6.4) and the weight (kg) of each grade was calculated by averaging the weight of each treatment. The overall percentage weight of insect-damage fruits of each treatment was calculated.

6.3 **Data analysis**

Scores and counts of insect pests, beneficial insects and natural enemies and scores on leaf damage due to insects' feeding collected from the two crops (okra and chilies) was subjected to square root transformation and analyzed using repeated-measures two way analysis of variance ANOVA (PROC GLM, SAS, 1995). Undamaged and insect damaged yields (kg) from the six treatments taken at harvest were transformed using square root, then subjected to Analysis of variance (ANOVA). The means were separated using the Student-Newman-Keuls (SNK) test (PROC GLM, SAS, 1995). The percentage of insect-damaged, diseased, other damaged and the undamaged fruits from each treatment were estimated.

6.4 RESULTS

6.4.1 Effect of neem products on insect pests of okra.

Neem products were observed to affect various insect pest species. The common pests described in table table 2.3 in both crop seasons included aphids, cotton stainers, leaf-eating caterpillars, leaf miner, fruit borers, flower beetles and flower thrips. Whiteflies, leafhoppers and a range of sucking bugs were observed on okra only during the first crop season while the red spider mites occurred only during the second crop season.

The various formulations of neem products appeared to be effective in reducing pest populations although some showed no significant differences compared to the control (table 6.5). There were significant difference ($p<0.05$) in aphid numbers between treatments. The 25g/l concentration of neem powder and both concentrations of neem oil (15ml/l and 20ml/l) had low numbers of aphids (1.99, 1.76 and 1.75 respectively) relative to the unprotected plot (2.45) during the first season crop. During the second crop season, aphid numbers from the neem treatments showed no significant differences compared to the control although they were effective to some extent in reducing the aphids.

None of the treatments was statistically different ($p>0.05$) from the control in whitefly population. However, low incidences (1.55 and 1.72) of whiteflies were observed from 15ml/l and 20ml/l neem oil treated plots. All treatments showed no significant difference between treatments in leafhopper population although neem products were slightly effective against leafhoppers. Although the treatments did not differ significantly from the control in cotton stainer populations in both crop seasons, the 15ml/l of neem oil during the first season and 25g/l of neem powder reduced (0.71 and 1.17) the cotton stainers.

The populations of leaf caterpillars, leaf beetles, sucking bugs, flower beetles and fruit borers in the treatments were low and showed no significant difference ($p>0.05$) with the control in both seasons. However, neem products appeared effective to some extent in reducing the pests except 25g/l of neem powder on caterpillars, leaf beetles and flower beetles, 50g/l of neem powder on caterpillars and flower beetles and 20ml/l of neem oil on leaf beetles. Population of leaf miners in all treatments did not show significant difference ($p>0.05$) with the control in both seasons. Neem formulations appeared to be effective in reducing the leaf miners except the 25g/l of neem powder and NSKE.

Flower thrips were relatively low during the first crop season but high during the second crop season and all treatment modules showed no significant difference ($p>0.05$) with the control in thrips population. All the neem products effectively reduced thrips relative to the control in both seasons while 25g/l of neem powder in the second crop season did not seem to reduce thrips. Although red spider mites were reduced by all neem formulations in comparison to the control except a formulation of 25g/l of neem powder, there were no significance differences ($p>0.05$) between the treatments.

6.4.1.1 **Effect of neem products on beneficial insects and natural enemies of okra.**

Both concentrations of neem oil appeared to slightly reduce visitation by bees (0.71) as compared to neem powder and chemicals (0.84 and 0.97) to the crop however, there no were no significant differences between the treatments. The wasps were reduced by all formulations of neem (table 6.6).

All neem formulations apart from 25g/l of neem powder in the second crop season appeared to affect the numbers of predatory coccinellids of aphids (*Cheilomenes propinqua*, *Cheilomenes lunata*, *Cheilomenes sulpurea* and unidentified *Cheilomenes* sp). The parasitoids of aphids (*Diaretiella rapae*; Aphidiidae and unidentified Encyrtidae) appeared to be affected by all the neem treatments apart from the 50g/l of neem powder in the second crop season. The numbers of syrphid (Syrphidae) larval stage predator on aphids were also slightly affected by all neem formulations compared to the control. The numbers of predatory beetles, *Casnoidae* sp (Carabidae) and *Scymnus lavaillanti* (Coccinellidae) on red spider mites were statistically different ($p < 0.05$) between the treatments. The 50g/l-neem powder (1.01) appeared to reduce their numbers more than the 25g/l-neem powder (2.97), 20ml/l-neem oil (1.85) and NSKE (1.54) which, appeared to have no effect on the mite predators.

6.4.1.2 **Effect of neem products on foliar damage and yield due to insect pest infestations of okra.**

The neem formulations in both seasons reduced the amount of leaf damage by insects although they showed no significant difference ($p > 0.05$) between treatments (table 6.7).

Both 50g/l and 25g/l of neem powder reduced (1.25 and 1.34) leaf damage more than either the chemical treatment (1.36) or the neem oil formulations during first crop season. Chemicals during the second crop season had the least (1.33) amount of defoliation than 20ml/l of neem oil (1.67), 50g/l of neem powder (1.79), 25g/l of neem powder (1.85) and NSKE (1.88).

There were significant differences ($p < 0.05$) between the treatments on the weight of insect-damaged fruits in both crop seasons (table 6.8). Similarly, no significant differences occurred on the weight of either the diseased or other injured and the undamaged fruits between the treatments of both seasons. Insect damaged fruits in 25g/l neem powder treated plots showed no significant difference with the chemical treated plots during the first crop season. Other neem formulations were more insect damaged fruits than the chemical treated plots in both crop seasons. However, both concentrations of neem powder appeared to reduce the amount of insect-damaged fruits (6.19 kg/plot and 1.9 kg/plot for 25g/l and 50g/l neem powder in season 1 and 2 respectively). Neem oil in both seasons and NSKE were apparently ineffective in reducing fruit damage by insects.

Insects caused 23% and 11.2% loss in yield during the first and second crop seasons respectively. The highest percentage of insect-damage yield was obtained from plots treated with 15ml/l and 20ml/l-neem oil (26.2% and 25.1%) figs. 6.1.a and b).

The reduction of insect damage yield by neem products was reflected by a gain in yield (table 6.8). Both of the neem powder concentrations in both seasons appeared to improve the marketable fruits while neem oil appeared to be ineffective in improving the marketable fruits. However, chemical treated plots improved the marketable yields than any of the neem formulations.

6.4.2 **Effect of neem products on insect pests of chilies.**

Neem products had different extent of effects on different insect pest species described in table 3.2.

The populations of whiteflies were significantly different ($p<0.05$) between the treatments (table 6.9). Neem products did not show significant difference with the control on whitefly population. However, they appeared to reduce the population apart from 50g/l-neem powder which, failed to reduce the whitefly population (1.92) below the control (1.90).

The numbers of leafhoppers, caterpillars, leaf miners, leaf beetles and sucking bugs appeared to be reduced by the neem formulations although the neem treatments showed no significant difference with the control. A formulation of 25g/l of neem powder appeared to be ineffective in reducing the number of caterpillars, leaf miner and sucking bugs relative to those of the unprotected plot.

The number of fruit borers in the neem treatments showed no significant difference ($p> 0.05$) with the control, however, neem formulations reduced their numbers. The number of flower thrips were significantly different ($p< 0.05$) between treatments where chemical treated plot recorded the lowest number (1.37). The neem formulations compared with the control and apparently reduced the number of thrips.

6.4.2.1 **Effect of neem products on beneficial insects of chilies.**

Visits by both bees and wasps to chilies appeared to be affected by formulations of neem and also the chemicals (table 6.10) and significant differences ($p< 0.05$) occurred between the treatments. Chemicals reduced numbers of bees and wasps (0.83) more than any other treatment while 20ml/l-neem oil appeared to least reduce the beneficial insects (0.94) as compared to 50g/l-neem powder (1.03), 25g/l-neem powder (1.12) and 15ml/l-neem oil (1.14). Predatory coccinellids and parasitoids occurred in very low populations and so could not be included for quantification.

6.4.2.2 **Effect of neem products on crop damage and yield due to insect pest infestations of chilies**

The foliar damage caused by insects was too low for quantification. None of the three grades of fruits revealed significant differences ($p< 0.05$) between treatments. Although neem treatment modules showed no significant difference with the control in insect damaged fruits, they reduced the extent of damaged related to insects more than from the control (table 6.11).

Plots applied with chemical insecticides had the least (7.03 kg/plot) insect-damaged fruits. 50g/l-neem powder appeared to reduce the amount of insect damaged fruits (8.16kg/plot) more than 15ml/l and 20ml/l of neem oil contrary to the 25g/l-neem powder formulation, which appeared to be less effective (10.99 kg/plot) in reducing the amount of insect damaged fruits. The reduction of insect damaged yield by neem products was reflected by a gain in the marketable fruits (table 6.11). All treated plots with neem appeared to increase the damage free fruits relative to the control where 50g/l of neem powder gave the highest gain (6.3 kg/plot).

6.5 Discussion

6.5.1 Effect of neem products on pest complex

Most of the pests occurring on okra and chilies were apparently reduced from the extent of infestation in unsprayed plots (control) by weekly applications of the neem products. The effects of the latter on the pests, however, appeared to be less than that of chemical insecticide treatments. Several conventional chemicals were applied to control the pest populations in these comparison plots. Among the five-neem formulations, 20ml/l-neem oil appeared to effectively reduce most pests on chilies and okra apart from the leaf beetles. The 15ml/l concentration of neem oil was also found to be more effective on most insect pests occurring on both crops apart from cotton stainers, leaf beetles and flower beetles on okra and leaf miner on chilies when compared with the neem powder (25, 50g/l) and NSKE (50g/l). This is in conformity with earlier studies on bean white flies (Guerrero, 1992) where two applications per week of 1% of formulated neem oil (Nim 80 EC: COPINIM) significantly reduced the population of white flies in 70 days after sowing. Zeledon (1988) also reported that treatment of bean leaves by neem oil reduced the oviposition of white flies. Roychoudhury and Jain (1993) demonstrated that the mortality of aphids and whiteflies was higher after neem oil treatment. In the present study, it was observed that leaf-eating caterpillars on okra desisted from feeding and starved to death on neem oil sprayed leaves.

The high concentration of neem powder (50g/l) appeared to reduce the pests below those in the control plots and also in plots with the lower concentration (25g/l). However, it was not found to appreciably reduce the populations of whiteflies on both crops except cotton stainers, leaf caterpillars, and flower beetles on okra. NSKE was found to be more effective on okra pests as compared to the 25g/ l-neem powder. Water extracts of neem seed kernel (50g/l) reduced the populations of aphids, leaf caterpillars, sucking bugs, pod borers, flower thrips and red spider mites on okra. This trend of results is comparable to studies by Miranda (1992) on *P. xylostella* of cabbage where application of neem seed water extract was found as effective as the commercially used *Bacillus thuringiensis* (DIPEL: Abbott Corp) biological based. He also reported that neem oil was superior to DIPEL in pest management on cabbage and was also less costly. Rivas and Mendez (1991) demonstrated that seven applications of water extract of powdered neem seed kernel (15g/l) 16-18 days after transplanting tomato, reduced the population of *H. armigera.*

The performance of some neem products on individual pests appeared to be comparable to those of the chemical insecticides and showed no significant differences. On okra, concentrations of neem oil on whiteflies, cotton stainers, caterpillars, sucking bugs, flower beetles and flower thrips appeared to perform equally or better compared with those of chemical treated plots. The effects of 50g/l of neem powder on cotton stainers, caterpillars and sucking bugs appreciably compared to the chemical treated plots. Similarly, neem oil treated plots of chilies appeared to compare in performance with the chemicals on caterpillars, leaf beetles and sucking bugs. The 50g/l of neem powder appeared to compare equally in performance with the chemicals on caterpillars, leaf miners, leaf beetles and sucking bugs.

The effect of neem treated plants on insects could have been due to its anti-feedant effect and the variation in the effect on different insects was due to the differences in the feeding behaviour of the insects as reported by Roychoudhury and Jain (1993).

6.5.2 **Effect of neem on natural enemies and other beneficial insects.**

Formulations of neem powder and neem oil slightly reduced the population of bees and wasps below the control. However, chemical insecticides reduced their populations more than the neem treatments. The coccinellid predators of aphids were reduced by all neem formulations apart from the 25g/l-neem powder. All neem formulations reduced the population of hymenopteran parasitoids and predatory syrphid flies except 50g/l of neem powder on the former. The predatory coccinellid and predatory carabid beetles were not affected by the lower concentration of neem powder, neem oil and the NSKE water extract. This is in conformity to earlier observations made by Venkateswara and Rosaiah (1993) where NSKE was found to conserve the coccinellid predators and syrphids on okra. Neem formulations in both crops appeared to conserve the beneficial insects. The numbers of bees and wasps, coccinellids, syrphid and carabids appeared to be more in neem treated plots compared with the chemical treated plots.

The results from this study suggest that neem formulation either alone or in combination with chemical insecticides could be used for the management of insect pest problems of okra, as they are safe, effective and promising in conserving natural enemies, which suppress the pests.

6.5.3 **Effect of neem products on yield**

The effect of neem formulations in reducing the amount of insect-damaged yield was variable. In chilies, both the concentrations of neem oil and 50g/l of neem powder appeared to be effective in reducing the amount of insect-damage. This supports earlier observations by Zeledon (1988), where higher commercial harvests of beans were obtained after application of neem oil formulations. In okra, both the concentrations of neem powder reduced the yield of insect-damaged weight more than the control. Neem oil and NSKE were apparently not effective in reducing the yield loss due to insects. Barahona (1990), Gomez *et al.,* (1990) and Miranda (1992) reported that rational applications of water extract of powdered seed kernel (40g/l) maintained the population of *P. xylostella* larvae at acceptable levels permitting the harvest of better quality, higher priced head cabbage in Nicaragua.

Neem products appeared to increase the quantity of marketable fruits of both crops. However, neem powder appeared to be more effective in reducing the amount of insect damaged fruits on both crops and compared well with the chemicals. Although the efficacy of neem oil in reducing the number of most insect pests was observed, it appeared to be less effective in increasing the amount of marketable fruits compared to the neem powder. Similarly, none of the neem products produced higher damage free yields compared with the chemical treated plots in both crops, but concentrations of neem powder (25, 50g/l) appeared to increase the marketable yields. Despite the apparent inefficiency of some of neem formulations to reduce effectively the yield loss from insect pests, there is an overall benefit in using the neem products. However, integrated pest management strategy, which involves rational use of all control measures is important in order to reduce the cost of production as well as chemical residues in yields.

6.6 Reference

Barahona, L. (1990). Effects of botanicals as biological insecticides on the entomofauna present in cabbage (in Spanish). Thesis Ing. Agr. ISCA, Managua, Nicaragua.

Bhalani, P.A. and Parsana G. J. (1987). Relative toxicity of certain newer insecticides to *Maruca testulalis* (Geyer) attacking pigeon pea. *Pesticides* **21**(4): 23-25.

Bournier, A., Lacasa A. and Pivot Y. (1982). Regime alimentaire d un thrips predateur *Aeolothrips intermidius* (Thysanoptera: Aeolothripidae). *Entomophaga,* 24: 353-361.

Gomez, D., Miranda, F., Guerrero, B., Rivas, I., Mercado, J. and Guharay, F. (1993). Neem for vegetable IPM in Nicaragua: Experiments and small farmers' perspective. *Neem and Environment* **10**: 82-89.

Gomez, D., Siman, J., Rivas, I., Rosset, P., Davila, R. and Guerrero, J. B. (1990). Diagnostics of the factors that influence the yield of tomato in the sixth region, pp 65 (in Spanish) *Memoria Resumen, 4to Congreso Nacional MIP, 3er Congreso Internacional "Humberto Tapia Barquero" (in Memoriam)*, Managua, Nicaragua,.

Guerrero, B. (1992). Evaluation of different formulations and doses of neem (*azadirachtina*) for the control of white flies, *Bamisia tabaci* Genn. (Homoptera, Aleyrodidae) in tomato *Lycorpersicum esculentum*. Mill in the valley of Sebaco, Nicaragua, pp 8. (in Spanish). *Memoria Jornada Gentifica-tecnica sobre el manejo de mosca blanca en el cultivo de tomate. Grupo Interinstitutional de Tomate,* Managua. (Memeo).

Ketkar, C. M. (1976). Utilization of neem (*Azadirachta indica* A. Juss) and its By-products, pp 234. Directorate of Non-edible and soap industries commission, Bombay

Miranda F. (1992). Assessment of the effect of biological and botanical insecticides against *Plutella xylostella*) in cabbage *(Brassica oleracea*) in two regions of Nicaragua. VAXTSKYDDSRAPPORTER, JORDBRUK 59. Swedish University of Agricultural sciences, Research Information Center, Uppsala, Sweden.

Narasimha Rao, B. (1990). Pesticide contamination, pp 1-18. Bulletin by A.P Agricultural University, Hyderabad

Ogol C. K. P .O and Spence J. R. (1997). Abundance, population dynamics and impact of the Leucaena psyllid *heteropsylla cubana* Crawford in a maize-leucaena agroforestry system in Kenya. *Insect Science application* **17**(2): 183-192.

Rivas, I. and Mendez, M. (1991). Effectivity of water extract and preformulated neem products for the control of lepidopteran pests in tomato, 1989-90 (in Spanish). *Annual Tech. Rep, Centro Nacional Proteccion Vegetal*, Managua, Nicaragua.

Roychoudhury, R. and Jain, R. K (1993). Neem for the control of aphid-white fly vectors and virus diseases of plants. *Neem and Enviromment.* Vol. 2. **82**: 763-69.

Roychoudhury, R. and Jain, R. K. (1991). Effect of neem oil and citronella oil on the developments of whitefly (*Bemisia tabaci*) and virus transmission. *Recent Advances in Medicinal, Aromatic and Spice crops*. Vol. I pp 159-61. Today and tomorrow's publishers, New Delhi

Saika, A. K and Muniyappa, V (1989). Epidemiology and control of tomato leaf curl in Sourthern India. *Tropical Agriculture,* **66**: 350-354

Samalo, A.P and Patnaik. H. P. (1986). Efficacy of different insecticides and their frequency of application on the pod borers infesting pigeon pea. *Madras Agricultural journal* **73**(6): 352-54.

Saxena, H. P (1978). Pests of grain legumes and their control in India, pp 15-23. In. *Pests of grain legumes, ecology and control.* S. R. Singh., H. F. Van Emden and T. A. Taylor (eds.), Academic press, London

Saxena, H. P. (1981). Insect pests of arhar. *Indian Farmg.* **31**(12); 16-17.

Simmonds, N.W (1976). Principles of Crop Improvement. In. Dent, D (1993) Insect pest management, pp 118. CAB International, Wallingford, UK

Statistical Analysis Systems (1995). *SAS Users Guide. Statistics, Version* 8 edn. SAS Institute Inc., Cary, NC.

Venkateswara Roa, S. and Rosaiah, B. (1993). Evaluation of Botanical insecticides alone and in combination with carbaryl against insect pest complex of okra. *Neem and Environment* Vol. I. **50**: 494-96.

Zeledon, B. (1988). Effects of neem oil on the oviposition of white fly (*Bamisia tabaci*) in bean seedling (in Spanish). Thesis Ing. ISCA, Managua, Nicaragua.

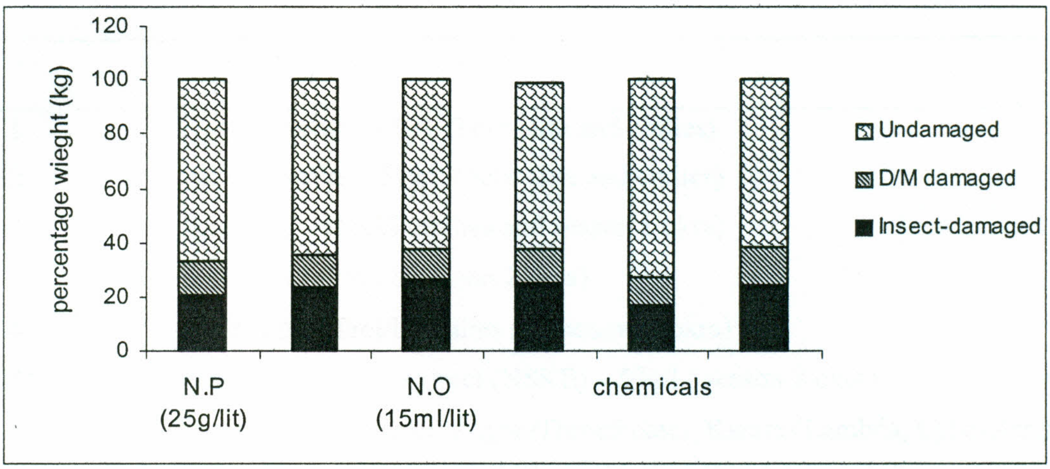

Fig. 6.1.a Percentages of fruit categories of okra during the first crop season (Oct 1998-Jan 1999). N.P= neem powder, N.O= neem oil, D/M= diseased/ other damaged

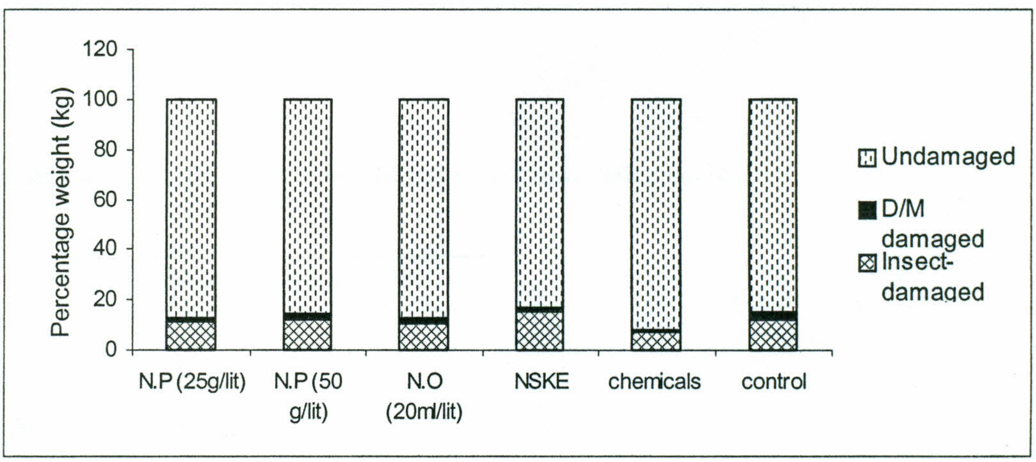

Fig 6.1.b Percentages of fruit categories of okra during the second crop season (Jan-April 1999). N.P= neem powder, N.O= neem oil, D/M= diseased/ other damaged

Table 6.1 Treatments modules.

	Treatment module and concentration
1	Neem powder –25g/l (both okra and chilies)
2	Neem powder – 50g/l (both okra and chilies)
3	Neem oil – 15ml/l (chilies and season 1 okra)
3*	Neem oil – 20ml/l (season 2 okra)
4	Neem oil – 20ml/l (chilies and season 1 okra)
4*	Neem seed kernel extract (NSKE) – 50g/l (season 2 okra)
5	Chemicals – (Evisect, Rogor (Dimethoate), Karate (Lambda, Cyhalothrin),
6	No treatment application (chilies and okra)

* -Formulated only in the second season crop of okra as a treatment

Table 6.2 Aphids, white flies and red spider mite rating scale

Rating	Estimated population
1	1-10
2	11-50
3	51-100
4	101-500
5	> 500

Table 6.3 Insect damage rating scale

Rating	% plant defoliation
1	1-10 %
2	11-25%
3	26-50%
4	51-75%
5	>76%

Table 6.4 Fruits grading system

Grade	Criterion of grading
1	Insect-damaged fruits
2	Any other damage
3	Undamaged fruits

Table 6.5 Relative effect of neem products on pests of okra at Kibwezi, Oct1998- Jan 1999 and Jan-April 1999.

Pest group (count/score)	Seasons (S1,S2)	Neem Powder (25g/lit)	Neem Powder 50g/lit.	Neem oil (15ml/lit.	Neem oil (20ml/lit)	NSKE 50g/lit.	Chemicals	Control
Aphids	S1	1.99a	2.06a	1.76ab	1.75ab		1.15b	2.45a
(score)		±0.39	±0.38	±0.31	±0.32		±0.21	±0.46
	S2	2.27a	2.22a		1.86a	2.06a	0.91b	2.32a
		±0.17	±0.20		±0.26	±0.25	±0.12	±0.22
White	S1	2.05	1.86	1.55	1.72		1.73	1.78
flies (score)		±0.28	±0.27	±0.29	±0.28		±0.20	±0.32
Leafhopper	S1	1.26	1.3	1.18	0.97		0.81	1.48
(count)		±0.19	±0.26	±0.24	±0.09		±0.07	±0.22
Cotton stainer	S1	1.05	1.03		0.88		0.79	0.90
(count)		±0.22	±0.15	0.71	±0.11		±0.09	±0.19
	S2	1.47	1.17	±0	1.54	1.25	1.18	1.22
		±0.60	±0.46		±0.39	±0.39	±0.18	±0.30
Caterpillar	S1	1.59	0.71	0.71	0.77		0.71	0.98
(count)		±0.81	±0	±0	±0.06		±0	±0.15
	S2	0.94	1.03		0.94	0.85	0.71	1.03
		±0.15	±0.15		±0.15	±0.15	±0	±0.15
Leaf	S1	3.11	2.25	2.17	2.49		1.96	2.58
Miner		±0.46	±0.47	±0.35	±0.37		±0.40	±0.47
(count)	S2	6.86	6.26		4.83	6.73	4.31	6.69
		±1.38	±1.54		±1.77	±1.66	±0.56	±2.06
Leaf beetles	S2	1.65	0.94		1.31	1.10	0.79	1.07
(count)		±0.44	±0.15		±0.24	±0.30	±0.09	±0.19
Sucking	S1	0.99	0.88	0.99	0.85		0.98	1.44
bugs (count)		±0.20	±0.11	±0.20	±0.15		±0.27	±0.22
Flower	S1	1.0	0.99	0.71	0.71		0.79	0.88
Beetles		±0.18	±0.20	±0	±0		±0.09	±0.11
(count)	S2	1.59	1.48		1.89	1.62	1.31	1.53
		±0.22	±0.25		±0.28	±0.30	±0.15	±0.21
Fruit borers	S2	—	—	—		—	—	1.14
(count)								±0.44
Flower	S1	1.93	2.16	2.02	0.79		0.85	2.68
Thrips		±0.71	±0.87	±0.69	±0.46		±0.30	±0.64
(count)	S2	4.26	3.0		4.0	3.65	2.20	4.14
		±2.03	±1.68		±2.05	±1.63	±1.55	±1.90
Red spider	S2	2.78a	2.30a	—	2.48a	2.28a	1.11b	2.71a
mite (score)		±0.22	±0.34		±0.37	±0.36	±0.13	±0.32

Means with the same subscripts within a row are not significantly different (SNK), $P<0.05$, and pests scores/counts in which subscripts don't appear were non-significant. —Indicates the absence of observations NSKE= neem seed kernel extract.)

Table 6.6. Relative effect of neem products on beneficial insects of okra at Kibwezi, Oct1998- Jan 1999 and Jan- April 1999

Beneficial insect (counts)	Season (S1, S2)	Neem Powder (25g/lit.)	Neem powder (50g/lit.)	Neem oil (15ml/lit.)	Neem oil (20ml/lit.)	NSKE (50g/lit.)	Chemical	Control
Bees	S1	0.84	0.97 ±0.15	0.71 ±0	0.71 ±0		0.84 ±0.13	0.71
	S2	—	—		—	—	—	—
Wasps	S1	0.84	0.84	0.84	0.71		0.84 ±0.13	0.88 ±0.17
	S2	—	—		—	—	—	—
Coccinellids (to aphids)	S1	0.90 ±0.19	0.79 ±0.09	0.79 ±0.09	0.79 ±0.09		0.71 ±0	0.94 ±0.15
	S2	1.33 ±0.26	1.08 ±0.12		1.01 ±0.12	0.84 ±0.08	0.71 ±0	1.30 ±0.21
Parasitoids	S1	1.31 ±0.35	1.29 ±0.37	0.94 ±0.24	0.94 ±0.24		1.54 ±0.60	2.06 ±0.67
	S2	—	0.97 ±0.26		—	—	—	—
Hover flies	S1	1.06 ±021	1.06 ±0.21	0.71 ±0	0.71 ±0		0.71 ±0	1.13 ±0.28
	S2	—	—		—	—	—	—
Predatory beetles (to mites)	S1	—	—	—	—		—	—
	S2	2.97a ±0.45	1.01cd ±0.18		1.85b ±0.37	1.54bc ±0.46	0.71d ±0	1.46bc ±0.32

Means with the same subscripts within a row are not significantly different (SNK), $P<0.05$, and pests scores/counts in which subscripts don't appear were non-significant. —Indicates the absence of observations, NSKE= neem seed kernel extract.)

Table 6.7 Foliar damage caused by insects of okra at Kibwezi, Oct1998- Jan 1999 and Jan- April 1999.

Treatments	Neem powder (25g/lit)	Neem powder (50g/lit)	Neem oil (15ml/lit)	Neem oil (20ml/lit)	NSKE	Chemicals	Control
Season 1	1.34 ±0.17	1.25 ±0.13	1.54 ±0.17	1.49 ±0.16		1.36 ±0.26	1.63 ±0.18
Season 2	1.85 ±0.34	1.79 ±0.28		1.67 ±0.35	1.88 ±0.35	1.33 ±0.23	2.07 ±0.26

Absence of subscripts after the means within a row are non-significant (SNK, p< 0.05), NSKE= neem seed kernel extract.

Table 6.8 Weight of fruits under different neem treatments on okra. Plot size 4x3m. Kibwezi, 1998-1999.

Treatment	Insect damaged fruits (kg/plot)		Damage free fruits (kg/plot)		% damage free fruits		% yield gain of damage-free fruits in different treatments	
	S1	S2	S1	S2	S1	S2	S1	S2
25g/l- neem powder	6.19b	2.3 ab	20.27	18.15	66.8	87.1	5.4	3.5
50g/l- neem powder	7.25a	1.9 ab	20.15	15.87	64.6	87.4	3.2	3.8
15ml/l- neem oil	7.21a	—	21.6	—	62.3	—	0.9	—
20ml/l- neem oil	7.9a	2.9a	20.29	23.16	63.1	86.9	1.7	3.3
50g/l NSKE	—	2.5 ab	—	14.68	—	84.0	—	0.4
Insecticides	6.96b	1.3b	24.54	16.0	69.4	91.8	8.0	8.2
Control	7.56a	2.1ab	18.89	13.73	61.4	83.6	NA	NA

Figures are square root transformation of weight in kg. Means with the same letter are not significantly different (SNK), P<0.05, and figures in which subscripts don't appear were non-significant, season 1 and 2 are rows denoting the means of yield in the first and second season respectively, NSKE= neem seed kernel extract.

Table 6.9 Relative effect of neem products on pests of chilies over one crop season trial at Kibwezi, Jan- May 1999.

Pest group (/count) ±	Neem Powder (25g/lit)	Neem Powder (50g/lit)	Neem oil (15ml/lit)	Neem oil (20ml/lit)	Chemicals	Control
White flies (score) ±	1.88a 0.17	1.92a 0.25	1.52ab 0.32	1.56ab 0.21	1.03b 0.15	1.90a 0.28
Leafhoppers (count) ±	1.69a 0.20	1.68a 0.21	1.70a 0.21	1.50ab 0.20	1.26b 0.15	1.87a 0.16
Caterpillars (count) ±	1.10 0.13	0.84 0.13	0.84 0.13	0.84 0.13	0.84 0.13	0.93 0.22
Leaf miner ±	0.94 0.15	0.71 0	0.88 0.11	0.79 0.09	0.71 0	0.88 0.11
Leaf beetles (count) ±	0.82 0.12	0.85 0.10	0.85 0.10	0.76 0.05	0.90 0.10	0.90 0.10
Sucking bugs (count)	1.22	0.71	0.71	0.71	0.71	0.71
Fruit borers (count) ±	0.84 0.13	0.84 0.13	0.71 0	0.84 0.13	0.71 0	1.10 0.13
Flower thrips (count) ±	3.54a 0.31	3.60a 0.39	3.10a 0.53	3.40a 0.59	1.37b 0.33	3.77a 0.41

Means with the same subscripts within a row are not significantly different (SNK), P<0.05 and pests scores/counts without subscripts were non-significant. NSKE= neem seed kernel extract.

Table 6.10. Effect of neem products on beneficial insects on chilies at Kibwezi, Jan- May 1999

Treatment	Neem Powder (25g/lit)	Neem Powder (50g/lit)	Neem oil (15ml/lit)	Neem oil (20ml/lit)	Chemicals	Control
Bees and Wasps	1.12a ±0.08	1.03abc ±0.07	1.14ab ±0.08	0.94bc ±0.06	0.83c ±0.04	1.21a ±0.07

Means with the same subscripts within a row are not significantly different (SNK), P<0.05
NSKE= neem seed kernel extract.

Table 6.11. Yields of chilies under different neem treatments at Kibwezi, Jan- May 1999, plot size 4x3m.

Treatment	Insect damaged yield (kg/plot)	Damage free yield (kg/plot)	% damage free yield	% yield gain in different neem treatments
25g/l- neem powder	10.99	44.45	65.9	1.8
50g/l- neem powder	8.16	44.16	70.4	6.3
15ml/l- neem oil	9.59	37.01	66.4	2.3
20ml/l- neem oil	8.55	37.18	65.1	1.0
Chemical	7.03	37.72	71.1	7.0
Control	10.73	37.8	64.1	NA

Means within the same column without subscripts are not significantly different (p<0.05), NA= not applicable.

CHAPTER SEVEN

7.0 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1 General Discussions

It has come out that a major contribution has been achieved from this research on vegetables. Apparently, vegetable production is an important income generating activity among many Kenyans, but this activity is in the danger of extinction if appropriate measures are not taken in advance to save the situation. Like many crops in the tropics, vegetables are also susceptible to pest and disease attack and this has necessitated the frequent use of chemical insecticides. This has led to an increased cost of production and high chemical residues in the produce. Consumers, especially importing countries are worried of the high levels of chemical residues. On the other hand farmers are spending more purchasing pesticides because pests develop resistance to these chemicals. Thus, the study has tried to explore alternatives in pest management in the Asian vegetable industry and has provided a baseline information on pest dynamics and critical stages of intervention for the two crops and possible environmentally friendly alternative control measures.

Observations of pests on okra and chilies under different treatment regimes over a period of two seasons provided baseline information on pest dynamics, the critical stage of pest infestation and the appropriate time for crop protection in semi-arid regions. Whereas, pests occurred at different times of crop growth for most pests, there was a trend of increasing from low infestation levels to high infestation levels during the crop growth before any limiting factors regulated their counts. However, insect pests of chilies were not as damaging to the crop as the diseases. Of all the insect pests of both crops, the fruit borers even in low populations, flower beetles and flower thrips were the most crucial pests causing yield loss in addition to the disease-spreading whiteflies and aphids.

Insect pests develop resistance after a continuous use of pesticides (Yu, 1993) and this was evident in the farm on which trials were conducted. Not all of the pesticides used at various intervals were effective against the pests. Systemic pesticides provided better protection to the crops against pests over long periods. However, an integrated pest management approach involving rational use of other control measures would provide a long lasting solution. The protection offered at certain short intervals of the various growth stages did not make any significant difference on the overall pest populations on the crops.

Natural enemies of insect pests of okra and chilies may have an important role in regulating pest populations. Under natural circumstances when limiting factors are constant, pest populations can be kept at minimum levels. However, man has destabilized the ecological conditions by abuses, overuse and misuse of chemical insecticides and eventually this has negatively affected the natural enemies. Apart from chemical insecticides, natural enemies are also faced with the problem of parasitism and hyperparasitism. Therefore, there is a need to conserve these natural enemies, as the chemical insecticides are increasingly becoming ineffective.

From the studies on insect damage and associated yield loss, it's apparent that insects affect and reduce the attainment of quality yields. In order to establish yield loss from insect damage, an ideal situation is required since yields are rarely optimal for all the various limiting individual components. Normally, the actual yield obtained is well below the optimum potentially attainable. Losses due to pests constitute just a small part of the complex of production constraints and yet their measurements alone provide multitude of problems to unravel and evaluate.

Results from the use of neem suggest that neem formulation either alone or in combination with chemical insecticides, could best be used for the management of the insect pest problems on okra and chilies, as they are safe, effective and promising in conserving natural enemies, which suppress the pests. It is apparent that neem oil appeared to be effective in reducing the population of most insect pests of okra and chilies, in addition, it appeared that all the neem products conserved the natural enemies that are important in regulating pests populations. However, neem powder appeared to have a higher yield gain of the marketable produce in both crops but more tests will be required to evaluate further promising effects of neem oil and NSKE on the pests with a direct impact to the yields.

7.2 Conclusions

The study has provided the following important findings ÷

a). Study provided baseline information on pests' dynamics of okra and chilies.

b). Study provided baseline information on critical stage of pest infestation and appropriate time for crop protection.

c). Study revealed that insect pests of chilies were not as damaging to the crop as the diseases.

d). For both crops, fruit borers, flower beetles and flower thrips were the most crucial pests causing yield loss in addition to the disease transmitting whiteflies and aphids.

e). Neem oil appeared to be effective in reducing the population of most insect pests of okra and chilies than neem powder and neem seed kernel extract.

f). All neem products conserved the natural enemies.

7.3 Recommendations

The following recommendations would provide reliable information on yield loss of okra and chilies in the semi-arid regions of Kenya ÷

i). Establishing the distribution and infestation of insect pests and the associated yield loss within and between localities and regions. An assessment of crop loss in a locality may be required in order to allow policy decisions to be made concerning priorities for research (which pest and or crop to study), and also assessing the need for controlling and identifying the regions, crops etc. most in need of assistance.

ii). Establishing the population structure of the infesting pest population in order to assess accurately the effect of insect intensity on yield loss.

iii). Assessing the physiological impact of pest infestation and it's implications on plant development and growth, since this may provide a better indication of the processes involved in yield reduction especially in complex multitude pest situations like the one encountered in this study. Plant growth analysis and plant growth models will be appropriate in this context.

iv). Quantifying the differences between crops on research stations/commercial farms and those in typical farmers' fields with the regard to the crop itself and, the pests and natural enemies present. Reed *et al.*, (1985) warns of anomalies that may occur as a result of conducting experimental trials at research/ commercial farms where cropping seasons are prolonged, with irrigation facilities, pest free crops, sick plots for maintaining pathogens etc. Particularly in the semi-arid tropics, such farms stand out as green oases which acts as reservoirs for pests.

7.4 Reference

Yu, S.J (1993). Inheritance of insecticide resistance and microsomal oxidase in the diamondback moth (lepidoptera: Yponomeutidae). *Journal of Economic Entomology,* **86**: 680-683

Reed, W., Davies, J.C and Green, S. (1985). field experimentation, pp 153-74. In Haskell, P.T. (ed.), *Pesticide Application: Principles and Practice.* Clarendon press, Oxford

KENYATTA UNIVERSITY LIBRARY