The use of neem products for sustainable management of homopterous key pests on potato and eggplant in the Sudan

By

Hamadttu Abdel Farag El Shafie

B.Sc. (Agric. Honor) University of Khartoum-Sudan

M.Sc. (Agric.) University of Khartoum-Sudan

Thesis

Submitted in fulfillment of the requirements for Doctor degree in agriculture (Dr. agr.)

(Fachbereich Agrarwissenschaften, Ökotrophologie und Umweltmanagement der Justus-Liebig-Universität Giessen)

Institute of Phytopathology and Applied Zoology

Experimental station

Justus Liebig University of Giessen

2001

Dissertation im Fachbereich Agrarwissenschaften, Ökotrophologie und Umweltmanagement
Institut für Phytopathologie und Angewandte Zoologie
der Justus-Liebig-Universität Gießen
27. August 2001

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„ Gedruckt mit Unterstützung des Deutschen Akademischen Austauschdienstes“

PREFACE

Sudan is a vast country with a total area of about 2.5 millions square kilometers. It is inhabited by a population of approximately 30.5 millions. Eighty percent of the work force is engaged in agricultural activities. More attempts of using different synthetic pesticides were made in the past and are being made at the present time to keep crops and their products out of the mandibles of the tiny arthropod animals. These arsenals of chemical are not without shortcomings for the environment and consumer's health. Moreover, they are very expensive and exhaustive to the limited returns of the farmers.

Around 2000 plant species or perhaps more have been examined worldwide for their biological activity against insect pests. The most important products from these plants are pyrethrum, rotenone, nicotine, sabadilla, limonene, and azadirachtin which is now receiving the attention of entomologists worldwide due to its proved efficacy against a wide range of insect pests. Some studies were carried out in Sudan on insecticidal activities of some other plants beside neem, these are ciant milkweed [*Calotropis procera* (Ait)], hoary basil (*Ocimum canum* Sims), bitter apple or in Arabic (handal) [*Citrullus colocynthis* (L.) Schrad.].

My interest in neem was initiated 13 years ago when I was still undergraduate student in the department of crop protection. At that time I came across an article under the title " Hundreds of scientists have met for the sake of a single tree; I remember that there was a picture of an adult desert locust and the word azadirachtin was written in bold. That tree was the neem (*Azadirachta indica* A. Juss; Meliaceae) which I have looked meticulously into the deep and enormous literature concerning the use of its products, and the success achieved so far in different parts of the world. I came out with the question why not this huge potentiality of neem be used in the Sudan? Neem products are not the panacea for all insect pest problems and synthetic pesticides are sometimes the only remedial measure available against outbreaks of local pests or the invasion of migratory ones. Neem products need support by other control tactics and they fit very well in an integrated approach of pest management.

Giessen, April 2001 Hamadttu Abdel Farag El Shafie

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ABBREVIATIONS AND DEFINITIONS OF TERMINOLOGY

AT	Action threshold
AZA	Azadirachtin
CIDS	Cumulative insect-days
CON	Control
EC	Emulsifiable concentrate
ED	Economic damage
EIL	Economic injury level
ETL	Economic threshold level
FAO	Food and Agricultural Organization of the United Nations
FOL	Folimat®
IDS	Insect-days
IM	Imidacloprid
IPM	Integrated pest management
KSS	Knapsack sprayer
NA	NeemAzal-T/S®
NO	Neem oil
NRC	National Research Council (United States of America)
NWE	Neem seed water extract
PLB	Palm leaf brush (straw broom)
RM	Rimulgan (emulsifying agent)
rpm	round per minute
SUM	Sumicidin®
ULV	Ultra low volume
Efficiency	The more or less fixed reduction of the population of the insect pests studied regardless of the number involved.
Emulsifier	Surface active substance used to stabilize suspensions of one liquid in another i.e. oil in water.
Feddan	A square measure for acreage commonly used in Sudan. It is equal to 0.42 ha
Systemic effect	The absorption of and translocation of substances through the vascular system of the plant.

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1 INTRODUCTION

1.1 General

Vegetables together with fruits represent very important and rich sources of essential vitamins, minerals and dietary fiber. They also contain additional calories. Therefore, they are most valuable and nutritious food commodities which can substantially contribute to improve the social welfare and health status of the rural as well as urban populations. FAO (1992) reported a total harvested acreage of vegetables at world level of 1,321,000 hectares, this area represent only 0.81% of the total estimated arable land (162,684,000 ha). This demonstrate clearly the potential for production of more food to meet the demand of the ever increasing world population.

Different vegetables are now cultivated in various parts of the Sudan, the main of which are onion (*Allium cepa* L.; Liliaceae), tomatoes (*Lycopersicum esculentum* Mill.; Solanaceae), potatoes (*Solanum tuberosum* L.; Solanaceae), eggplants (*Solanum melongena* L., Solanaceae), okra (*Hibiscus esculentus* L.; Malvaceae), sweetpepper (*Capsicum annuum* L.; Solanaceae), garlic (*Allium sativum* L.; Liliaceae), cucumbers (*Cucumis sativus* L.; Cucurbitaceae), pumpkins (*Cucurbita maxima* Duch; Cucurbitaceae), Jew's mallow (*Corchorus olitorius* L.; Tiliaceae), purslane (*Portulaca oleracea* L.; Portulacaceae), garden rocket (*Eruca sativa* L.; Brassicaceae), and some other vegetables like carrot (*Daucus carota* L.; Apiaceae), cabbage (*Brassica oleracea* L.; Brassicaceae), red beet (*Beta vulgaris* L.; Chenopodiaceae), lettuce (*Lactuca sativa* L.; Asteraceae) and haricot beans (*Phaseolus vulgaris* L.; Fabaceae). Most of these crops are grown in the winter season (November-March) along the river Nile in the north and its tributaries in the central parts of the country and in the main agricultural schemes like Gezira and Rahad.

Agricultural production in the Sudan was mainly focused on field crops especially the cash ones like cotton, groundnut, gum Arabic and other stable food crops with large acreage, intensive inputs and modern techniques of production. Vegetables were neglected and were left for the domain of private sectors where they were grown in limited areas with low inputs and indigenous way of management. Now, an attention is being paid for the production of vegetables to meet the demand of the rapid expansion of the population, urbanization and the socioeconomic changes that affected the eating habits of the majority of these populations. Peoples have changed their eating habits from traditional meals to healthy, nutritionally well-balanced ones.

In 1992, Sudan harvested around 36,000 hectares of vegetables which represent only 0.28% of its total arable land of 12,830,000 ha. (BAUDOIN 1994).This will obviously reflects the huge potential of increasing vegetable production in the country both horizontally and vertically.

1.2 Historical background, present situation and future prospects

Many traditional vegetables were known to be grown in the central clay plain of the Sudan. The collection of wild vegetables like okra, Jew’s mallow, cucurbits and hot pepper were supposed to originate in Sudan and some vegetables like onion and garlic seem to be known in the Sudan since the old pharaonic era (El HASSEN 1994). Vegetables like tomatoes and eggplant were introduced later. The literature on the introduction of potato to Sudan is contradictory, some agriculturists think that it was introduced to the country during the late 1930s of the last century (EL HASSEN 1994), other think of the early 1920s (ABDALLA and EL SHAFIE 1983; MOHAMED et al.1999).

Potato production was started in the late 1930s in El Gaili north of Khartoum and from there it has spread along the river Nile north and south of El Gaili town, then was taken across the river to El sarrorab and Sheheinab areas where it became one of the most important crop in the area (EL HASSAN 1994). Now the crop is grown in an area of 5000 ha with an average yield of 16.5 ton per hectare (MOHAMED et al. 1999).

The reason behind this increase of potato production could be attributed to the acceptance of taste by consumers, the high price of the product which could be obtained by the farmers and perhaps the relatively long shelf-life of the tubers especially under traditional storage techniques compared to other perishable vegetables. Potato is an important food crop specially in the northern temperate zone. The nutritive value of the crop is high, which is attributed mainly to the biological value of its proteins, vitamin contents especially vitamin C, and the contents of some minerals (VAN DER ZAAG 1976).

About 50% of the potato area in the Sudan is planted with the Dutch cultivars mainly Alpha. Zalinge stocks are local cultivars which are cultivated mainly in western

Sudan particularly in Jebel Mara (elevation of up to 3000 m above sea level) and in the south where two crops can be grown per year (from April to August, and from June to October).

Eggplant is considered as an important crop especially in a complex market of vegetables production systems, where growers may produce around eight different vegetable crops in a season. It was grown in an area of about 3,000 ha (FAO 1992) and the total area under cultivation by this crop has increased to reach 5000 ha in the 1998 with an average total production of 110,000 metric tons (FAO 1998).

The importance of eggplant to the farmers stems from the fact that it has a reasonably consistent and high yield about 19 tons/ha and up to 15 pickings per growing season could be harvested. The crop is relatively hard and could withstand adverse conditions better than other crops. It could also be chopped and allowed to re-grow as a perennial, a practice which is adopted by some farmers as the crop senesce or highly infested by foliage pests. The eggplant is well known for its nutritive value as a source of carbohydrates, proteins, minerals and vitamins (FAO 1995).

1.3 Pests and diseases as major constraints of vegetable production in the Sudan

The environment of the tropics and subtropics is very conducive to the development of pests and diseases throughout the year (BRADER 1979). In the Sudan, this conducive environment is further enhanced by the expansion of vegetable production along the river Nile coupled with mechanization and establishment of agricultural schemes which result in the extension of the growing season. Both the diversification and intensification of the production system deliver more food and shelters for insect pests (ANON. 1986).

Vegetable pests and diseases constitute a challenging problem about which little has been done. It is one of the fundamental problems facing the production of more and sustainable yield of vegetables. Yield losses due to insects pests, diseases and weeds were estimated to be around 25% (ELWASILA 1981) which is by all means a great loss. POLLARD (1955a) was the first to give in one source of useful account on the insect pests of vegetables in the Sudan. A directed research towards the solution of some elementary aspects of vegetable production including control of the common pests and diseases is urgently needed.

In the past ten years, the concern was to increase yield of vegetables by all possible means to meet the high demand regardless of the impact on the environment and sustainability of the agroecosystems. In an attempt to curb the pests population with synthetic pesticides, evidence of irrational use appeared and seems to be responsible for many environmental hazards and contamination risks of vegetable products

1.4 Aims of the study and future orientations

To help alleviate the existing problems and to contribute to long-lasting solutions, the present work was chosen to focus on two important solanaceous vegetable crops, namely potato and eggplant. They rank third and fourth, respectively, in the order of importance among the major vegetables grown in the country. They come after tomatoes, onion and water melon with respect to the area of production (ANON. 1986). Among the many insect pests which attack these two crops, only homopterous mainly jassids, whitefly and aphids were selected as foliage pests for this study, because of the severe damage they inflict on these two crops. Laboratory, semi-field and field trials were conducted in an attempt to construct a foundation for the management of these pests in the Sudan and to stimulate other researcher to pay more attention to vegetable pests and to contribute in the establishment of a sustainable production system.

Future activities will be aimed to increase production of vegetables for the local market with the use of locally produced neem formulations where the cosmetic quality of the product is not so high as in the case of production for export. In this case the neem products could be used as cheap, available, renewable and environmentally friendly insecticides. The role of natural control agents will be fully exploited, every effort will be made to enhance their action and the production of organic vegetables and ecological farming will be the theme of my research activities in the future.

The present work has the following four major objectives:

a) To judge the performance of standardized commercial neem products in on-farm trials and to compare their efficacy with the most commonly used synthetic insecticides.

b) To evaluate the potentiality of neem products as a home-made insecticide and to examine their role in the management of three homopterous pests of potato and eggplant.

c) To investigate the possible side-effects of the neem products, both commercial and home-made on beneficial insects particularly predators.

d) To establish an action threshold for the cotton jassid on potato adaptable to the local farmers.

2 REVIEW OF LITERATURE

2.1 Economic importance of homopterous pests associated with potato and eggplant, their injury and feeding habits

There are enough differences between the Homoptera and Hemiptera (Heteroptera) to recognize them as separate orders, and still some authors consider the Homoptera to represent a suborder of Hemiptera (BORROR et al. 1989). They divided the order Homoptera into two suborders, the Auchenorrhyncha and the Sternorrhyncha. The former is further divided into superfamilies and families, it includes the superfamily Cicadoidea and the family Cicadellidae (Jassidae) to which the leafhoppers or jassids belong. The latter includes the superfamilies Aleyrodoidea and the family Aleyrodidae of the whiteflies as well as the superfamily Aphidoidea and the family Aphididae of the aphids.

The Homoptera consists of large group of far more than 20,000 species which are found in nearly all climates, but prefer the tropics and subtropics (SCHMUTTERER 1969). The order rank fifth in global diversity after the largest insect orders (Coleoptera, Hymenoptera, Lepidoptera, and Diptera) (CODDINGTON and LEVI 1991). This order includes plant sucking insects, such as leafhoppers, planthopper, aphids, whiteflies, psyllids, and scale insects. The members of this group are highly successful and specialized plant parasites (SAXENA 1995, COHEN et al. 1996). They cause considerable damage to agricultural crops world-wide (SCHMUTTERER 1969, EL HAG and HORN 1983) and they affect the plants in many different ways.

A typical direct effect is caused by the removal of the plant sap and nutrients from the vascular bundle (MITTLER 1967). They also reduce the chlorophyll content of the leaf and photosynthetic capacity per unit of remaining chlorophyll (BUNTIN et al. 1993). The ability of homopterous pests in the transmission of phytopathogenic viruses and MLOs is well known as an indirect effect of this group of insect pests (GRANADOS et al. 1968; SCHMUTTERER 1969; ROSE 1974; BIRD and MARAMOROSCH 1978).

Many homopterous produce copious excretion of sugary material known as honey dew or asal (in Arabic) which encourage the growth of sooty mould on the plant. The build up of sooty mould gives the plant a blackened appearance and dirt may also adhere on the honey dew and this together with sooty mould cause some retardation in the photosynthetic ability of the affected plants (RIPPER 1965). The symptoms produced by jassid on different plants was described by JOYCE (1961) as hopperburn. This symptom appears as triangular brown areas which begin at the tip of an infested leaflet and progress basipetally toward the center of the leaflet as the feeding continues (LADD and RAWLINS 1965); they pointed out that the injury could be detected before the hopperburn appears as curling of the leaflet and whitening of veins on the under surface of the leaf. Jassids could also do damage to plants during the act of oviposition (RIPPER 1965).

The literature concerning the production of hopperburn by jassid is very rich and many theories have been put forward to explain the phenomenon. Some authors suggested that it is mechanical due to the blockage of phloem with saliva during feeding, others stressed the accumulation of photoassimilates in the leaves. Further information on this topic is found in the articles written by the following authors (SMITH and POOS 1931; NIELSON et al. 1990; ECALE and BACKUS 1995). The feeding site in the plant tissue, the morphology and the stylet penetration of the three homopterous pests under the current investigation is given in Table 1.

Table 1: Morphology of the stylet, feeding behavior and feeding sites of jassid, whitefly and aphid.

Species	**Feeding site**	**Morphology of the stylet**	**Stylet Penetration**	**Reference**
Jacobiasca lybica (cotton jassid)	Phloem Xylem Mesophyll	With barbs	Intracellular	SMITH 1926 RIPPER 1965
Bemisia tabaci (cotton whitefly)	Phloem	Smooth	Intercellular Stomata	NAULT & RODRIGUEZ 1985 SCHMUTTERER 1969
Aphis gossypii (cotton aphid)	Phloem	With barbs	Intercellular (mainly) Intracellular	NIELSON et al. 1990 POLLARD 1968

JOYCE (1961) reported the cotton whitefly on 150 plant species in the Gezira region including all common annual weeds. He listed the number of host plants to be visited by jassids which were 53 species also including the annual weeds.

The economic importance of homopterous pests to the Sudanese agriculture in general and vegetables in particular has been documented in the past fifty years by so many authors, the following are pre-eminent (HANNA 1950; JOYCE 1961; EVANS 1963, 1965; RIPPER 1965; SCHMUTTERER 1969; ELWASILA 1973; EL KHIDIR 1976/77; ELWASILA and BURGSTALLER 1984; BINYASON 1997).

2.2 The effect of neem products on homopterous key pests.

Most neem studies have involved insects with chewing mouthparts, whereas agricultural pests with piercing-sucking mouthparts have not been thoroughly investigated (SCHMUTTERER 1990). The neem tree, *Azadirachta indica* A. Juss. produces many limonoid allomones with known biological activities, which were extensively studied during the past 30 years and demonstrated to have a remarkable effect against 413 species in 16 different insect orders including Homoptera (SCHMUTTERER and SINGH 1995). The biological activities of the neem allelochemicals include feeding and oviposition deterrence, repellency, growth disruption, reduced fitness and sterility (SCHMUTTERER 1990).

Since homopterous insect pests are piercing and sucking ones depending mainly on the plant sap as a source of nutrients, the systemic action of neem products is of considerable interest in maintaining the population of these notorious pests below a level which causes economic damage. The importance of using azadirachtin in the field at the levels causing primary antifeedancy may have been overemphasized in the past (MORDUE (LUNTZ) et al. 1996); although they agree with this concept which is applicable and sound for many species, they emphasized that the control of other pests, e.g. aphids, may best be achieved using level of azadirachtin (AZA) below those which cause primary antifeedancy but causes a reduction in fitness and fecundity. SAXENA (1995) stated that the growth inhibitory and disrupting effects of neem derivatives on homopterous insects are much more pronounced than either the repellent or the antifeedant effect. The same results were found by MOURIER (1997) on cassava mealy bug (*Phenacoccus manihoti*). LOWERY and ISMAN (1994) demonstrated that nine species of aphids were susceptible to the insect growth regulating (IGR) activities of neem seed oil or AZA, and the mortality occurred mainly during failed attempts to moult.

The argument of MORDUE (LUNTZ) et al. (1996) is that the strategy of using neem product at low levels with the systemic mode of action may give the added benefit of not harming beneficial insects. This strategy is well supported by the evidence that the neem products can be easily taken and translocated by different parts of the plant which was demonstrated by OSMAN and PORT (1990) who studied the uptake of the neem products by the root system of the intact cabbage plant. The uptake of the active principles of neem occurs by the intact plants of several species e.g. *Chrysanthemum spp*. which caused antibiosis against agromyzid flies (LAREW et al. 1985). The systemic action of neem products against sucking insects is well documented (LAREW 1988; OSMAN and PORT 1990; NISBET et al. 1993). Many homopterous insects particularly planthopper and aphids are highly sensitive to neem products (NRC 1992). The effectiveness of these products appear to be influenced by many factors e.g. the host plant, insect species and weather conditions (LOWERY et al. 1993). Neem-based insecticides can be effective in controlling aphids (SCHAUER 1984, SCHMUTTERER 1990; NISBET et al. 1994).

Most of the earlier investigations concerning the effect of neem products on homopterous insects were carried out either in the laboratory or the greenhouse. Some practical experiments were also carried out in the field. Due to the differences of the conditions of the laboratory and the field and the difficulty in extrapolating the results of the former to the latter, the survey of the literature on this topic is reviewed under two separate subheadings: laboratory/greenhouse and field experiments.

2.2.1 Laboratory and greenhouse experiments

NISBET et al. (1994) used a concentration as low as 25 ppm in AZA-treated diet to study its effect on the peach-potato aphid *Myzus persicae*. They reported a post-ingestive secondary antifeedant effects as well as drastic reduction in fecundity. No nymphs were produced by aphids previously fed on diet containing 25 ppm AZA and all nymphs produced by aphids that had ingested diet containing 10-20 ppm Aza were non-viable (MORDUE (LUNTZ) et al. 1996). Neem seed extract reduced oviposition, prolonged larval development, and induced larval mortality of *Bemisia tabaci* on cotton foliage (COUDRIET et al. 1985b).

2.2.2 Field experiments

SAXENA et al. (1981) treated rice plants with an ultra low volume (ULV) spray of 3% neem oil and found them to be less attractive to the brown planthopper *Nilaparvata lugens* and the white backed planthopper *Sogatella furcifera* than control plants. *Bemisia tabaci* was controlled with different treatments of neem water extract in a field trial on eggplant in the Dominican republic (SERRA and SCHMUTTERER 1993). LOWERY et al. (1993) used neem seed oil (NSO) and neem seed extract (NSE) in field trial against different species of aphids, they demonstrated that the materials were effective aphicides and their performance was as effective as the botanical insecticide Pyrethrum especially on pepper and strawberry, but less effective for the control of aphids on lettuce.

The application of neem extract of ground fruits and leaves soaked in water used at a rate of 1 kg/40 liter water controlled foliage pests of potato namely; *Jacobiasca lybica*, *Aphis gossypii* and *Bemisia tabaci*. An increase in yield of 0.5 ton/ha was reported (SIDDIG 1987). DREYER (1987) obtained good results in controlling *Jacobiella facialis* in a field of eggplant in Togo (west Africa) by weekly application of aqueous extracts prepared with 25 or 50 g neem kernel powder (NKP) per liter water. He applied also neem oil with a mini ULV sprayer at a rate of 5 or 10 l/ha, and obtained results similar to that of water extracts.(the concentration of AZA content was not specified in both formulations).

2.3 Side-effects of neem on beneficial arthropods and other organisms

2.3.1 Predators and parasitoids

To use neem allelochemicals as soft pesticide in IPM programs, their impact on predators and parasitoids of agricultural pest should be studied in more details (LOWERY et al. 1993; SCHMUTTERER 1997). Very little work has been published on the effects of neem extracts and other neem products on natural enemies of agricultural pests or host/parasitoid relationship (OSMAN and BRADELY 1993; ROGER et al. 1995). Neem products are safe to spiders, adults of numerous beneficial insect species and eggs of many predators such as coccinellids whereas the nymphal/larval instars are more or less susceptible especially under laboratory conditions (SCHMUTTERER 1997); he also attributed the resistance of spiders to neem products to the fact that they have hormonal system differing more or less from that of insects. Some of the previous works carried out so far to determine the side-effects of neem products on predatory arthropods and parasitoids is given here under the following two sub-headings:

2.3.1.1 Laboratory experiments

Experiment with adults of the coccinellid beetle (*Coccinella septempunctata*) kept on neem oil-treated glassplates did not show increased mortality or reduction of fecundity when compared with untreated control, but the metamorphosis of the larvae was interrupted (SCHMUTTERER 1981). The European earwig (*Forficula auricularia*) showed no increased mortality or reduced ingestion when treated with NeemAzal-F; the fecundity of the tested animals was not adversely affected (SAUPHANOR et al. 1995). ROGER et al. (1995) studied the effect of neem oil and neem aqueous suspension on the predacious coccinellid (*Coleomegilla maculata* Lengi Timb.). They found that only one dose of neem oil (10%) AZA content, v/v 13.7 ppm resulted in significantly greater mortality than in the control group. Azatin was reported to cause less mortality on this predator compared with the synthetic carbamate carbaryl (Sevin) (SMITH and KRISCHIK 2000). On the other hand, treatment with aqueous suspension of ground neem seeds showed no toxicity but caused 50% reduction in the number of aphid consumed after fifteen minutes from the start of the experiment. Laboratory experiment conducted by KAETHNER (1990) showed 79% mortality in larvae of the broad-spectrum predator (*Chrysoperla carnea*) after topical treatment with a mixture of 1000 ppm AZT-UR-K and 250-30,000 ppm neem oil.

LOWERY and ISMAN (1995) reported that the eclosion of adults of the coccinellids (*Coccinella undecimpunctata*) and the syrphid (*Eupeodes fumipennis*) was negatively affected by the application of neem oil in concentrations of 0.5%, 1% and 2%. Both predators and their prey were kept on potted canola (rape) plant. The eclosion of adult derived from neem-oil treated larvae was completely prevented in the former and reduced to 11%, 7% and 0% respectively in the latter. The foraging behavior of the coccinellid *Cryptolaemus montrouzieri* was influenced by application of crude neem seed extract and Azatin EC (commercial neem based product) in a laboratory experiment (SIMMONDS et al. 2000).

SCHUSTER and STANSLY (2000) tested Azatin EC on two species of green lacewings, *Chrysoperla rufilabris* and *Ceraeochrysa cubana* at a concentration of 0.005% AZA by weight. They found that the neem product was not toxic to eggs, larvae and adults topically or residually. On the other hand NeemAzal-T/S (formulation dried residues on glass panes) was harmful to larvae of the lacewing *Chrysoperla carnea* causing mortality and difficulties to molt (HERMANN et al. 1997). SRIVASTAVA et al. (1997) studied the effect of alcoholic and hexane extracts of 17 neem ecotypes on the external gregarious larval parasitoid *Bracon brevicornis* (Wesm.) in India and reported toxic effects on its egg, larval and pupal stages. FELDHEGE and SCHMUTTERER (1993) reported that the application of Margosan-O at a rate of 10 ppm was not toxic to the parasitoid (*Encarsia formosa*) of the greenhouse whitefly (*Trialeurodes vaporariorum*) but a concentration of 20 ppm caused slight but significant reduction of the fitness of the parasitoid. So, in all, under hard and artificial laboratory conditions it is possible to induce some effects of Azadirachtin on beneficial insects.

2.3.1.2 Field experiments

Adults of a syrphid fly derived from the larvae collected in the field on peach trees treated with NeemAzal-F showed marked reduction in number (EISENLOHR et al. 1992). SAUPHANOR et al. (1995) showed that the nymphal population of the European earwig was reduced by 70% when sprayed with NeemAzal-F at a concentration of 50 ppm. The authors admitted that if a high population of the predator is required to obtain sufficient reduction of aphids, application of NeemAzal-F should be avoided. It worth mentioning here that the above stated insect is polyphagous and behaves as both pest and predator depending on the prevailing conditions (SCHMUTTERER 1997). NeemAzal-S, an old formulation, had also negative environmental effect which was attributed to its emulsifier and solvent agents (SAUCKE and SCHMUTTERER 1992). OSMAN and BRADELY (1993) showed that neem seed extract was capable of having direct negative effects on the braconid parasitoid of the larvae of the cabbage butterfly (*Pieris brassicae*).

2.3.2 Pollinators

Insect pollinators play a very crucial role in the ecosystem. They pollinate many of the most economical crops as well as wild plants. Thus maintaining an ecological biodiversity and contribute more to agricultural sustainability. The majority of the insect pollinators belong to the order Hymenoptera and bees are the most important group. Bees could be solitary, semi-social or social bees and all or some of these groups are encountered in the different agroecosystems and hence the review of the effect of neem products on them is of importance. The side-effect of the neem products on the honey bees will be emphasized in this chapter and it could be extrapolated to other hymenopterous pollinators which occur less frequently than the honey bees but still they contribute in the pollination of agricultural crops.

In greenhouse trials conducted in the Federal republic of Germany, bee colony consisting of a queen and about 3000 workers showed no negative effect of fitness of the workers nor the breeding activity after three sprayings of *Phacelia tanacetifolia* and other plants in full blossom with 500 ppm AZT-UR-K per liter of water, but very small bee populations consisting of a queen and about 200 workers were temporarily affected owing to the difficulties of some young bees in emerging from the cells (SCHMUTTERER and HOLST 1987).

Margosan-O (commercial neem-based insecticide) proved to be non-toxic to honey bee workers in the United States after application as a direct contact product in concentration up to 4418 ppm AZA/ha (SCHMUTTERER 1990). REMBOLD et al. (1981) stated that the honey bee (*Apis mellifera* L.) is sensitive to neem extract especially the pure active ingredient azadirachtin A. Under field conditions serious damage to the bees by the neem products seems to be unlikely, however, they are not completely safer to bees and to exclude any risk they should be avoided (SCHMUTTERER and HOLST 1987). NeemAzal-T/S was sprayed at a rate of 6 l/400 l water on flowering plants (*Phacelia tanacetifolia* and *Brassica napus*) grown in tents containing bee hives: no negative effects on the worker bees or brood were reported in the hive (LEYMANN et al. 2000). The effect of neem oil emulsions (3% and 6%), aqueous neem seed extract (5% and 10%) and aqueous neem kernel extract (5%and 10%) on the Indian bee, *Apis cerana indica* ; the little bee *Apis florea* and the dammer bee *Melipona iridipennis* was studied by SADAKATHULLA (1994). He reported no significant difference between treatments and control on the inflorescence of coconut trees after being sprayed with the neem products.

2.3.3 Compatibility of neem with other entomopathogenic agents

The neem products were found to be compatible with entopathogenic fungus *Nomuraea rileyi* (DEVI and PRASAD 1996), the entomoparasitic rhabditid nematode *Steinernema carpocapsa*e (GUPTA et al. 2000), the bacterium *Bacillus thuringiensis* (WALTER 1999) and the polyhedrosis virus of the gypsy moth *Lymantria dispar* (SHAPIRO et al. 1994) and *Spodoptera litura* (RABINDA et al. 1998).

2.4 Agroecosystem; integrated pest management and the concept of economic threshold

2.4.1 Agroecosystem

Agroecosystems are living, biological systems with many components interacting together in complex ways. The biological forces at work in any ecosystem are extremely powerful and they are only partially controllable by man and then only for short periods. Interference with any one component is likely to affect the rest of the system, and thus it is important to pay attention to the relationships amongst variables as well as the variables themselves. Biodiversity in agroecosystem can not be high because the natural complex of the plants is usually replaced by a monoculture, agrotechniques, for instance ploughing and the usage of pesticides which lead to the elimination of many animals and plants. The degree of intervention and activities of human draw the line of distinction between natural ecosystem and agroecosystem (TSHERNYSHEV 1995). NYFFELER and BENZ (1979) stated that annual crop fields or agroecosystems are disturbed systems where growers periodically destroy the vegetation at the end of each growing season and the system becomes uninhabitable for phytophagous as well as zoophagous arthropods except for the soil-dwellers.

Good knowledge and analysis of the agroecosystem and how it responds to the natural and introduced variables is one key to the formulation of viable pest management packages and reducing both pest losses and environmental contamination (VAN DEN BOSCH and STERN 1962; NORGAARD 1976; LEVIN and WILSON 1980; KOGAN 1998).

2.4.1.1 The role of epigeal predatory arthropods in the agroecosystem

Spiders, carabids, staphylinids and earwigs are hardly mentioned when the talk is about the role of predators in the agroecosystem. This group of polyphagous predators play a very important role in controlling agricultural insect pests. Their significance is well documented in the entomological literature (BASEDOW 1973). Spiders are considered as natural control factors, they feed almost exclusively on insects such as plant bugs, leafhoppers, planthopper, fleahoppers, aphids and thus constitute a regulatory factor in the ecosystem (RIECHERT and LOCKLY 1984; NYFFELER et al. 1994).

The order Araneae is very large, composing of more than 30000 species, and it ranks seventh in term of number of species after the largest insect orders of Coleoptera, Hymenoptera, Lepidoptera, Diptera; and Hemiptera (CODDINGTON and LEVI 1991). The efficacy of spiders as control agents is measured by the predation rate which is defined as the number of prey killed/spider/day and this is variable, depending on spider size, sex and age, the physiological state, weather conditions, and availability of prey (NYFFELER and BREENE 1990). NYFFELER et al. (1994) stated that a typical agroecosystem spider may capture an average of ≈ 1 prey per rain-free day in the field.

Carabids and staphylinids (Coleoptera) and earwigs (Dermaptera) species are also important predators on insect pests in agricultural fields (KAMATA and IGARASHI 1995; SAUPHANOR et al. 1995; ANDERSEN 1997; KOLLAT 1997 ; KOLLAT-PALENGA and BASEDOW 2000). These groups of predators are subjected to the negative effects of the agrochemicals and some entomologists are paying more attention to this problem. Harvesting and tilling of the vegetation and pesticides application represent the major source of mortality to spiders population (RIECHERT and LOCKLEY 1984; GRAVESEN and TOFT 1987; BISHOP and RIECHERT 1990; BASEDOW 1998). The application of the insecticide Parathion when applied in overdose can be very harmful to the population of carabids in the agroecosystem (BASEDOW 2000).

Some agricultural practices were recommended by some entomologists to help alleviate the negative effect of pesticides on carabids, spiders and staphylinids and to encourage the build up of their populations in the temperate region. These measures include the ecological farming and planting of boundaries or hedges at least in some farms in the agricultural area to serve as overwintering sites and reservoir of biocenoses (ANDERSEN 1997; BASEDOW 1998). Except of the observations of CLOUDSLEY and IDRIS (1964) on some activities of zoophagous coleopterous insects, it is hard to find literature on the field activities of carabids, staphylinids and predacious spiders in the Sudanese agroecosystems.

2.4.2 Integrated pest management (IPM)

2.4.2.1 Historical perspective

IPM is considered as important component of sustainable agriculture with the most robust-ecological foundation to arise during the second half of the twentieth century. Although the concept being heavily discussed in all entomological arenas, it is not new and its roots in history can be traced back to the late 1800s when ecology was identified as the foundation for scientific plant protection (KOGAN 1998). In the absence of powerful pesticides, crop protection specialist relied on knowledge of pest biology and cultural practices to produce multitactical control strategies that in some instances were precursors of modern IPM system (GAINES, 1957). CARSON (1962) pointed out the impact of the heavy use of organosynthetic chemicals on the environment.

The impression caused by the publication of the silent spring accelerated the acceptance of integrated control concept (VAN EMDEN and PEAKALL 1996). GEIER (1966) stated that the term pest management has no value other than that of a convenient label coined to convey the idea of intelligent manipulation of nature for human lasting benefit as in wildlife management. The entomological literature recorded 64 definitions of integrated control, pest management or integrated pest management (BAJWA and KOGAN 1996).

A broad definition of IPM is “ integrated pest control is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintain the pest population at levels below those causing economic injury” (FAO 1975). PHILIP et al. (1990) stated that IPM involves strategies for pest control suited to current production practices and the objectives of IPM programs are to maintain farmers income while minimizing the use of chemical pesticides through substitution of information and farmer management skills. KOGAN (1998) analyzed the key words in those 64 definitions of IPM and found that all authors attempted to capture the notion of IPM in term of a) the appropriate selection of pest control methods used singly or in combination b) the economic benefits to growers and society c) the benefit to the environment, d) the decision rules that guide the selection of the control action and e) the consideration of the impacts of multiple pests. He offered the following definition based on the analysis of the definitions developed in the last 35 years. " IPM is a decision support system for the selection and use of pest control tactics singly or harmoniously coordinated into a management strategy, based on cost/benefit analyses that take into account the interests of and impacts on producers, society, and the environment".

2.4.2.2 Decision making and decision rules

2.4.2.2.1 Decision making

Decision making in pest management, like all other economic problems involves allocating scarce resources to meet human needs (MUMFORD and NORTON 1984). The same authors stated that, decision making exist at many levels from farmers, manager and contractors. It is a key aspect of current integrated pest management programs and will continue to play an important role as IPM programs run (WEARING 1988). Decision making depends on protocol for deciding on need for some management action to be done based on an assessment of the state of a pest population and its natural enemies. These protocols which are referred to as control decision rules consist of at least two components and may include a third (BINNS and NYROP 1992).

The control decision rules are: a) a procedure for assessing the density of the pest population (BINNS and NYROP 1992); b) an economic threshold (PEDIGO et al. 1986) and c) a phenological forecast (LOGAN et al.1979). BRADER (1979) stated that in all programs of IPM emphasis is on three elements, these are: a) utilization of workable economic damage threshold and effective pest sampling; b) maximum use of cultural control practices and c) optimum exploitation of natural occurring parasites and predators supplemented by mass breeding and release.

Decisions in pest management is very important for two reasons; first, the decision making protocols, e.g. the use of economic thresholds can be exploited to reduce pesticides needed, second, if control tactics such as biological control and cultural practices fail, the pest control can still be accomplished through the effective use of pesticides and decision and the decision making protocols must be available always to determine when to take control action (BINNS and NYROP 1992).

2.4.2.2.2 The concept of economic threshold

The topic of economic threshold level (ETL) probably is the most often-discussed issue in economic entomology and insect-pest management today. This concept of economic injury level (EIL) is the backbone for the management of pests in an agricultural system (STERN 1973; PEDIGO et al. 1986).The concept of the economic threshold had been introduced by STERN et al. (1959) as the density of the pest population at which control measures should be taken to prevent an increasing pest from reaching the economic injury level. The EIL is always below the ETL to allow for the initiation of the control measures to prevent the pest population from exceeding the economic injury level.

The economic definition of the threshold is the density of pest population where the benefits of the treatment just exceed its costs (MUMFORD and NORTON 1984). Thus, the concept includes: a) threshold for economic damage (ED), which is the amount of injury that justify the cost of artificial control measures, b) the economic injury level (EIL) which is the lowest number of insect pests that will cause economic damage or the minimum number of insects that would reduce yield equal to the gain threshold, and c) the economic threshold level (ETL), which is the number of insects when management action should be taken.

Economic threshold is not static, it may fluctuate with so many factors such as local climatic conditions, time of the year, the stage of plant growth and development, the type of the crop, plant variety, cropping system, the market situation of the crop, the taste of the consumer and the cosmetic quality of the product. High cosmetic quality of product intended for export results in low threshold levels, and the reverse is true for the product of local markets (ROGER 1976). PHILIP et al. (1990) pointed out the importance of considering the interdependencies of many factors such as cropping system, watering, soil conditions, pest-predator interaction in determination of economic threshold; they went to say that any threshold based on limited information and divorced from these factors may not produce optimal control decisions applied to the production system. On the other hand, some entomologists recommended the use of practical action threshold adaptable to the farmer developed from relatively simple data based on empirical evidences and past experiences (CAMMELL and WAY 1987; WEARING 1988).

2.4.3 Economic thresholds established for the jassid, whitefly and aphid in the Sudan

The development of the action threshold for vegetable insect pests based on economic injury levels would be of primary importance in Sudan, as vegetables are largely cultivated by farmers at the subsistence level to whom considerations of the costs of production are vital. Most of the work concerning the economic threshold in the Sudan was done for the major pests of cotton which is the most important cash crop in the country. ABDIN (1963) was the first to initiate studies concerning the economic threshold for the cotton jassid *Jacobiasca lybica* (de Berg) in the Sudan. He used cage experiment and investigated four different jassid levels /leaf (0, 2, 4, and 7) and demonstrated that there was a proportional decrease in yield of cotton as the number of jassid per leaf increased. RIPPER and GEORGE (1965) established a range of 50-100, 100-200 and 200-300 jassid nymphs/100 leaves for the months of October, November and December respectively. They initiated the present figure "50" now associated with jassid ETL. On the other hand, 100 nymphs/100 leaves was found to be satisfactory for spraying (HASSAN 1967). ABDELRAHMAN et al. (1992) proposed that ETL for jassid be increased to 100/100 leaves to replace the "50" level, based on some information collected recently on the population dynamic of this pest. The action threshold (AT) for *Bemisia tabaci* was officially raised from 200 to 600 adults per 100 leaves, and from 20% to 30% level of infestation for the cotton aphid *Aphis gossypii* (STAM et al. 1994). The availability of information on the economic threshold of aphids on cotton in the Sudan is limited and the presently adopted ETL "20% infested plants" has been in use since aphid spraying on cotton started in the late 1970s, however, there was evidence that predation and parasitization of this aphid was considerable (ABDELRAHMAN et al. 1992).

The practical economic damage threshold and the pest sampling methods are comparable from one place to another, thus direct benefit can be drawn from experience gained elsewhere (BRADER 1979). Based on this statement, it worth's to mention that

BASEDOW et al. (1994) determined a threshold for the non-viruliferous cereal aphids attacking winter wheat at 4 aphids per ear and/or flag leaf. They stated that an attack of 65% of ears and/or flag leaves is equivalent to the 4 aphids. The threshold they specified was deduced from 44 experiments carried out over a period of 12 years in the period from 1980 to 1992.

The economic threshold levels determined so far for cotton key pests in the Sudan were based on empirical evidence i.e. by deduction from replicated observations and experience with the pest in the past (STAM et al. 1991). The literature on ETL for insect pests of vegetables in the Sudan is very scant. Nevertheless, some attempts were made and are being made in this context. BINYASON (1997) established ETL for jassid on eggplant at seedling, vegetative, and flowering stages to be 50 jassids/100 leaves, 100-150 jassids/100 leaves and 200-300 jassids/100 leaves respectively. He also specified the action threshold for the same insect on caged eggplant at 0.5 jassid/leaf or 50 jassids/100 leaves in Sudan.

3 MATERIALS AND METHODS

This work was carried out during the period from 1.4.1998 to 28.3.2000 and it is divided into two parts: laboratory/greenhouse experiments and semi-field/field trials.

3.1 Laboratory/greenhouse experiments

All experiments were done with the objective of testing the efficacy of neem-based products against piercing and sucking insects in the laboratory, and to construct a base for further tests in the field. All the laboratory experiments were conducted at the Institute of Phytopathology and Applied Zoology, University of Giessen, Germany. One more greenhouse experiment was carried out in the department of crop protection, University of Khartoum, Sudan.

3.1.1 Laboratory experiments

These experiments were carried out with the aim of determining the effects of NeemAzal-T/S and neem oil on the immature as well as on the adult stages of the greenhouse whitefly *Trialeurodes vaporariorum* Westwood (Homoptera: Aleyrodidae) and to compare their efficacy with Confidor® 70 WG. The greenhouse whitefly was obtained from a colony held in the laboratory. The insects were reared on cabbage plants (*Brassica oleracea* L.; Cruciferae) grown in pots (about 8 cm in diameter). The pots were kept in a cage (49.5 x 49.5 x 59.5 cm) with meshed walls. All experiments were conducted under laboratory conditions of 23.0 ± 2 °C, 40.6 ± 3.0% RH and artificial light of 16 h per day.

3.1.1.1 The effect on the egg stage

A randomized complete block design experiment was carried out in 4 replications to investigate the systemic and contact action of NeemAzal-T/S, neem oil with Rimulgan (Emulgator) on the egg stage of the glasshouse whitefly. Five females were confined at the lower side of the cabbage plant leaf with the help of small screen cage and left for 72 hrs to lay eggs, they were then removed with a fine brush. The number of eggs was equalized to 25 eggs per a single leaf with the help of a binocular. The treatments were applied using a paint-spray device which gives very fine droplets (sometimes called “air-brush”). The number of hatched and unhatched eggs were counted thereafter to calculate the percentage of unhatchability and hence the efficacy of each product.

3.1.1.2 The effect on the nymphal stages

The effect of neem products on the second and third nymphal stages was studied. Adult females were allowed to lay eggs on the underside of the leaves for three successive days, after which all adults were removed with an aspirator. The eggs were allowed to developed into the second and third instars. Then 25 larvae per leaf were encircled with a 5 mm diameter circle made with a red-colored marker. The neem products were applied as in the case of egg stage and Imidacloprid was applied in the soil. The larvae that failed to develop into the puparial stages were considered dead and the percent mortality was calculated according to the following formula:

$$\%Mortality = \frac{NumberofDeadLarvae}{TotalNumberofLarvae} \times 100$$

3.1.1.3 The effect on the puparial stage

Adult females were allowed to lay eggs as in the case of the nymphal stage-experiment and the eggs were allowed to develop into the puparial stage (red-eye stage) which is very easily to identify. Twenty five pupae were encircled with a marker and were considered as an experimental unit to which the various treatments were applied as described before. The number of adults emerged was recorded and the pupae that failed to develop to adults were considered dead (the emerged adults of the whitefly leave a T-shaped opening in the puparium which obviously demonstrates a successful emergence of the adult).

3.1.1.4 The effect on the adult stage

NeemAzal-T/S and neem oil were sprayed on the surface of the plants and Imidacloprid was applied in the soil. The treated plants were allowed for 30 minutes to dry before each group was transferred in a separate medium size glass cage. Twenty five adults were chosen randomly regardless of their sex, fitness and age, and then carefully introduced on the cabbage plants inside the cage with the help of an aspirator. The number of dead insects was counted 48 hrs later and monitoring was continued for further 6 days to obtain the percentage of mortality and the degree of the effectiveness of each product.

3.1.2 Greenhouse experiment (the effect of neem products on the 2nd and 3rd nymphal instars of the cotton jassid)

The systemic effect of NeemAzal-T/S and neem oil was studied in stage-dependent experiment, where the 2nd and 3rd nymphal stages were used. The biological effect of Folimat on these stages was compared with that of the neem products. The experiments were carried out in the winter season 1999 under the greenhouse conditions of the Faculty of Agriculture, University of Khartoum. They were arranged in a randomized complete block design. A piece of potato tuber containing only one bud was planted in a plastic container (7 x 7 cm) and was allowed to grow to a height of about 16 cm.

The plants were then placed in a glass of a normal lamp fitted with a mesh at the top to prevent any possible escape of the insects as well as the entry of unwanted intruders of the same or other species. The plants were arranged into four groups with a replication of four times. After spraying of the plants, they were allowed for 20 minutes to dry before 40 nymphs of the cotton jassid were carefully transferred on each plant with the aid of a fine camel-hair brush. The nymphal instars were brought from a nearby potato field just few minutes before being transferred on the plants. The monitoring of the insects started thereafter and continued until the insects died or otherwise developed into the next stage (the presence of cast skins is a good indicator of the development of insect into the next stage).

3.2 Field and semi-field experiments

All field experiments were carried out in the Sudan during the period from 2.11.1998 to 28.3.2000 i.e. two winters and one autumn season. The experiments were designed to reflect the ingenuity and accumulated experience of the farmer, i.e. the usual practices and cropping system applied by local farmers were followed, so that the yield estimate and recommendations for pest control could be applied in the fields of other farmers. Some shortcomings may be that the estimates did not take into account conditions of other factors such as soil, diseases and other uncontrollable factors.

3.2.1 Semi-field experiment (field-cage experiment)

The objective of the experiment was to determine the lowest population of the cotton jassid at which it is obvious to the farmers to decide themselves when to take an action against this pest in their potato fields. i.e. to establish jassid density-damage relationship. Cage controlled artificial infestation with different population densities of the cotton jassid *Jacobiasca lybica* (de Berg) was used. Although caged plants may not behave in the same way as plants in the open field, and it is difficult to extrapolate the cage results to field results, nevertheless, the experiment will give a hint for evaluating the impact of jassids as a foliar pest on potato in the Sudan, which is hitherto unknown.

Potato tubers were cut into two halves each with 3-4 buds. The tubers were then planted in a plastic container (25 x 21 x 18 cm). These containers were made simply by cutting an empty oil jerrycan into two parts, and each halve was perforated at the bottom to facilitate good drainage. It worths here to mention that these containers were much cheaper and available in the local market if compared with the clay pots which are commonly used for such experiments. Each container with a potato plant was placed in the greenhouse. Fertilization was given as recommended for field crop. Irrigation was done every 3-4 days depending on the weather conditions.

All experimental plants in these containers were placed in an insect-proof net to prevent an infestation by the jassids or other insects. Since jassids lay eggs inside the plant tissue, the infestation could proceed undetected until the first hatchlings appeared and by that time it is difficult to get jassid-free plants. The plants were transferred afterward into an iron-rod cage measuring 45 cm in diameter and 65 cm height, covered with an insect proof netting made of a fine cotton cloth. The netting was provided with a zip fastener to facilitate easy watering and observation of both plant and jassids. The cages were sprayed with 20% emulsifiable concentrate (20% E.C.) of Sumicidin to ensure that the cages contained no insect (BINYASON 1997). The cages were allowed to stand for 7 days before the tested insects were introduced into them.

Jassids were collected from the field with a normal insect-hand net. They were brought to the lab, where they were released into a three-side cage made of glass which was placed near a window to stimulate the insects to crawl towards the light. An aspirator was then used to pick the insects carefully and individually. This procedure has also made it easier to count the required number of insects needed for each treatment. The adult jassids were chosen regardless to their sex, age or fitness because it was difficult to specify these parameters. The collected insects were then released into the cages according to the number in each treatment.

Five treatments were used, (0) with no jassid was used as control, (1), (3), (5) and (10) jassids per leaf. The number of leaves per each plant were carefully counted before jassids were introduced and accordingly the required number of jassids in each cage was calculated. Each treatment was replicated 4 times in a randomized arrangement of a complete block design. Observation of the symptoms developed on the leaves were recorded at an interval of two weeks from the start of the experiment and continued for 5 weeks.

The yield of the caged plant was harvested at the end of the experiment (weight and number of tubers) and was used in the estimation of the ETL. A significant linear yield-infestation graph relationship was used in the estimation. At the end of the observations 15 farmers were selected randomly and interviewed individually to choose freely by only looking at the color changes on the photographed symptoms at which level they would decide to spray their crop. Where the majority of the farmers coincide in their color choices was considered as the action threshold index (ATI). This method was adopted to determine the AT of the cotton jassid on eggplant (BINYASON 1997). The method adopted by FAKI and STAM (1989) to evaluate the economic aspects of pest management in the Gezira was used in this investigation to calculate the economic threshold. This method is actually the cost/benefit ratio and it is shown bellow in the following formula:

$$ETL = \frac{CostOfInsecticidalApplication / feddan}{MarketPriceOfPotato / kg \times b}$$

The insecticides used were neem products and b represents the regression coefficient. This experiment was carried out in the winter season 1998/99 and repeated in the following winter of 1999/2000.

3.2.2 Field experiments

3.2.2.1 Field experimental site and crop plants

3.2.2.1.1 Description of the experimental site

All field experiments were carried out in Khartoum state. The region is semi-desert, lies between Lat. 22°N and Lat.12°N. The annual rainfall ranges from 75 to 800 mm, occurring mainly during the period from July to September. The winter time is from November to March and is cold and dry. The remaining months of the year represent the Summer season which is hot and dry. Mean maximum and minimum temperature in Khartoum are 41.7°C and 15.6°C respectively. The area is generally flat with a few scattered hills. The blue and white Niles flow from south to north. They unite at Khartoum to form the river Nile. The area found between these two rivers is considered as the most important agricultural zone in the country (Fig. 1).

Fig. 1: Map of the Sudan showing the different vegetation divisions and the study area (after BEBAWI and NEUGEBOHRN 1991)

The top farm (Khartoum university demonstration farm) was chosen to be the field experimental site. It is located in the low land of the river Nile, about 750 m from the river bank. The soil is silty clay loam with physical and chemical properties which make it ideal for vegetable production. Pumping of water from the river Nile is common and the only method of irrigation in this 500 feddan farm. Subsoil water is used in some neighboring farms as the main source of irrigation.

3.2.2.1.2 Crop plants

Two important vegetable crops of the nightshade (family Solanaceae) were thoroughly studied, namely potato and eggplant. Some description of these crops is given in Table 2.

Table 2: Taxonomy, botany, and nomenclature of the experimental crops.

crop	Scientific name	Common name	Local name	Botany
Potato	*Solanum tuberosum* L.	White potato Irish potato	Batatis	Herb
Eggplant	*Solanum melongena* L.	Garden egg Bringal	Aswad Basingan	Annual or perennial herb

The weeds species found in these crops during the two study seasons were listed. Their frequencies and importance were also studied.

3.2.2.2 Target insects, neem products and formulations

3.2.2.2.1 Target insects

The insects species focused in this study fall into two categories:

3.2.2.2.1.1 Phytophagous insects

Three homopterous pestiferous insects were studied. These are: tobacco or cotton whitefly *Bemisia tabaci* (Gennadius); the leafhopper *Jacobiasca lybica* (de Berg) (Homoptera: Cicadellidae), and the cotton aphids *Aphis gossypii* Glover (Homoptera: Aphididae). Other insect species observed on the two crops were only listed as pest, beneficial, indifferent or visitors.

3.2.2.2.1.2 Predaceous insects

All predaceous insects observed on the two crops were recorded. Emphasis was given to three species which were studied in more details. These are: the common green lacewing *Chrysoperla carnea* (Steph) (Neuroptera: Chrysopidae); the aphidophagous hoverfly *Xanthogramma* sp. (Diptera: Syrphidae) and the coccinellid beetle *Scymnus sp.*(Coleoptera: Coccinellidae). The fact that the lacewing is a well known voracious predator of a wide variety of insect pests and the prevailing dominance of the two other predators are the reasons behind the choice of these three species. Other predacious insect of importance were also listed.

3.2.2.3 Neem products and formulations

Neem allelochemicals such as azadirachtins, salanin. Nimbinie and nimbin which are present in different formulations were used in the present investigation. Commercial as well as home-made formulations were tested.

3.2.2.3.1 Commercial formulations

1) NeemAzal-T/S 1% supplied by Trifolio-MGmbH Lahnau, Germany. This commercial neem product consists of 4% NeemAzal-T/S i.e. 1% Azadirachtin A (10g/l) and 3% other neem substances. It contains about 51% plant oil. The product is now registered in Germany as commercial insecticide for the control of greenhouse and some field pests. It was applied at a rate of 2 l/ha.

2) Neem oil-Rimulgan supplied by Neem-Handel GbR, Griesheim-Germany. Neem oil was produced through cold pressing of freshly dried neem seeds without any additive chemical substances or synergistic materials. Azadirachtin content was less than 500 µg/g. Rimulgan® was added as an emulsifying agent. It was produced from 68% castor bean oil plus 25% ionic fatty acid, 5% anionic Calcium salt and 2% alcohol. It also contains antioxidant to enhance its shelf-life. This antioxidant consists of Tocopherol (vitamin E) and citric acid. The formulation was used at a rate of 5 ml (g) neem oil-Rimulgan mixture per liter water in a ratio of 4:1 (neem oil:Rimulgan).

3.2.2.3.2 Home-made-formulation

Neem seed water extract (NWE) was prepared with a village-level technology. Simple method adaptable to the local farmer was used. Freshly ripened, good quality seeds of the neem tree (*Azadirachta indica* A. Juss) were collected in Shambat area. (Khartoum North). Yellowing of the fruits was taken as an indicator of their ripening. The seeds were collected by three methods, a) using straw broom to gather the already fallen seeds which were packed in plastic bags, b) shaking the branches of the tree vigorously to detach the ripe fruits and to cause them to fall on the ground, c) hand picking of ripe fruits on branches near the ground.

The de-pulping of the fruits was done immediately by macerating the seeds by hand. The de-pulped seeds were thoroughly washed in running water to remove the sugary flesh coating the seed before being spread on a jute bag to help absorb excessive moisture. The addition of wood ash to the seeds will reduce their mucilaginous nature and the removal of the seed coat becomes easier. This process of de-pulping is very essential for proper storage of the seeds. The pulp absorbs moisture during storage and the sugary material acts as a nutritive medium for the fungi (PURI 1999). Some seeds were already de-pulped presumably by birds and bats.

The seeds were allowed to stand for one hour in the sun, then were transferred into the shade and left to dry. Drying and storage were carried out according to standard procedure to avoid the seeds being spoiled by fungi. The seeds were then crushed (with shell) into a fine powder with a normal pestle and mortar.

The neem seed water extract was prepared by taking 50g of the neem powder in one liter of water (SERRA and SCHMUTTERER 1993). Mixing of the powder in water was done manually by stirring with stick. The whole mixture was left in a bucket overnight. The supernatant was taken then and filtered through a fine piece of cloth to obtain a homogenous extract, free of any large neem seed particles. This practice was done to avoid blockage of the nozzle of the spraying machine.

3.2.2.4 Synthetic insecticides

Three commercial synthetic insecticides were used as a yard-stick to judge the performance of neem-based insecticides. These are, Sumicidin® (20% E.C.), a broad spectrum pyrethroid insecticide which was applied at rate of 0.3 l/fed. The second insecticide was Imidacloprid, commercially known as Confidor® 70 WG. This chemical is a new systemic insecticide of the chemical group Chloronicotinyle. It was applied at a rate of 500g/ha. The third insecticide was omethoate (organophosphorous group) commercially known as Folimat®, with a systemic action. It was applied at a rate of 50g a.i./100 l. The three insecticides were included in this study for comparative purposes because, the first and third are currently used by the farmers in vegetable fields and the second is well known for its high efficacy and systemic action against sucking insects.

3.2.2.5 Equipment and spraying technique

The conventional technology in the use of synthetic insecticides has not been very effective in many cases against numerous homopterous pests because they generally feed on the underside of the foliage or they are protected most of the time by the plant canopy. The ultra-low-volume technique (ULV) was used quite often with particular pesticides against certain pests and in most cases proved to be effective. This is one of the techniques used in the present study.

All applications of neem products and the synthetic pesticides which were used for comparison, were carried out with the ULVA+ sprayer, unless otherwise stated. This sprayer is a hand-held agricultural machine with optional refilling system. It is powered by torch (D-cell/R20) batteries. An electric motor spins the atomizer disc to produce uniform spray droplet size (the actual size of the droplets produced depends on the atomizer disc speed which is in turn determined by the number of batteries fitted, speed of ≈ 7500 rpm was used in this study). The sprayer was supplied by the Micron sprayers Ltd. (Three Mills, Bromyard, Herefordshire, England).

The machine produces very small droplets which are distributed and deposited by wind and gravity. Thus allowing good coverage of the whole canopy. Five batteries with the trade mark "Nile power" were used to give spray time for up to twenty hours. Since wind is a crucial factor in the distribution of the spray droplets, the sprayer was held downwind of the operator. Spraying was carried out only with a crosswind of at least 1m/second (3.6 km/hr). Spraying operations were stopped when the wind speed exceeded 4 m/second to avoid the spray drift to neighboring plots. The wind speed was measured before and during spraying. A device (anemometer) was kept in the field, placed at a height corresponding to that of the plants to measure the velocity of the wind at the time of application. Spray pass interval of 2.5 m was used as described by the following formula:

$$WalkingSpeed(m/s) = \frac{FlowRate(ml/\min.)}{6 \times SprayPassInterval(m) \times TotalSprayVolume(l/h)}$$

3.2.2.6 Insects monitoring

3.2.2.6.1 Insect pests

3.2.2.6.1.1 Treated plots

Adult whiteflies, jassid nymphs and aphids were counted from a random sample of 20 plants taken from each plot. Five leaves were chosen randomly on each plant, two from the bottom (older leaves), one from the middle and two from the top (younger leaves). The lower surface of the leaf was thoroughly examined for the presence of insects. Counts were made before 08.30 hr (Sudan local time) to avoid the excessive mobility of the adult insects after this time, but nevertheless, the migration of the fast moving and mobile adults from one plot to the other could not be totally avoided.

There was no problem encountered with respect to the counting of jassid and whitefly, but the suddenness and the rapidity with which aphids build up large numbers created difficulties in counting their absolute numbers. DUNN and WRIGHT (1955/56) used the sweeping method to sample pea aphid population. WALKER et al. (1972) used a volumetric method for estimating the populations of the green bug *Schizaphis sp.* on grain sorghum.

In this study the estimation of the actual numbers of aphid was adopted by using a ring of 1.5 cm in diameter. The ring was made of a thin Copper wire. Small aphid colonies were counted easily with the aid of insect-counter. Large colonies covering the whole leaf blade were estimated using the ring described above. The ring was placed on the leaf blade and all the aphid individuals encircled were counted. A calibration of the ring was made after a repeated counting of 10 times. The number of circles measured on an infested leaf was multiplied by the number of individual aphids in one circle to give an estimate of the total insects per leaf. The data were pooled over the season and season's average were combined to provide an overall average density per plot. The population density of each species are expressed as number of individuals per 100 leaves of the plant.

3.2.2.6.1.2 Untreated plots

The seasonal fluctuations and the population dynamics of the target insect pests was studied on untreated plots of eggplant grown in the vicinity of the experimental plots to avoid the effect of the treatments on the insect population. The availability of data concerning the population dynamics of homopterous insect pests through out the year and knowledge of the phenological data of the vegetation are of vital importance in planning a management system for these pests. The existence of eggplant all the year round justifies its selection for this study which will give a complete picture of the seasonal fluctuation of the pests under the current investigation.

3.2.2.6.2 Beneficial insects

3.2.2.6.2.1 Plant-dwellers

Here only the immature stages were counted and the variation in their population numbers in the different plots was taken as an indication of the effects of different treatments on these predaceous insects. It was very difficult to find the adults of *Scymnus* sp. and *Chrysoperla carnea* in the field, and hence the attention was given to the immature stages. One reason of the study of the immature stage of the hoverfly is that, this group comprises also saprophagous insects (FRANK, 1999) and counting the immature stages will help to avoid the confusion and moreover, it is difficult counting adults comparing the larvae.

Twenty plants were selected randomly for sampling. With a gentle touching of the plant, all plant parts were then thoroughly checked for the presence of any moving predator. These were then counted visually with the aid of manual counter device. Sampling was done at an interval of ten days during the growing season of each crop. The data were pooled over the season and the average density per plot was calculated.

3.2.2.6.2.2 Soil-dwellers

The abundance patterns of epigeal predatory arthropods in a field of eggplant was studied. The information about the abundance of these epigeal predatory arthropods, particularly members of the order Araneae is very crucial and needed for the evaluation of the predation impact of this group on the population densities of sucking insects and other small-sized pests.

The field where the survey was carried out was characterized by the following features: It was located at the bank of the blue Nile (10 m away from the bank of the river), the size of the field was 2.5 feddan, with clay loamy soil. The eggplant was grown as the main vegetable crop (plant density was 4 plants/m^2) rotating with tomato, onion, Jew's' mallow, okra and green pepper. The field was managed in a conventional farming system with urea and Superphosphate as the main two fertilizers and Sumicidin, Malathion, Sevin and Folimat as chemical weapons against pests. The nut grass or Seeda (*Cyperus rotundus*) and Bermuda-grass or Nageel (*Cynodon dactylon*) dominated the species composition of the weeds and weed control activity was carried out entirely with hand hoe and sickle.

Ten pitfall traps per field were set in the center of the field at a distance of at least 10 m from the edge of the field and 10 m from each other. Each trap consisted of double set of plastic beakers of 10 cm in diameter and 9 cm deep. The traps were half filled with the 0.05% Formalin plus detergent as trapping fluid. The traps were emptied at a weekly interval in the period from 25.1. to 25.2.2000.

All traps were covered with a wire mesh (10 x 10 mm) to avoid the removal of the catches by arthropods-consuming animals. The smoothening of the soil at the trap's edge was done every time after emptying the traps to avoid cracks formation around the traps. The trapped arthropods were then emptied with a sieve and funnel into small plastic bottles filled to the half with 70% alcohol. The samples were labeled and stored until sorting, counting and finally identification were made.

In addition to the pitfall traps, the square flooding method (1 m^2 per field per week during the trapping period) described by BASEDOW et al. (1988) was also used to confirm the faunistic analysis and density of the epigeal predatory arthropods composition in the agroecosystem of eggplant. This method is simply consists of square metal frame (31.62 x 31.62 cm) and (8 cm) deep. Ten sites were chosen randomly in the middle of the field, the frame was then pressed down into the soil. Ten liters water were poured on the soil encircled by the frame, the water was splitted into two doses. Each flooded square frame was carefully observed for 10 minutes and the predators floated on the surface of water were collected with a light forceps in a plastic bottle containing 70% alcohol and labeling indicating the date of sampling and the locality.

3.2.2.7 Performance profile of NeemAzal, neem oil and neem seed water extract against homopterous key pests of potato

The experiment was carried out during the winter seasons 1998/99 and 1999/2000 respectively. The variety used in this study was Alpha which was imported from Holland and propagated in the low land along the river Nile banks for one generation cycle. Alpha is a late maturing variety with low yield but is preferred by the farmers, because of its good storability in pits (traditional underground storage system used by some potato growers) and cold storage. As potatoes are very sensitive to water logging, the land was prepared carefully and flat well-leveled seed bed was obtained to ensure even water distribution.

Medium size tubers (35-55 mm) were cut longitudinally into halves and the two halves were left together for 3-4 days in the shade with good ventilation to tuberize and sprout (this practice usually reduces the time of stay in the soil and hence reduce the probability of rottening). Large size tubers were cut in 3-5 pieces with 2-3 eyes in each piece. Planting was done by hand before irrigation on the northern side of the ridges which were 70-80 cm running East-West. The spacing between plant holes was 20 cm and sowing depth was 7.5 cm. Potato was sown on 7. December 1998 (first season). Superphosphate was applied at a rate of 50 kg per feddan before planting. Nitrogen was applied in the form of urea (46% N) at a rate of 100 kg per feddan splitted into two equal doses, one at the emergence and the other at hilling up or earthing up (45 days after planting).

To avoid seed tubers rottening and poor crop stand, light irrigation was given from planting to tuber initiation at weekly interval. During the bulking period i.e. the period of tuber growth and enlargement, heavy irrigation was followed also at a weekly interval. Irrigation was stopped two weeks before harvest. Two preventive spraying of Tilt® (fungicide) was given as a measure against Alternaria leaf spots. Sixteen or twenty plots (5 m x 5 m) were meticulously prepared for the experiment (1998/99 or 1999/2000, respectively). Strips, 2 meter wide, were made to serve as guard areas.

Four treatments namely, NeemAzal-T/S, neem oil, Sumicidin and control were assigned at these plots, arranged in a completely randomized design. Each treatment was replicated 4 times (winter 1998/99). Spraying started immediately after tuberization and continued thereafter at 7-day interval until the harvest time. All spraying was done in the late afternoon except for one where this was carried out in the early morning due to strong storm which had made it impossible to conduct any operation. A barrier made of plastic bags (used for packing sugar) was used to prevent possible drift of spray to neighboring plots.

All control plots were sprayed with tap water (a volume corresponding to that used in making the different formulations). As all the products used in this investigation were water-based, clean, neutral, uncontaminated water (tap water) was used in making the formulations. It is worth mentioning that high acidity or impurities in water might negatively affect the activity of AZA (NRC 1992).Weeding was done with a hand hoe at 10-day interval. The frequency and types of weeds were recorded before being removed.

A wooden counting frame of one meter square was used in determining the frequency of weeds. The frame was placed randomly 10 times at different sites in the whole field and the number and species of all weeds encircled were recorded. The average was taken to represent the density of individual species per square meter. Identification of the different species was done with the help of the books of BEBAWI and NEUGEBOHRN (1991) and BRAUN et al. (1991). The experienced staff of the department of agricultural botany of the faculty of agriculture (University of Khartoum) helped to confirm the identification. The weed frequency was determined through numerical estimation of the ratio of individual weed species to the total population of weeds present in the quadrat.

Yield was determined per unit area (1 m^2 per plot) at the end of the experiment. as weight of tubers. It was then expressed as ton/feddan. Tubers were separated into marketable tubers (> 4.5cm in diameter) and cull tubers (< 4.5 cm in diameter). The cull tubers are also sold in the market, but with lower price and hence it was included in the final evaluation. The term yield was used throughout the text to mean all tubers whether they are small or large. This parameter was used together with the insect count in the tested plot to evaluate the general performance of each treatment. The same experiment was repeated in the winter season 1999/2000 with addition of neem seed water extract as a 5th treatment. In this second season the potato was sown on 12th December 1999.

3.2.2.8 The efficacy of NeemAzal, neem oil, and neem seed water extract in controlling homopterous pests of eggplant

Seedling of eggplant variety long purple were raised in the nursery for 45 days and then were transplanted in field plots measured 5 x 5 m in size. Transplanting was carried out in the early morning. of 15th November 1998. Pre-transplanting watering was given to avoid the transplanting shock. The seedlings were planted in ridges, about 90 cm apart with 60 cm space between plants. Irrigation, weeding and other cultural practices were carried out as and when necessary by local farmers.

Four treatments were assigned to 20 plots. Each treatment was replicated 4 times.(for the winter season 1998/99). Five treatments, NeemAzal-T/S, neem oil, neem seed water extract, Sumicidin and control were tested on the summer crop sown on 25.

June 1999 and winter crop of 1999/2000. which was sown on 30.11.1999. The application of the products as well as the count of insects were carried out as described in the experiment with potato. The yield of each plot was collected every 5 days, right from the beginning of the first harvest and continued until the end of the growing season i.e. the cumulative yield per unit area.

Only fruits of marketable size (> 6 cm) were used at each picking. The cumulative yield was used together with the insect count to judge the performance profile of each formulation. The smallest fruit of eggplant harvested had about 13.5 x 5.5 cm size which is suitable for the local market. Smaller than this can not be sold for consumers. This standard size had been reached after inquiries with the farmers and mediators at the central market for fruits and vegetables which is located not far from the experimental plots. These mediators have accumulated a great experience in marketing vegetables and they know exactly the consumer needs. The unavailability of new, good quality neem seed at the beginning of the winter of 1998/99 was the reason behind its exclusion in this season.

3.2.2.9 The efficacy of neem seed water extract applied with different techniques

The aim of the experiment was to find out whether using a brush made from the leaves of date palm (broom) in the application of NWE is equably effective compared to modern methods or not. This method of application is simple and affordable to the farmers (village-level-technology). The performance of the palm leaf brush (broom) abbreviated as PLB in the text for convenience was compared with that of the knapsack sprayer (KSS) and ULVA + sprayer. The treatments were arranged in a completely randomized design with 4 replicates for each treatment. All applications were carried out in the late afternoon to escape heat and radiation of the day. The mean populations of homopterous pests as well as the yield of each plot were taken as criteria to evaluate the efficacy of neem water extract in each case. The experiment was conducted in the summer of 1999 and repeated again in the winter of 1999/2000.

3.2.2.10 Evaluation of the effectiveness of different treatments

The performance profile of each treatment was judged by the reduction of the insect population densities in the treated plots and it was further confirmed by the comparison of yield obtained in each case at the end of the cropping cycle. The fields of potato and eggplants were sampled for the number of jassid , whitefly, and aphid two weeks before the start of the application of the treatments and was continued throughout the season at a weekly interval as described before.

The insect-days (IDS) as proposed by RUPPEL (1983) as an index of the efficacy of insecticides in crop protection was used. The cumulative insect-days (CIDS) serve as indices of the overall effectiveness of the treatments, it provides a simple, single measure of the intensity of the insect attack. The insect-days is defined as the area under the curve of insect numbers on time and it combines both number and time into a single expression of the intensity and duration of the infestation. The insect-days under the curve can be estimated by the following equation:

Insect-days = $(X_{i+1}-X_i)[\,(Y_i+Y_{i+1})\div 2]$

Where; X_i and X_{i+1} are adjacent points of time, Y_i and Y_{i+1} are the corresponding points of insects number. The cumulative insect-days was computed simply by sequentially summing the individual insect-days and the percent control was then calculated from these data for each treatment as follows:

$$\%Control = \left(1 - \frac{C.I.DS.inTreatedPlot}{C.I.DS.inUntreatedPlot}\right) \times 100$$

The jassid, whitefly and aphid feeding days were summed for each plot and the results were analyzed in a completely randomized design analysis of variance (ANOVA).

3.3 Statistical analysis and evaluation of the results

The methods adopted by ABBOTT (1925) and RUPPEL (1983) were used in the calculations of mortality and efficiencies of the different treatment. The statistical package SPSS for Windows 9.0 was used for the analysis of data, with one exceptional case where the statistical software SAS for windows 6.08 was used. This was true for the data of the greenhouse experiment concerning the effects of neem products on the immature stages of the cotton jassid. Duncan multiple range test (DMRT) for $\propto = 5\%$ was used for separation of means.

Most of the data were subjected to simple analysis of variance (ANOVA) and presented as means ± standard deviations. The data concerning the cage experiment were transformed to log and then subjected to regression analysis. Where significant F values were found, contrast among different means of individual treatments was determined by the Tukey test. The significant differences were identified at 95% level of confidence. The data collected in the two different seasons were compared using the Student's t-test for independent samples. The book of KÖHLER et al. (1996) was consulted for the interpretation and presentation of the data.

4 RESULTS

4.1 Laboratory and greenhouse experiments

4.1.1 Laboratory experiments

The experiments were carried out to study the effect of NeemAzal-T/S, neem oil and Imidacloprid on different developmental stages of the greenhouse whitefly (*Trialeurodes vaporariorum*).

4.1.1.1 The effect of NeemAzal-T/S, neem oil and Rimulgan on the egg stage of the greenhouse whitefly

Rimulgan, NeemAzal-T/S and neem oil reduced the egg hatchability of the greenhouse whitefly by 9.00 ± 1.50%, 10.25 ± 1.96% and 25.4 ± 1.71% respectively. The efficacy of neem oil was 23.09% followed by NeemAzal-T/S (7.47%) and Rimulgan (6.18%). Statistical analysis showed a significant difference between the effect of neem oil and NeemAzal-T/S. The effect of NeemAzal-T/S and Rimulgan was not significantly different ($P > 0.05$). There was only 3% reduction in the hatchability of the control (Fig. 2).

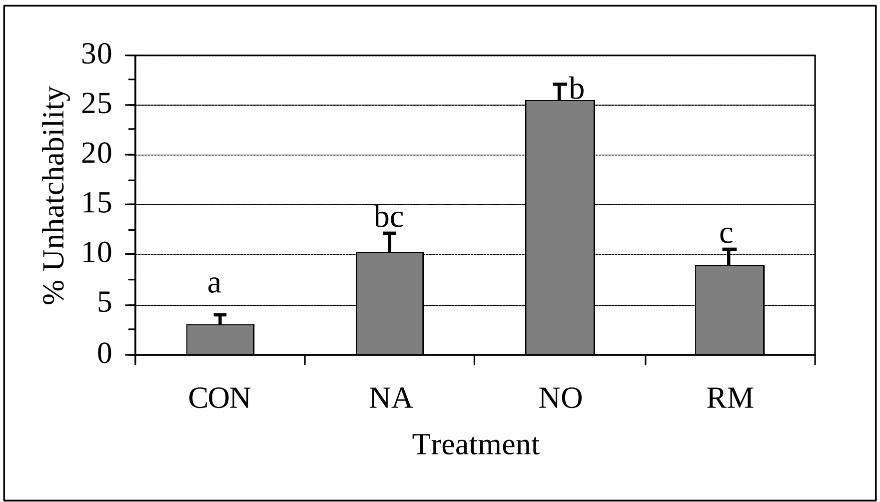

Fig. 2: The effect of NeemAzal-T/S, neem oil and Rimulgan on the hatchability of the eggs of the greenhouse whitefly (*Trialeurodes vaporariorum*). Columns annotated with different lower are significantly different ($P < 0.05$, Duncan multiple range test). The T-shaped beams represent the standard deviations.

4.1.1.2 The effect on the nymphal stages

The three products under investigation, namely NeemAzal-T/S, Neem oil and Imidacloprid resulted in a mean percentage mortality of 95.7 ± 3.82, 91.8 ± 4.21 and

97.5 ± 2.93 respectively on the second and third larval stages (L_2 and L_3) of the greenhouse whitefly (Fig. 3). A significant difference existed between the means of these treatments (P < 0.05). The highest efficacy was recorded for Imidacloprid (97.37%) followed by NeemAzal-T/S (95.47%) and neem oil (91.37%). There was 5% mortality among the individuals in the control.

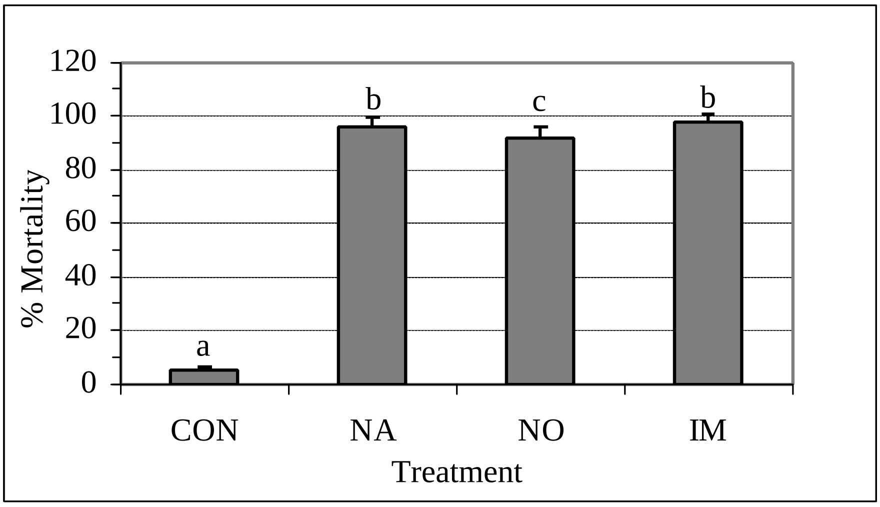

Fig. 3: The effect of NeemAzal-T/S, neem oil and Imidacloprid on the nymphal stages of the greenhouse whitefly (*T. vaporariorum*). Values having different letters are significantly different (P < 0.05, Duncan multiple range test). The T-shaped beams represent the standard deviations.

4.1.1.3 The effect on the puparial stage

From Fig. 4, it is evident that NeemAzal-T/S was more effective than neem oil in its action of inhibiting puparial development of the greenhouse whitefly. The two products caused a mortality of 86.7 ± 2.26% for NeemAzal-T/S and 40.5 ±1.29% for neem oil. The effect of NeemAzal-T/S differed significantly from that of neem oil and the control (P < 0.05). There was only 2% mortality recorded in the control and accordingly, an efficacy of 86.43% and 39.28% was calculated for NeemAzal-T/S and neem oil respectively.

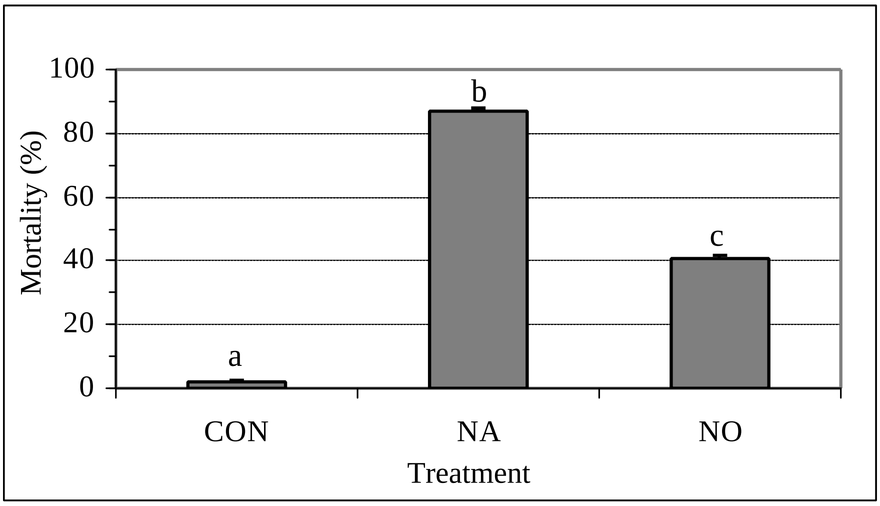

Fig. 4: The effect of NeemAzal-T/S and neem oil on the puparial stage (red-eyed stage) of the greenhouse whitefly (*T. vaporariorum*). The different letters on the tops of columns indicate a significant difference ($P < 0.05$, Duncan multiple range test). The T-shaped beams represent the standard deviations.

4.1.1.4 The effect on the adult stage

NeemAzal-T/S, neem oil and Imidacloprid resulted in adult mortality of 10.5 ±1.41%, 18.4 ± 1.83% and 100 ± 0.00% respectively. Imidacloprid gave no chance for the test insects even to establish themselves on the leaves of the treated plants. In case of the neem products, the adults established well on the treated plants and some of them started to lay eggs. The mortality of adult insects observed in the untreated check was 3.2%. The treatments differed from each other significantly ($P < 0.05$). These findings are presented graphically in Fig. 5. Imidacloprid was 100% efficient compared with 15.70% and 7.54% efficiencies for neem oil and NeemAzal-T/S respectively.

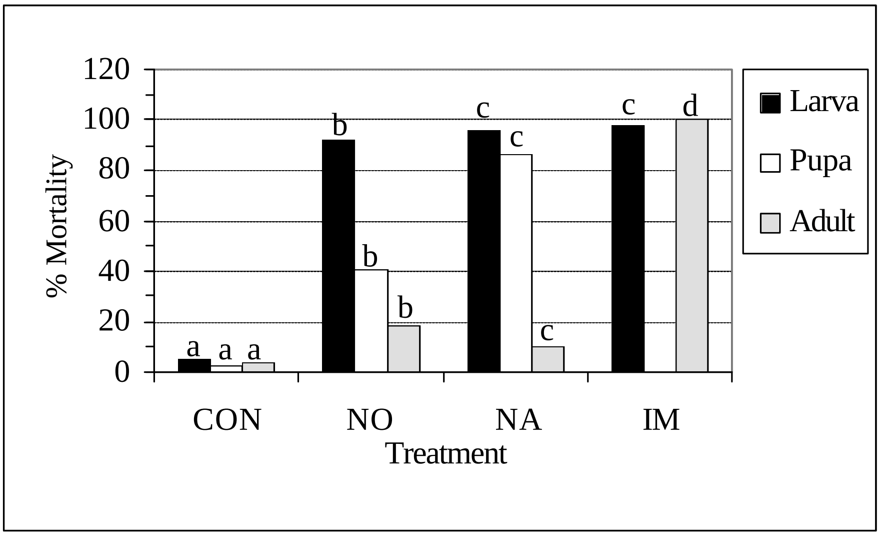

Fig. 5: The effect of NeemAzal-T/S, neem oil and Imidacloprid on the different developmental stages of the greenhouse whitefly (*T. vaporariorum*). Columns annotated with the same lower case letter representing the same developmental stage are not significantly different ($P > 0.05$, Duncan multiple range test).

4.1.2 The greenhouse experiment

The experiment was carried out to study the effect of NeemAzal-T/S and neem oil on the nymphs of cotton jassid in stage-dependent manner. Folimat was included for comparison. The insect number that survived the treatments is given in Table 3. NeemAzal-T/S, neem oil and Folimat resulted in a mean percent mortality of 91.88 ± 3.5, 90.63 ± 2.95 and 100.00 ± 0.00 respectively on the 2^{nd} nymphal stage of the cotton jassid *Jacobiasca lybica* (de Berg) (Fig. 6). Folimat caused the highest mortality, followed by NeemAzal-T/S and neem oil. Only 5% mortality was recorded among the individuals in the control. Detail statistical analysis is given in Tables A1a and A1b. The efficiency of each formulation was calculated based on the above mortality data and was found to be 100% for Folimat, 91.45% for NeemAzal-T/S and 90.14% for neem oil.

Table 3: Surviving number of the 2nd nymphal instar of the cotton jassid *Jacobiasca lybica* (de Berg) on potato in greenhouse experiment (winter 1998/1999).

Treatment	Number. of nymphs		Mortality %
	Initial number	Average number (after 7 days)	
Control	40	38.00 ± 0.82 a	5.00
NeemAzal-T/S	40	3.25 ± 0.5 b	91.88
Neem oil	40	3.75 ± 0.95 b	90.63
Folimat	40	0.00 ± 0.00 b	100.00

Figures followed by the same letter are not significantly different (*P* > 0.05, Duncan multiple range test).

It has been observed that Folimat had a very quick knock down effect, demonstrated by the fact that most of the test insects died on the day after treatments. Unlike the neem products, which allowed the insects for some days before they could exert their effects. Duncan's multiple range test showed no significant differences between the efficacy of Folimat and neem products (*P* > 0.01).

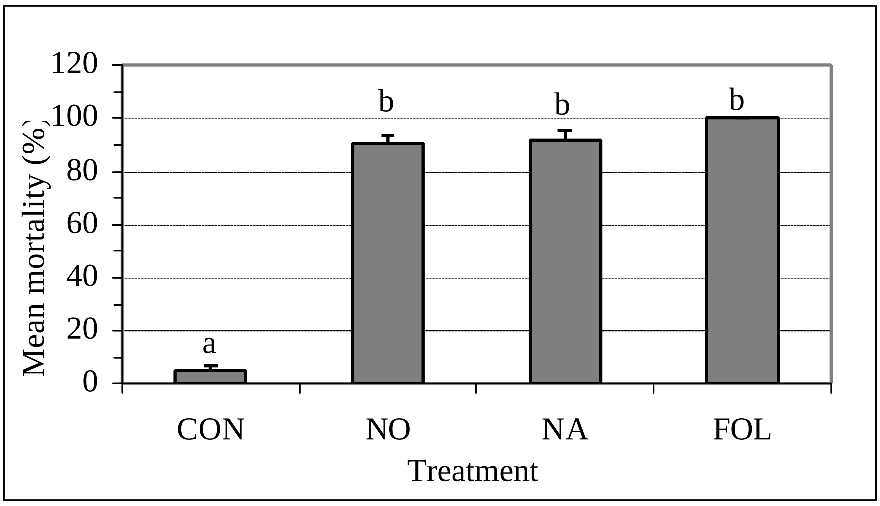

Fig. 6: The percent mortality (mean ± SD) caused by NeemAzal-T/S, neem oil and Folimat on the 2nd nymphal instar of the cotton jassid, *Jacobiasca lybica* (de Berg) on potted potato (winter season 1998/1999). Means sharing the same letter do not differ significantly (*P* > 0.05, Duncan multiple range test). The T-shaped beams represent the standard deviations.

Table 4 shows the effect of the three products under investigation on the 3rd nymphal instar of the cotton jassid. A highly significant difference was found between the mean mortalities caused by Folimat (93.75 ± 2.58%) and neem oil (59.38 ± 2.71%). On the other hand, no significant difference in mortalities was detected between Folimat (93.75 ± 2.58%) and NeemAzal-T/S (78.13 ± 3.95%). (Tables A2a and A2b). The mortality on the 3rd nymphal instar is shown in Fig. 7. The mortality in the control using the third instar was higher (6.25%) than in the second instar and the efficiency of Folimat was 93.42% compared with 76.98% and 57.24% for NeemAzal-T/S and neem oil respectively. The efficacy of the three products seem to be high on the 2nd instar compared with the 3rd instar. Fig. 8, made in combination of Figures 6 and 7, intended to enable valid comparison and general prospects to be made between the effects of these products on the two immature stages of the cotton jassid.

Table 4: Surviving number of the 3rd nymphal instar of the cotton jassid *Jacobiasca lybica* (de Berg) on potato in greenhouse experiment (winter 1998/99).

Treatment	Number. of nymphs		Mortality %
	Initial number	Average number (after 7 days)	
Control	40	37.5 ± 1.29 a	6.25
NeemAzal-T/S	40	8.75 ± 0.95 c	78.13
Neem oil	40	16.25 ± 1.71 b	59.38
Folimat	40	2.5 ± 0.58 c	93.75

Figures followed by the same letter are not significantly different ($P > 0.05$, Duncan multiple range test).

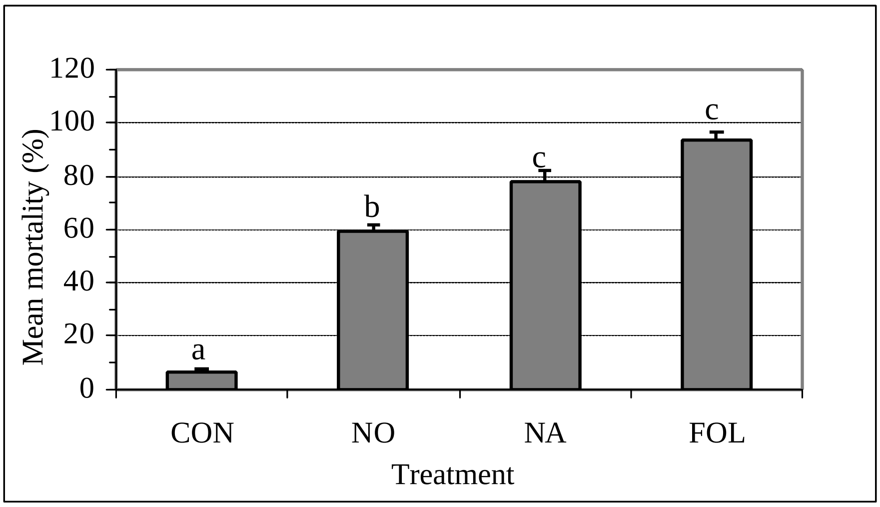

Fig. 7: The percent mortality (mean ± SD) caused by NeemAzal-T/S, neem oil and Folimat on the 3rd nymphal instar of the cotton jassid *Jacobiasca lybica* (de Berg) on potted potato (winter season 1998/1999). Means sharing the same lower case letter do not differ significantly ($P > 0.05$, Duncan multiple range test). The T-shaped beams represent the standard deviations.

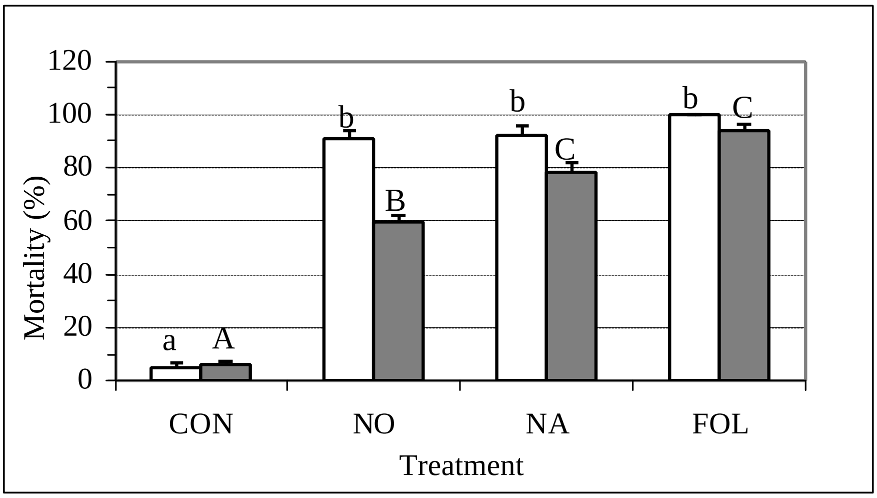

Fig. 8: The percent mortality (mean ± SD) caused by NeemAzal-T/S, neem oil and Folimat on the 2nd (white bars) and 3rd (hatched bars) nymphal instars of the cotton jassid *Jacobiasca lybica* (de Berg) on potted potato (winter season 1998/1999). Means sharing different lower or upper case letter are significantly different ($P < 0.05$, Duncan multiple range test). The T-shaped beams represent the standard deviations.

4.2 Semi-field and field experiments

4.2.1 Semi-field experiment (field-cage experiment)

The results presented in Table 5 and Fig. 9 demonstrate a direct negative relation between the jassid number on caged potato plants and mean weight of the tubers produced. The linear relationship between the mean yield and the number of jassid per leaf was statistically significant than 0 (r^2 = !0.987 and ! 0.995 for the winter season 1998/1999 and 1999/2000 respectively, $P < 0.05$). The ANOVA tables for the linear regression analysis of jassid on yield is shown in Tables A3 and A4 for the two seasons of the study respectively. The high coefficient of determination indicates that the yield and the number of jassid are highly linearly related with small value of residual sum of squares. A corresponding reduction in the mean tubers weight of 92.40 and 91.74% were observed with an increase in jassid density from 1 to 10 during winter 1998/1999 and 1999/2000 respectively. Plants with high density of jassid 5 or 10 started to show hopperburn symptom. At a low jassid density (1 jassid per leaf), the percent reduction in yield was 7.76% in the winter season of 1998/1999 and 6.72% in the following winter season of 1999/2000. This reduction is well below 10% crop loss which could still be accepted. With 3 insects per leaf, the percent reduction reached 57.40% and 50.97% in both the two study seasons which resulted in a serious crop loss.

Table 5: The effect of different jassid densities/leaf on the mean weight of tubers as yield component of potato in cage experiment (winters 1998/1999 and 1999/2000).

Jassid density/leaf	**Mean tuber yield/plant**			
	Weight of tubers (g)		% reduction in wt. of tubers	
	1998/1999	1999/2000	1998/1999	1999/2000
0	201.38 ± 15.1	419.83 ± 23.4	---	---
1	185.75 ± 8.6	368.30 ± 5.7	7.76	6.72
3	85.78 ± 5.9	193.55 ± 7.7	57.40	50.97
5	69.18 ± 6.5	129.10 ± 7.0	65.65	67.19
10	15.29 ± 2.9	32.58 ± 5.4	92.40	91.74

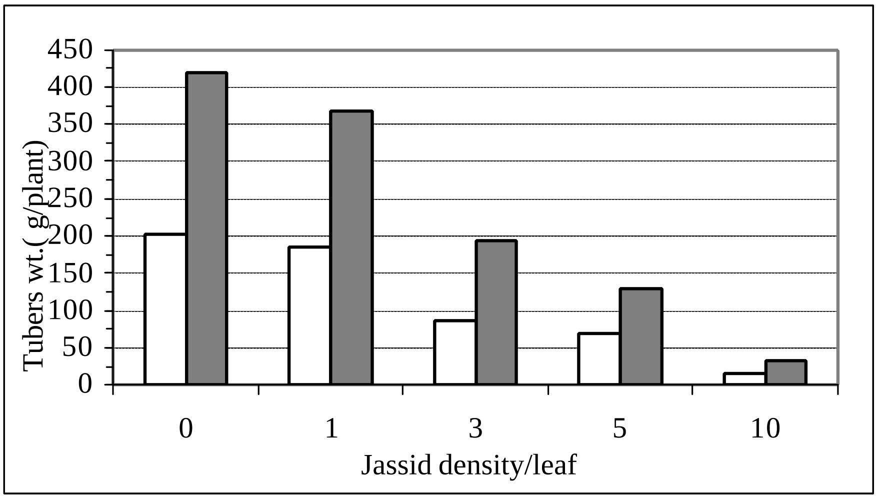

Fig. 9: The effect of different jassid densities/leaf on the mean weight of potato tubers in cage experiment conducted in two consecutive winter seasons of 1998/1999 (white bars) and 1999/2000 (hatched bars).

The trend of yield reduction increased in correlation with increasing jassid densities. A reduction of 92.40 and 91.74% was reached at 10 jassid per leaf in the winters of 1998/1999 and 1999/2000 respectively. This high reduction in yield which is near to the point of “No yield” due to high jassid densities reflect clearly the severity of jassid on caged potato artificially infested with the insects in field cages. Since one jassid per leaf resulted in yield reduction of less than 10%, it is proposed as ETL for jassid in caged potato.

The least squares equation for the line of best fit to describe the relationship between tuber yield and infestation of jassid is shown below:

Predicted yield = 216.805 .$e^{-0.262.\text{jassid}}$ for the season 1998/1999

Predicted yield = 444.967 .$e^{-0.260.\text{jassid}}$ for the season 1999/2000

Where 216.805 and 444.967 are the points of intercept or the predicted yield when there is no jassid infestation. e = exponential, and – 0.262 and – 0.260 are Lin. of slopes of each line or the change in predicted yield for a unit change in jassid number. Using the equation described above and the concept of crop loss not more than 10%, the ETL was determined to be 0.4 jassid/ leaf or 40 jassid /100 leaves for the two seasons. Combining the ETLs obtained from the observed and predicted yield, a range of 0.4 to 1 jassid/leaf or 40 to 100 jassid/100 leaves could be obtained. The interviewed farmers were unable to indicate their sprayable jassid level from the photographs obtained from the field cage experiments due to the unclear symptom. The ETL for jassid in the field cage experiment was found to be 231 jassids/100 leaves in the 1998/1999 season and 246 jassids/100 leaves in the 1999/2000 season.

4.2.2 Field experiments

4.2.2.1 Faunal biodiversity of potato and eggplant ecosystems

4.2.2.1.1 Arthropods fauna of potato

A survey of arthropod fauna of potato ecosystem in the study area revealed 25 different species which were belonging to 8 different orders. The majority of these insects was phytophagous which constituted 64% of the total number. The number of species which were found to inflict foliage damage were 13 while only 3 were reported to be responsible for the harmful effect on the underground parts or the tubers. The beneficial insects constituted 32% and the indifferent species was only 4%. Although the number of harmful species seems to be high, the significant crop damage is caused by only 3-5 key pests (Table 6).

Table 6: The composition of insect species of potato ecosystem arranged by orders and families.

Species	Common name	Status
Coleoptera/Coccinellidae		
Adalia bipunctata L.	2-spotted lady bird beetle	Beneficial
Adonia variegata (Goeze)	13-spotted lady bird beetle	Beneficial
Coccinella quinquepunctata L.	5-spotted lady bird beetle	Beneficial
Coccinella undecimpunctata L.	11-spotted lady bird beetle	Beneficial
Cydonia sp.	Lady bird beetle	Beneficial
Scymnus sp.	Lady bird beetle	Beneficial
Epilachna canina (F.)	Melon beetle	Pest
Coleoptera/Meloidae		
Epicauta aethiops (LATR.)	Grey blister beetle	Pest
Diptera/Muscidae		
Musca domestica L.	House fly	Indifferent
Diptera/Syrphidae		
Xanthogramma sp.	Syrphid/hover fly	Beneficial
Heteroptera/Miridae		
Campylomma sp.	Campylomma bug	Beneficial (mostly)
Heteroptera/Pentatomidae		
Nezara viridula (L)	Green vegetable bud	Pest
Homoptera/Aleyrodidae		
Bemisia tabaci Genn.	Cotton or tobacco whitefly	Pest
Homoptera/Aphididae		
Aphis gossypii Glover	Cotton aphid	Pest
Brevicoryne brassicae (L.)	Cabbage aphid	Pest
Myzus persicae (Sulzer)	Peach-potato aphid	Pest

Table 6: Contd.

Species	Common name	Status
Homoptera/Cicadellidae		
Erythroneura lubiae	Lubia jassid	Pest
Jacobiasca lybica (de Berg.)	Cotton jassid	Pest
Isoptera/Termitidae		
Microtermis thoracalis SJÖST.	Cotton soil termite	Pest
Lepidoptera/Gelechiidae		
Phthorimaea operculella Zeller	Potato tuber moth	Pest
Lepidoptera/Noctuidae		
Agrotis segetum (Schiff.)	Cutworm	Pest
Antigastra catalunalis (Dup.)	Sesame webworm	Pest
Spodoptera exigua (HB.)	Lesser army worm	Pest
Neuroptera/Chrysopidae		
Chrysoperla carnea Stephens	Green lacewing	Beneficial
Orthoptera/Acrididae		
Schistocerca gregaria (Forskal)	Desert locust	Pest

4.2.2.1.2 Faunal diversity of eggplant

4.2.2.1.2.1 Harmful arthropods

Twenty eight species of insect pests were recorded from the eggplant during the study period (Table 7). These species belong to 7 different insect orders. The number of insect pests associated with damage on the reproductive parts (flower buds and fruits) was 7 species. Three species were responsible for the damage observed on stem and roots, while 18 species were notorious for their occurrence as foliage pests. The red spider mites, *Tetranychus spp*. (Acari: Tetranychidae) was also found as a foliage pest. The presence of ground scavenger beetles (unidentified) with a high abundancy especially during autumn (kharif) season was not uncommon.

Table 7: Insect pests associated with eggplant.

Species	Common name	Site of damage
Coleoptera/Coccinellidae		
Epilachna canina (F.)	Melon beetle	Leaf
Coleoptera/Galerucidae		
Aulacophora africana Weise	Red melon beetle	Leaf
Coleoptera/Halticidae		
Epithrix torvi BRY.	Flea beetle	Leaf
Phyllotreta sp.	Flea beetle	Leaf
Coleoptera/Meloidae		
Epicauta aethiops (LATR.)	Grey blister beetle	Leaf
Diptera/Calliphoridae		
Sacrophaga destructor Mall.	Fruit fly	Fruit
Diptera/Lonchaeidae		
Lamprolonchaea aurea (MACQ)	Fruit fly	Fruit
Diptera/Muscidae		
Atherigona orientalis Schiner	Fruit fly	Fruit
Diptera/Tephritidae		
Ceratitis capitata (Wied.)	Mediterranean fruit fly	Fruit
Heteroptera/Miridae		
Campylomma sp.	Campylomma bug	Leaf
Creontiades pallidus (Ramb)	Shedder bug	leaf
Heteroptera/Pentatomidae		
Calidea sp.	Plant bug	Leaf
Nezara viridula (L.)	Green vegetable bug	Leaf
Heteroptera/Tingidae		
Urentius hystricellus (Richt)	Tingid bug	Leaf

Table 7: Contd.

Species	Common name	Site of damage
Homoptera/Aleyrodidae		
Bemisia tabaci (Genn.)	Cotton whitefly	Leaf
Homoptera/Aphididae		
Aphis gossypii Glover	Cotton aphid	Leaf
Homoptera/Cicadellidae		
Jacobiasca lybica (de Berg)	Cotton jassid	Leaf
Homoptera/Pseudococcidae		
Ferrisia sp.	Mealy bug	Leaf
Isoptera/Termitidae		
Microtermis thoracalis STöst.	Cotton soil termite	Stem/root
Lepidoptera/Arctiidae		
Utetheisa lotrix (CRAM.)	Arcttiid moth	Leaf
Lepidoptera/Gelechiidae		
Gnorimoschema heliopa (Low.)	Bud-worm	Flower bud
Lepidoptera/Noctuidae		
Eublemma admota (Felder)	Leaf spinner	Leaf
Helicoverpa armigera (Hübner)	African boll worm	Fruit
Spodoptera exigua (HB.)	Lesser army worm	Leaf
Spodoptera littoralis Boisd	Greater army worm	Leaf
Lepidoptera/Phycitidae		
Daraba laisalis (WLK.)	Eggplant fruit borer	Fruit
Euzophera sp.	Eggplant stem borer	Stem/root
Orthoptera/Gryllotalpidae		
Gryllotalpa africana P.DEB.	African mole cricket	Stem/root

4.2.2.1.2.2 Beneficial arthropods

4.2.2.1.2.2.1 Plant-dwellers or visitors

The insect predators recorded belong to 5 different taxonomical orders. These were mainly Coleoptera which constituted 60% of the total number of the species found. Other orders namely, Neuroptera, Diptera, Hymenoptera and Mantoidea with a frequency of 10% each (Table 8). The predators which were not identified but observed commonly in the eggplant ecosystem included common wasps (hornet, yellow jacket and mud dauber) of different sizes which were found hovering over the flowering eggplant during the study period. Dragonflies were also recorded roosting and hovering over the surface of small water bodies created by the unevenness of the bed of the minor watering canal, presumably feeding on small flies and mosquitoes' larvae. The antlions were also common in the guard unflooded neighboring areas. Their presence was easily detected by their cone-shaped burrows in the ground in which their larvae hide and wait passively for the falldown of small crawling insects. Two species of the honey bees *Apis mellifera* and *Apis florea* were also observed on the flowering eggplant in addition to unidentified solitary bees.

Table 8: A list of species (arranged by order and family) showing the spectrum of predaceous, plant-dwelling insects of the eggplant ecosystem (1998-2000).

Species	Common name	Stage observed
Coleoptera/Coccinellidae		
Adalia bipunctata L.	2-spotted lady bird beetle	Adult
Adonia variegata (Goeze)	13-spotted lady bird beetle	Adult
Coccinella quinquepunctata L.	5-spotted lady bird beetle	Adult
Coccinella undecimpunctata L.	11-spotted lady bird beetle	Adult
Cydonia sp.	Lady bird beetle	Adult
Scymnus sp.	Lady bird beetle	Larva
Diptera/Syrphidae		
Xanthogramma sp.	Syrphid/hover fly	Larva & adult

Table 8: contd.

Species	Common name	Stage observed
Heteroptera/Miridae		
Campylomma sp.	Campylomma bug	Nymph & adult
Mantoidea/Mantidae		
Mantis religiosa L.	Praying mantid	Egg & nymph
Neuroptera/Chrysopidae		
Chrysoperla carnea Stephens	Green lacewing	Egg & Larva

4.2.2.1.2.2.2 Soil-dwellers

This study was carried out in a farmer's field to give an account on the populations of these arthropods as they might be affected by the routine agronomical practices adopted by the local farmers. Tables 9 and 10 give qualitative as well as quantitative data of surface predatory arthropods in a field of eggplant grown in the study area. The faunistic analysis of the catches gave 8 different taxonomic groups. The Formicidae was the most frequently occurring group (878 individuals) during the study period. With regards to the species composition, it was also ranking top (4 species). Forficulidae was ranking second to the Formicidae with respect to frequency (119 individuals), followed by Araneae (71 individuals). Half of the captured spiders was belonging to the family Lycosidae. Gryllidae occupied the 4th position with a total number of 20 individuals followed by Carabidae and Staphylinidae which were represented by 6 and 4 individuals respectively. Chilopoda was the least frequent group represented by only one individual in both pitfall traps and square flooding methods. All the groups found in the pitfall traps were also recovered by the square flooding method except the order Heteroptera (predatory bugs).

Table 9: Relative abundance of surface predatory arthropods recovered from 10 pitfall traps set in an eggplant field (farmer field) grown in the winter season 1999/2000).

Taxon	Total number caught				Mean ± SD
	Sampling date				
	01. Feb.	08. Feb.	15. Feb.	22. Feb.	
Araneae	27	13	15	16	17.8 ± 6.3
Carabidae	2	1	2	1	1.5 ± 0.6
Chilopoda	0	0	0	1	0.2 ± 0.5
Forficulidae	34	27	19	39	29.7 ± 8.7
Formicidae	252	216	206	204	219.5 ± 22.3
Gryllidae	5	4	5	6	5.0 ± 0.8
Heteroptera	0	2	0	1	0.8 ± 1.0
Staphylinidae	0	3	0	1	1.0 ± 1.4

Table 10: The total number of soil-dwelling predatory arthropods per m^2 (on two different sampling dates) revealed from a farmer's field of eggplant grown in the study area (winter 1999/2000).

Taxon	Total number caught		Mean ± SD
	Sampling date		
	16. Feb.	21. Feb.	
Araneae	3	4	3.5 ± 0.7
Carabidae	2	2	2.0 ± 0.0
Chilopoda	1	0	0.5 ± 0.7
Forficulidae	1	3	2.0 ± 1.4
Formicidae	1	2	1.5 ± 0.7
Gryllidae	1	0	0.5 ± 0.7
Staphylinidae	1	3	2.0 ± 1.4

4.2.2.2 Floral biodiversity of potato and eggplant ecosystems

4.2.2.2.1 Floral biodiversity of potato ecosystem

Twenty three species of weeds from 15 different families were recorded in the agroecosystem of potato during the course of this study (Table 11). Three species namely; *Cyperus rotundus, Cynodon dactylon* and *Boerhavia erecta* could be considered as major weeds (frequency > 10%). *Abutilon figarianum* Webb. was found to harbor a large population of the tingid bug *Urentius hystricellus* (Richt)., while the pentatomid bug *Calidea sp*. and the flea beetle *Phyllotreta sp*. were associated preferably with the weeds *Phyllanthus niruri* L. and *Aristolochia bracteolata* Lam. respectively. A large number of the gray blister beetle *Epicauta aethiops* was observed on a nearby growing weed (*Solanum dubium* Fresen) on the 28.12.1998. The insects invaded the newly emerged seedling of potato and resulted in complete defoliation of some plants. These examples will clearly demonstrate the importance of weeds and their role in providing food and shelter for unwanted insects species.

4.2.2.2.2 Floral biodiversity of eggplant

The weed species encountered in the eggplant ecosystem during the two successive winter seasons of the study are shown in Table 12. The weed composition consisted of 14 species belonging to 10 different families. As in the case of potato the *Abutilon figarianum* was found to harbor the tingid bug which sometimes represents a major sucking insect on the eggplant. The similar three major species of weeds found in the potato ecosystem were also important as major weeds in the ecosystem of eggplant (frequency > 10%) grown in the 1998/1999 and 1999/2000 cropping seasons.

4.2.2.3 Microscopic faunas and floras composing potato and eggplant ecosystems

In addition to insects and weeds there were also communities of bacteria, fungi and microscopic invertebrate animals that compose the ecosystem. Some of these agents were found to be responsible for the ailments of potato and eggplant observed during the course of the study period (Table 13).

Table 11: Floral biodiversity of potato ecosystem (1998/99-1999/2000 winter seasons)

Species	Common/Arabic name	Frequency (% per m^2)	
		1998/99	1999/2000
Amaranthaceae			
Amaranthus viridis L.	Lisan Teir Kabir	3.25	2.83
Digera alternifolia (L.)	Lablab Ahmer	1.04	2.54
Aristolochiaceae			
Aristolochia bracteolata Lam.	Um Galagil	4.82	3.75
Asteraceae			
Sonchus apollinea (Del.) DC.	Moleita	3.48	1.76
Convolvulaceae			
Ipomea cordofana Choisy	Tabar	6.37	5.48
Cyperaceae			
Cyperus rotundus L.	Nut grass/Seeda	18.61	16.47
Euphorbiaceae			
Euphorbia aegyptiaca Boiss	Malbaina	0.00	1.09
Euphorbia indica Lam	Malbaina	3.21	0.00
Phyllanthus niruri L.	-----	5.69	7.60
Aizoaceae			
Trianthema portulacastrum L.	Rabaa	1.82	4.00
Poaceae			
Cynodon dactylon (L.) Pers.	Bermuda grass	19.47	14.86
Echinochloa colonum (L.)	Difera	1.63	0.00
Malvaceae			
Abutilon figarianum Webb.	Gargadan	2.01	3.51
Nyctaginaceae			
Boerhavia erecta L.	Terba	10.12	7.63

Table 11: Contd.

Species	**Common/Arabic name**	**Frequency (% per m^2)**	
		1998/99	1999/2000
Papaveraceae			
Argemone mexicana L.	Mexican poppy	5.27	3.53
Fabaceae			
Crotalaria saltiana Andr.	Sifaira	0.00	1.24
Indigofera oblongifolia Forsk.	Dahasir	2.05	4.02
Rhynchosia memnonia (Del.) DC.	Adana	1.34	2.19
Tephrosia apollinea (Del.) DC.	Amyoga	0.99	0.00
Portulacaceae			
Portulaca oleracea L.	Purslane/Rijla	1.97	2.05
Solanaceae			
Datura stramonium L.	Sakaran	0.00	2.81
Solanum dubium Fresen	Gubain	4.91	9.94
Tiliaceae			
Corchorus trilocularis L.	Molokhia	1.95	2.70

Table 12: The weed composition of the ecosystem of eggplant grown during two successive winter seasons (1998/99 and 1999/2000).

Species	Common/Arabic name	Frequency (% per m^2)	
		1998/99	1999/2000
Amaranthaceae			
Amaranthus viridis L.	Lisan Teir Kabir	6.12	7.82
Digera alternifolia (L.)	Lablab Ahmer	4.23	2.04
Aristolochiaceae			
Aristolochia bracteolata Lam.	Um Galagil	0.00	2.34
Asteraceae			
Sonchus apollinea (Del.) DC.	Moleita	1.76	3.45
Convolvulaceae			
Ipomea cordofana Choisy	Tabar	8.02	9.17
Cyperaceae			
Cyperus rotundus L.	Nut grass/Seeda	20.71	22.87
Euphorbiaceae			
Euphorbia aegyptiaca Boiss	Malbaina	7.29	5.89
Euphorbia indica Lam	Malbaina	2.33	3.60
Phyllanthus niruri L.	-----	6.01	0.00
Aizoaceae			
Trianthema portulacastrum L.	Rabaa	5.83	3.56
Poaceae			
Cynodon dactylon (L.) Pers.	Bermuda grass	17.04	20.15
Echinochloa colonum (L.) Link	Difera	3.91	0.00
Malvaceae			
Abutilon figarianum Webb.	Gargadan	2.54	1.76
Nyctaginaceae			
Boerhavia erecta L.	Terba	14.21	17.35

Table 13: List of some general diseases of potato and eggplant observed during two cropping seasons of 1998/1999 and 1999/2000

Crop	Disease	Causal organism	Group	Incidence*
Potato	Leaf spots	*Alternaria alternata*	Fungi	High
	Soft rot	*Erwinia carotovora*	Bacteria	R. low
	Leaf roll	Potato leaf roll virus	Virus	Low
Eggplant	Powdery mildew	*Levellula taurica*	Fungi	Low
	Mosaic	Mosaic virus	Virus	Low
	Wilt	*Meloidogyne sp.*	Nematode	Low

* High = > 30%
Low = < 10%
Relatively low = < 15%

4.2.2.4 The annual seasonality and phenology of jassid, whitefly and aphid on untreated eggplant

The populations of the whitefly was found at lowest level during the summer months May and June. It started to increase gradually with the onset of the rainy season in mid July with slight fluctuation during this season. A rapid build up started in mid October and reached the peak density in December. This was followed by a rapid decline in the population during January and February. The population dynamics of jassid followed the same seasonal trend (Fig. 10). The mean population of whitefly (adult insects/100 leaves) was 29.35 ± 11.52 in summer, 203.10 ± 27.12 in autumn and 210.92 ± 32.84 in the winter season. The mean jassid population was 179.51 ± 40.19, 421.80 ± 65.73 and 671.66 ± 120.18 in summer, autumn and winter respectively (Fig. 11). The aphid appeared as small scattered colonies which built up rapidly. The downwind passive dispersal by winged form (adult female) played a vital role in the initial infestation at the end of December and early January and during that time the north winter wind started to blow. The population reached a peak in late winter and then waned as the summer season advanced (Fig. 12). Practically no aphid was observed during the summer and autumn seasons.

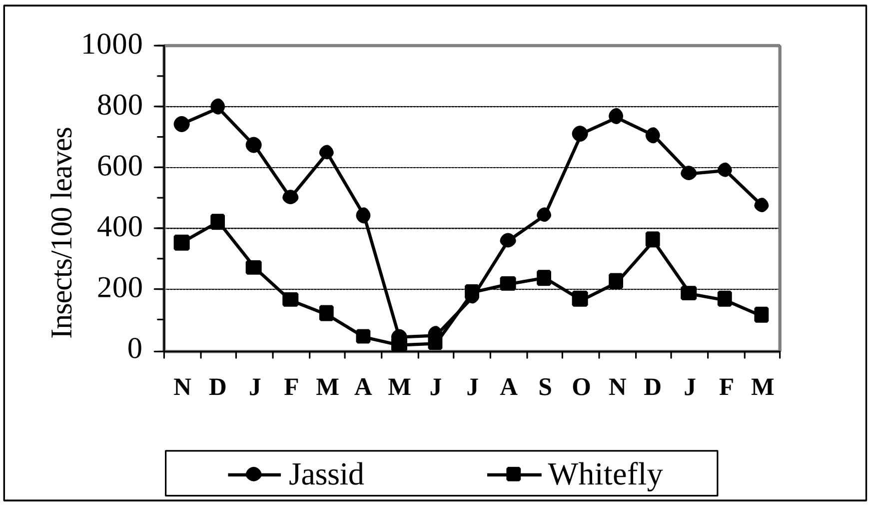

Fig. 10: The annual population trend of jassid and whitefly in an untreated eggplant field (November 1998-March 2000)

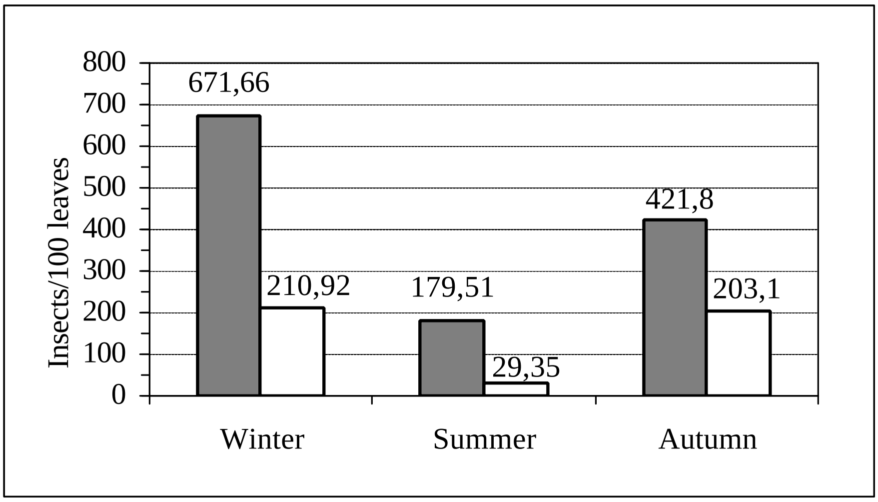

Fig. 11: The inter-seasonal fluctuations of jassid (hatched bars) and whitefly (white bars) in unsprayed field of eggplant (1998/1999)

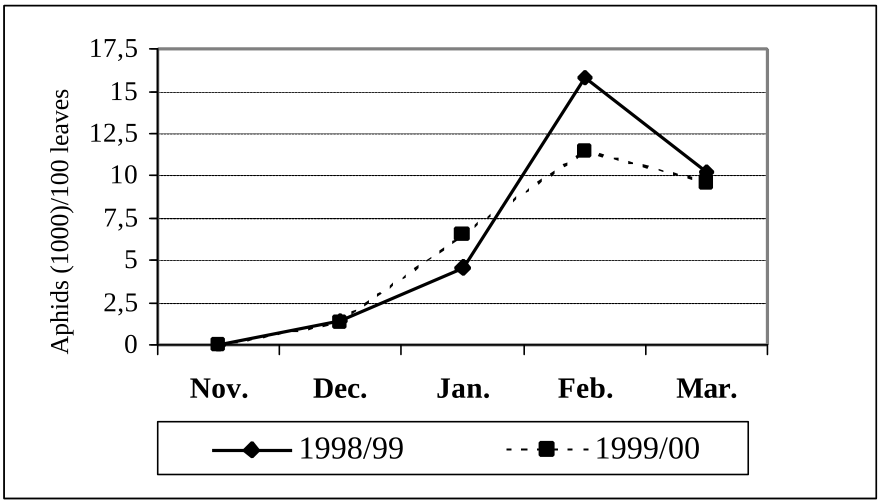

Fig. 12: The intra-seasonal population dynamic of the cotton aphid on unsprayed eggplant (winter seasons 1998/1999 and 1999/2000).

4.2.2.5 The performance profile of NeemAzal-T/S, neem oil and neem water extract against homopterous key pests of potato.

4.2.2.5.1 The populations of jassid, whitefly and aphid in the treated plots

Tables 14 and 15 show the cumulative insect-days and the percent control for the different treatments for the control of the three homopterous pests on potato grown in 1998/1999 and 1999/2000 winter seasons. Treatment effect for jassid was significant (F = 610.35; df. = 3,12; *P* = 0.000) for 1998/1999 season and (F = 278.12; df. = 4,15; *P* = 0.000) for the 1999/2000 season. The spraying of the crop with Sumicidin resulted in a considerable reduction of jassid populations of 82.08 and 85.97% in the two seasons respectively. NeemAzal-T/S achieved 81.65 control for the same species in 1998/1999 season and 85.4% in the winter of 1999/2000. There was no significant different between Sumicidin and NeemAzal-T/S with respect to the cumulative insect-days calculated for each during the two study seasons. The treatment effect concerning the population of the whitefly was significant (F = 178.54; df. =3,12; *P* = 0.000) for the 1998/1999 season and (F = 153.43; df. = 4,15; *P* = 0.000) for the 1999/2000 season. The cumulative insect-days was 748.5 ± 157.90 for Sumicidin and 812.25 ± 107.08 for NeemAzal-T/S in the 1998/1999 season and 1673.73 ± 172.78 and 1773.19 ± 237.08 for the two products respectively in 1999/2000 seasons. There was no significant differences between these means.

Table 14: Percentage reduction in cumulative insect-days of jassid, whitefly and aphid on potato after application of Sumicidin and two neem formulations in the winter of 1998/1999

Treatment	Cumulative insect-days (CIDS)*			Percentage reduction in CIDS.		
	Jassid	Whitefly	Aphid	Jassid	Whitefly	Aphid
Control	34792.13 ± 1585.20 a	2739.38 ± 90.64 a	508729.50 ± 45756.27 a	—	—	—
Sumicidin	4881.38 ± 263.53 b	748.5 ± 157.90 b	63046.88 ± 2310.22 b	85.97	72.68	87.61
NAzal	5047.50 ± 82.75 b	812.25 ± 107.08 bc	109538.25 ± 2465.50 b	85.49	70.35	78.47
Neem oil	12100.63 ± 1626.47 c	1067.75 ± 186.72 c	208783.25 ± 1797.83 c	65.22	61.02	60.00

* Insects per 100 leaves based on 7 counts per the cropping season.
NAzal = NeemAzal-T/S.
The percentage reduction was calculated from the cumulative insect-days for the untreated check (Ruppel 1983).

Means within a column followed by different letters are significantly different ($P < 0.05$; Tukey-HSD test).

Table 15: Percentage reduction in cumulative insect-days of jassid, whitefly and aphid on potato after application of Sumicidin and three neem formulations in the winter of 1999/2000

Treatment	Cumulative insect-days (CIDS)*			Percentage reduction in CIDS.		
	Jassid	Whitefly	Aphid	Jassid	Whitefly	Aphid
Control	21784.80 ± 1339.97 a	7566.70 ± 650.66 a	407797.83 ± 9475.33 a	—	—	—
Sumicidin	3905.69 ± 76.40 b	1673.73 ± 172.79 b	64570.48 ± 2694.16 b	82.08	77.89	84.17
NAzal	4009.40 ± 350.72 b	1773.19 ± 237.08 b	109446.17 ± 3278.49 c	81.60	76.5	73.16
Neem oil	9273.83 ± 768.88 c	2709.29 ± 410.13 c	164850.51 ± 2923.48 d	57.43	64.19	59.58
NWE	12000.27 ± 1171.39 d	3304.88 ± 295.49 c	174860.80 ± 1581.51 d	44.91	56.32	57.12

* Insects per 100 leaves based on 7 counts per the cropping season.
NAzal = NeemAzal-T/S.
The percentage reduction was calculated from the cumulative insect-days for the untreated check (Ruppel 1983).

Means within a column followed by different lower case letters are significantly different ($P < 0.05$; Tukey-HSD test).

The performance of Sumicidin and NeemAzal-T/S in checking the population of aphid in the 1998/1999 season was similar with no significant difference between the cumulative insect-days obtained for each group of plots. However, their performance differed significantly in the winter of 1999/2000 season. The effect of NWE and neem oil on the population of aphid during the winter of 1999/2000 was not significantly different.

4.2.2.5.2 The yield

Table 16 shows the yield of potato obtained during the two seasons of the study. Treatments effect was significant (F = 14.091; df = 3, 12; *P* = 0.000). More statistical details are given in Tables A5a and A5b. The performance profile of NeemAzal-T/S and Sumicidin was similar. No significant difference was observed ($P > 0.05$). Both products increased the yield of potato by 1.49 and 1.74 ton/feddan respectively in the 1998/99 season. The same trend in yield was obtained in the 1999/2000 season (Tables A6a and A6b). With an increase of 2.73 ton/feddan for NeemAzal-T/S and 2.99 ton/feddan for Sumicidin. The statistical analysis showed a significant difference between these two means with that of the control. The yield obtained from the plots treated with neem oil was not significantly different from the yield of the untreated plots in both seasons. The yield of the neem water extract treated plots was significantly higher than that of the control in the winter season 1999/2000.

The yield of potato obtained from the control and neem oil treated plots during the two seasons of the study was not significantly different (student's t-test, t = 1.2498 and 0.4177 respectively , $P > 0.05$). However, the plots treated with NeemAzal-T/S and Sumicidin produced significantly more yield (t = 2.8001 for NeemAzal-T/S and 2.8100 for Sumicidin) in the winter of 1999/2000 (6.09 ± 0.38 for NeemAzal-T/S and 6.35 ± 0.36 for Sumicidin) than in winter 1998/99 (5.12 ± 0.57 and 5.37 ± 0.59 for NeemAzal-T/S and Sumicidin respectively).

Table 16: The average yield of potato grown during winter seasons of 1998/99 and 1999/2000.

Treatment	Yield (ton/feddan)*	
	Winter 1998/99	Winter 1999/2000
NeemAzal-T/S	5.12 ± 0.57 a	6.09 ± 0.38 a
Neem oil	3.92 ± 0.34 b	4.04 ± 0.46 bc
Neem seed water extract	---------------	4.32 ± 0.44 b
Sumicidin	5.37 ± 0.59 a	6.35 ± 0.36 a
Control (water treatment)	3.63 ± 0.20 b	3.36 ± 0.38 c

* Means (± SD) within a column followed by the same letter are not significantly different (P< 0.05; Tukey test).
--- Neem seed water extract was not used in this season.

4.2.2.6 The efficacy of NeemAzal-T/S, neem oil and neem seed water extract in controlling homopterous insect pests on eggplant

4.2.2.6.1 The effect on the population densities of the three pests under investigation

The quantitative measures of insect population densities expressed as cumulative insect-days was used as an index for the effectiveness of the tested neem products under field conditions. The data of the population densities of the three homopterous pests collected from eggplant in the three seasons of the study were subjected to calculations of the cumulative insect-days and percent control.

Table 17 shows the cumulative insect-days and the percent control for the different treatments for the control of jassid, whitefly and aphid on eggplants grown during the winter season 1998/99. All the treatments reduced the population of jassid significantly compared to the control (F = 243.977; df = 3,12; P = 0.000). The number of cumulative insect-days was 54595.25 ± 4928.21 in the control compared to 5361.25 ± 478.42, 8434.88 ± 670.62 and 17914.38 ± 2946.66 in the plots treated with Sumicidin, NeemAzal-T/S and neem oil respectively. Similar results were obtained for the whitefly and aphid. The efficacy of Sumicidin and NeemAzal-T/S in the reduction of jassid populations was not significantly different but it was superior to NeemAzal-T/S in checking the population of the whitefly.

Table 17: Percentage reduction in cumulative insect-days of jassid, whitefly and aphid on eggplant after application of Sumicidin and two neem formulations in the winter of 1998/1999

Treatment	Cumulative insect-days (CIDS)*			Percentage reduction in CIDS.		
	Jassid	Whitefly	Aphid	Jassid	Whitefly	Aphid
Control	54595.38 ± 4928.21 a	7417.00 ± 380.03 a	513227.50 ± 21583.17 a	—	—	—
Sumicidin	5361.38 ± 478.42 b	1732.00 ± 80.35 b	91591.63 ± 3276.05 b	90.18	76.65	82.15
NeemAzal-T/S	8434.88 ± 670.62 b	2732.65 ± 357.97 c	104377.76 ± 58559.37 b	84.55	63.16	79.66
Neem oil	17914.38 ± 2946.67 c	3774.5 ± 336.63 d	208462.25 ± 12582.09 c	67.18	49.12	59.38

* Insects per 100 leaves based on 7 counts per the cropping season.
The percentage reduction was calculated from the cumulative insect-days for the untreated check (Ruppel 1983).
Means within a column followed by different letters are significantly different ($P < 0.05$; Tukey-HSD test).

The number of insect-days accumulated for jassid in the Sumicidin-treated plots in the autumn of 1999 was 2985.69 ± 175.27 compared to 4882.97 ± 406.53 found in the NeemAzal-T/S-treated plots. Both were found non significant from each other but they differed significantly from the control (35206.12 ± 2151.57) (Table 18). The performance of neem oil and neem seed water extract on the population of jassid was similar. The cumulative insect-days for the whitefly in the neem oil and NeemAzal-T/S treated plots were not significantly different (2368.09 ± 157.92 and 2095.05 ± 265.51 for neem oil and NeemAzal-T/S respectively).

The cumulative insect-days and the percent control or the reduction in cumulative insect-days for the different treatments for the control of jassid, whitefly and aphid on eggplant grown during the winter season of 1999/2000 was computed. Treatment effects on the population of jassid was significant (F = 621.91; df. = 4,15; $P = 0.000$). All the treatments reduced the cumulative insect-days significantly. Sumicidin, NeemAzal-T/S, neem oil and neem seed water extract reduced the infestation of jassid in the treated plots of eggplant by ca. 39016.12, 35898.75, 30679.5 and 26794.5 insect-days respectively (Table 19). On the other hand, the spraying of the crop with neem seed water extract reduced the population densities of the whitefly and aphid by 3051.50 and 246600.5 insect-days respectively. Sumicidin was excellent in reducing the population of jassid (94.28%), followed by NeemAzal-T/S (86.75%), Neem oil (74.14%) and neem seed water extract (64.75%). NeemAzal-T/S resulted in a seasonal percent reduction of 86.75, 63.24 and 78.08% in the populations of jassid, whitefly and aphid respectively. The effect of all tested products on the whitefly was not significantly different. The performance profile of Sumicidin and NeemAzal-T/S in checking the aphid population was not significantly different, likewise neem oil and neem seed water extract performed equally with no significant difference between them.

Table 18: Percentage reduction in cumulative insect-days of jassid and whitefly on eggplant treated with Sumicidin and three neem formulations in autumn 1999

Treatment	**Cumulative insect-days***		**% reduction**	
	Jassid	Whitefly	Jassid	Whitefly
Control	35206.13 ± 2151.6 a	4966.25 ± 156.5 a	—	—
Sumicidin	2985.69 ± 175.3 b	1708.46 ± 161.6 b	91.52	65.60
NeemAzal-T/S	4882.97 ± 406.5 b	2095.05 ± 265.5 c	86.13	57.81
Neem oil	13589.25 ± 1551.3 c	2368.09 ± 157.9 c	61.40	52.32
NWE	16087.05 ± 2714.4 c	2857.71 ± 74.0 d	54.31	42.46

* Insects per 100 leaves based on 7 counts per the cropping season.
NWE = Neem seed water extract
Means within a column followed by different lower case letters are significantly different (Tukey's test, $P < 0.05$).

Table 19: Percentage reduction in cumulative insect-days of jassid, whitefly and aphid on eggplant after application of Sumicidin and three neem formulations in the winter of 1999/2000

Treatment	Cumulative insect-days (CIDS)*			Percentage reduction in CIDS.		
	Jassid	Whitefly	Aphid	Jassid	Whitefly	Aphid
Control	41382.75 ± 1489.91 a	5445.50 ± 1059.24 a	481002.50 ± 126127.33 a	—	—	—
Sumicidin	2366.63 ± 865.90 b	1589.25 ± 154.55 b	86461.00 ± 5572.94 b	94.28	70.82	82.00
NAzal	5484.00 ± 646.80 c	2001.87 ± 339.60 b	105444.63 ± 6982.56 bc	86.75	63.24	78.08
Neem oil	10703.25 ± 1985.33 d	2415.00 ± 866.24 b	216934.75 ± 5173.21 cd	74.14	55.65	54.90
NWE	14588.35 ± 653.54 e	2394.00 ± 279.55 b	234402.00 ± 14406.95 d	64.75	56.04	51.27

* Insects per 100 leaves based on 7 counts per the cropping season.
NAzal = NeemAzal-T/S
NWE = Neem seed water extract
The percentage reduction was calculated from the cumulative insect-days for the untreated check (Ruppel 1983).
Means within a column followed by different lower case letters are significantly different (*P* < 0.05; Tukey-HSD test).

4.2.2.6.2 The yield

Table 20 and Fig. 13 summarize the yield obtained from plots of eggplant grown in three successive seasons, treated with different neem formulations. The application of NeemAzal-T/S increased the yield by 5.44, 4.98 and 6.11 ton/feddan in the winter season 1998/99, autumn 1999 and winter 1999/2000 respectively (Tables A7a, A7b, A8a, A8b, A9a and A9b respectively). The plots treated with Sumicidin produced an increase in yield of 5.11, 3.88 and 6.01 ton/feddan in the three successive seasons respectively. The performance of NeemAzal-T/S was superior to that of Sumicidin in autumn 1999 (the two means differed significantly, $P < 0.05$). Their performance was similar in both winter seasons. (no significant difference was detected in yield obtained from the plots treated with these two products).

The efficacy of neem oil and neem seed water extract was equal in autumn 1999 as well as in winter 1999/2000. (Table 20 and Fig. 13). The application of neem seed water extract increased the yield of eggplant significantly by 1.83 ton/feddan in autumn 1999, but the yield obtained from plots treated in such a way with the same product was not significantly different from that of the untreated check during the winter season 1999/2000.

The yield of eggplant was significantly higher in the 1999/2000 growing seasons ($t = 8.1712$, $P < 0.001$) compared with the yield in 1998/1999. Likewise, significantly more yield was harvested from the control plots in the winter seasons 1998/1999 ($t = 5.2844$) and 1999/2000 ($t = 10.8126$, $P < 0.001$) compared with autumn 1999. The same trend was followed in the neem and Sumicidin treated plots.

Table 20: The average yield in eggplant field treated with Sumicidin and three different neem formulations in three consecutive seasons.

Treatment	Yield (ton/feddan)*		
	Winter 1998/99	Autumn 1999	Winter 1999/2000
NeemAzal-T/S	9.80 ± 1.15 a	8.79 ± 0.83 a	11.74 ± 0.79 a
Neem oil	5.92 ± 0.43 b	6.59 ± 0.53 c	7.75 ± 1.46 b
NWE	--------------	5.64 ± 0.25 c	7.36 ± 1.69 b
Sumicidin	9.47 ± 1.22 a	7.69 ± 0.61 b	11.64 ± 1.34 a
Control (water)	4.36 ± 0.11 b	3.81 ± 0.17 d	5.63 ± 0.28 b

* Means (± SD) within a column followed by the same character are not significantly different ($P < 0.05$; Tukey's test).
Neem seed water extract
---- Neem seed water extract was not applied in this season.

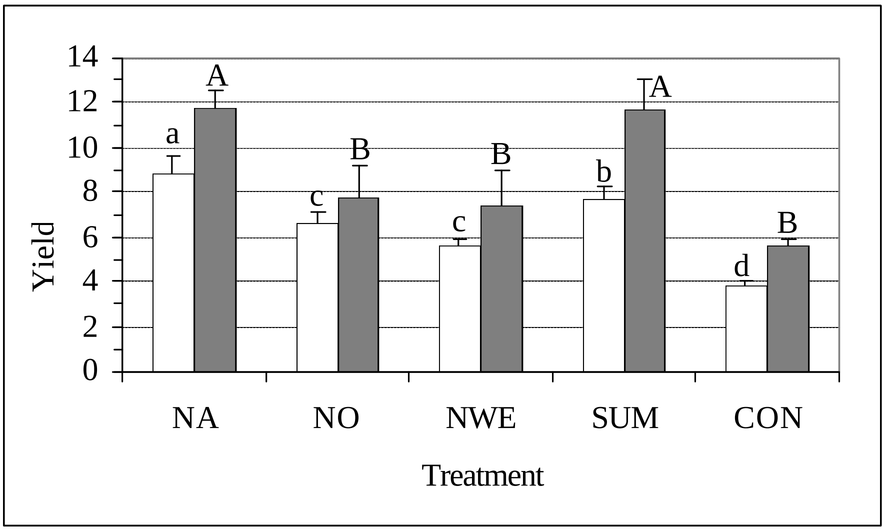

Fig. 13: The average yield of eggplant (ton/feddan) treated with Sumicidin and three different neem formulations in autumn 1999 (white bars) and winter 1999/2000 (hatched bars). Means sharing the same upper or lower case letter do not differ significantly ($P > 0.05$, Tukey's test). The T-shaped beams represent the standard deviations.

4.2.2.6.3 The population densities of the three important beneficial insects in the treated plots

4.2.2.6.3.1 The green lacewing *Chrysoperla carnea* (Neuroptera: Chrysopidae)

Field counts were carried out on the populations of this predator throughout the growing season and the density is indicated as individuals per plot. The mean larvae number of this predator was 18.00 ±1.63 in the control compared with 13.75 ±1.50 and 12.50 ± 1.73 larvae counted in the plots treated with neem oil and NeemAzal-T/S, respectively. Both means proved to be significantly lower than the control ($P < 0.05$). The plots treated with Sumicidin showed the least population density of larvae (3.75 ± 0.96) which is significantly less than the densities in the neem treated plots. These results are shown in Fig. 14. More statistical details are presented in Tables A10a and A10b.

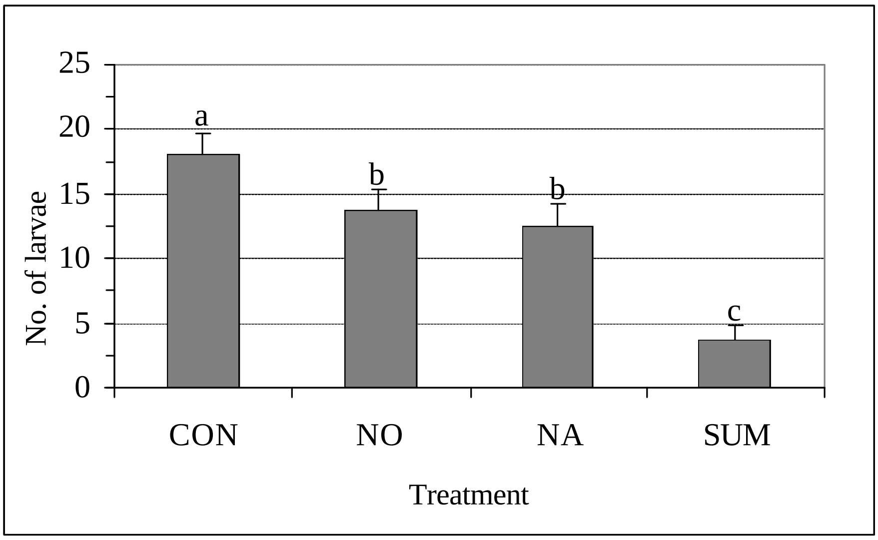

Fig. 14: The population density (mean ± SD) of the green lacewing per plot of eggplant (5 x 5 m) grown in winter 1998/1999 after application of Sumicidin and two neem formulations. The same character on the top of bars indicates no significant difference at 5% level of significance (Tukey's HSD multiple range test). The T-shaped beams represent the standard deviations.

The same counting of the larvae of this predator was carried out in the 1999/2000 season with addition of neem water extract as a fourth treatment. The data obtained are illustrated in Fig. 15. The mean number of larvae in the plots treated with neem oil and neem water extract was similar as that enumerated in the untreated check i.e. 21.00 ± 2.45 and 20.75 ± 2.75 compared with 22.00 ± 2.16 in the control. Statistically, no significant differences were detected among the treatments.

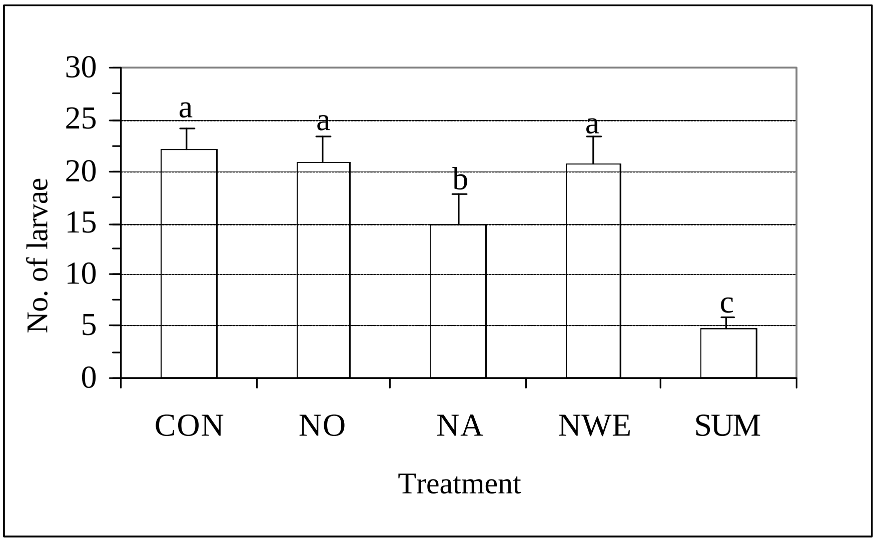

Fig. 15: Mean number of green lacewing per plot of eggplant (5 x 5 m) counted during winter of 1999/2000 after application of Sumicidin and three different neem formulations. The same character on the top of bars indicates no significant difference at 5% level of significance (Tukey's HSD multiple range test). The T-shaped beams represent the standard deviations.

There was a very small number of individual larvae in the plots sprayed with Sumicidin (4.75 ± 0.96) which is significantly different from the number in the untreated plots and the plots treated with neem products. Tables A11a and A11b show the ANOVA for the collected data. These results clearly demonstrate the significant negative influence of Sumicidin on the population density of the lacewing under field condition as compared with neem products. The data obtained during the two seasons are combined in Fig. 16 to allow for a quick comparison of these results.

There was no significant different of lacewing populations in the NeemAzal-T/S and Sumicidin treated plots of eggplant grown in the two winter seasons of the study (Student's t-test, t = 1.555 and 1.477 respectively, $P > 0.05$). Significantly more lacewings were counted in the untreated plots in the 1999/2000 growing season compared with 1998/1999 season (t = 2.954, $P < 0.05$). Similar trend was also observed in the neem oil treated plots (t = 5.0482, $P < 0.01$).

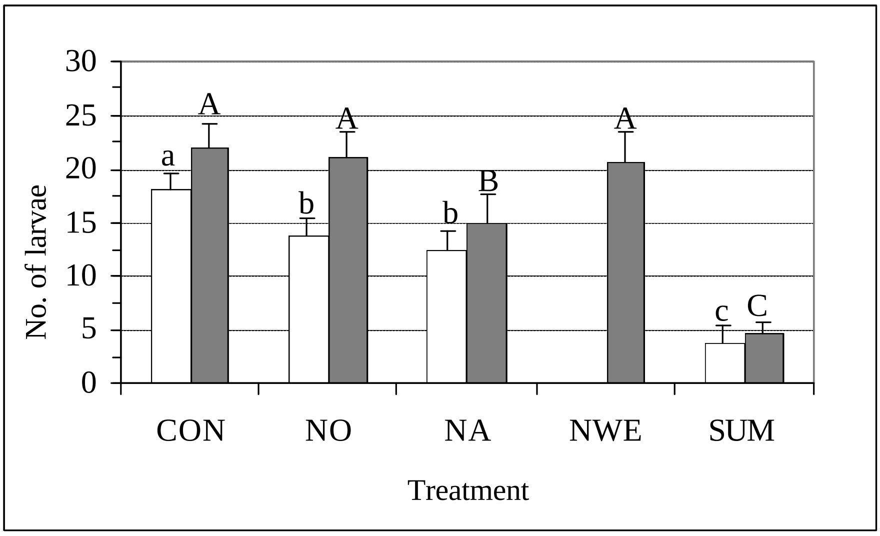

Fig. 16: The population density (mean ± SD) of the green lacewing per plot of treated eggplant (5 x 5 m) grown during winter 1998/1999 (white bars) and 1999/2000 (hatched bars). The different character on the top of bars indicates a significant difference (*P* < 0.05, Tukey's HSD test). The T-shaped beams represent the standard deviations.

4.2.2.6.3.2 The coccinellid beetle *Scymnus sp.*(Coleoptera: Coccinellidae)

Fig. 17 shows the mean number of *Scymnus sp*. in four different groups of plots treated with different neem formulations during the 1998/1999 winter season. The population density of larvae was 19.5 ± 1.91 in the untreated plots, 14.24 ± 3.86 in the neem oil treated plots and 14.50 ± 3.00 larvae in the plots sprayed with NeemAzal-T/S. The least population density of this beetle was recorded in the plots treated with Sumicidin (5.75 ± 0.96). Statistical analysis attested for a significant difference between the Sumicidin treated plots and that of the control. No significant influence was detected among the different neem treatments and their influences on the population density were not significantly different from the control (Tables A12a and A12b). The same results were true for the 1999/2000 season except that the population of the beetle larvae in the plots treated with NeemAzal-T/S was significantly less than that of the control (*P* < 0.05). Significantly higher population density was found in the plots treated with neem water extract compared with the NeemAzal-T/S treated plots (Fig. 18). More statistical data are shown in Tables A13a and A13b. The results of the two seasons are presented in Fig. 19.

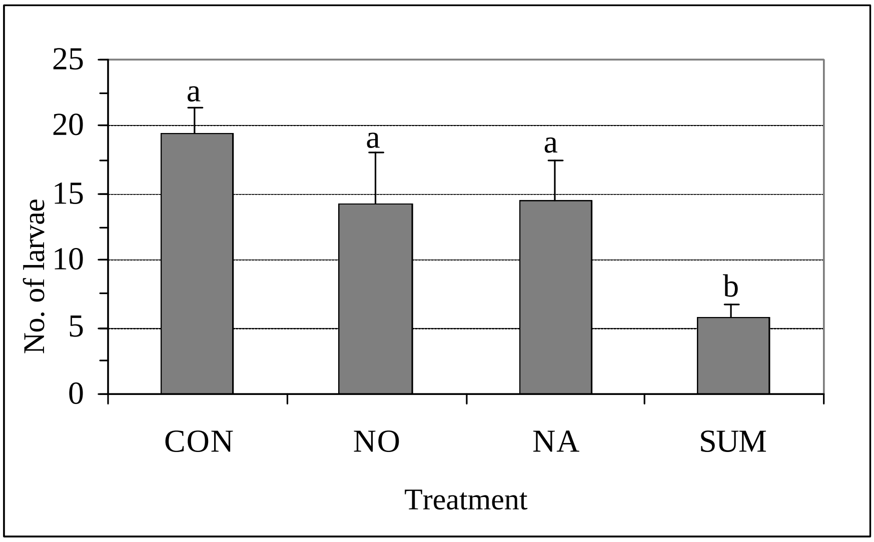

Fig. 17: The population density (mean ± SD) of the coccinellid beetle (*Scymnus sp*.) per plot of eggplant (5 x 5 m) treated with Sumicidin and two neem formulations (winter season 1998/1999). Means sharing the same letter are not significantly different (*P* > 0.05, Tukey's test). The T-shaped beams represent the standard deviations.

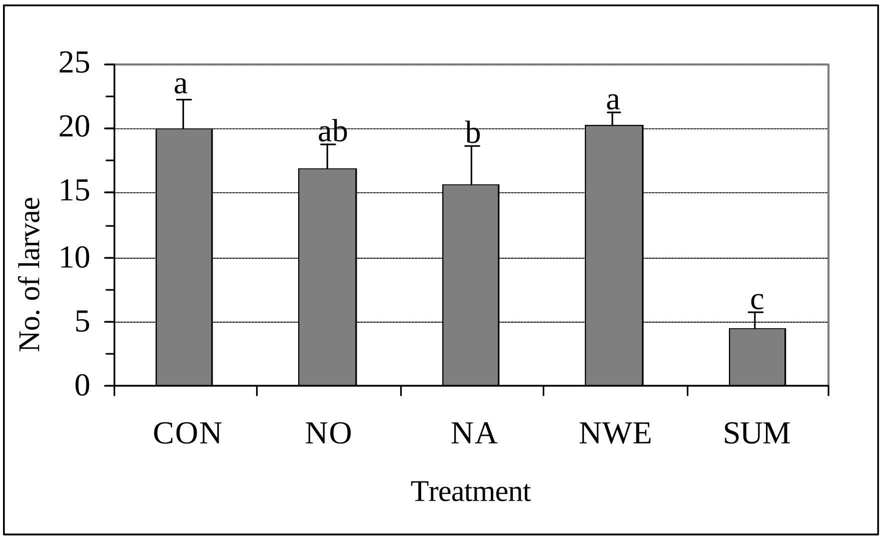

Fig. 18: The population density (mean ± SD) of the coccinellid beetle (*Scymnus sp*.) per plot of eggplant (5 x 5 m) treated with Sumicidin and three neem formulations (winter season 1999/2000). Means sharing the same letter are not significantly different (*P* > 0.05, Tukey's test). The T-shaped beams represent the standard deviations.

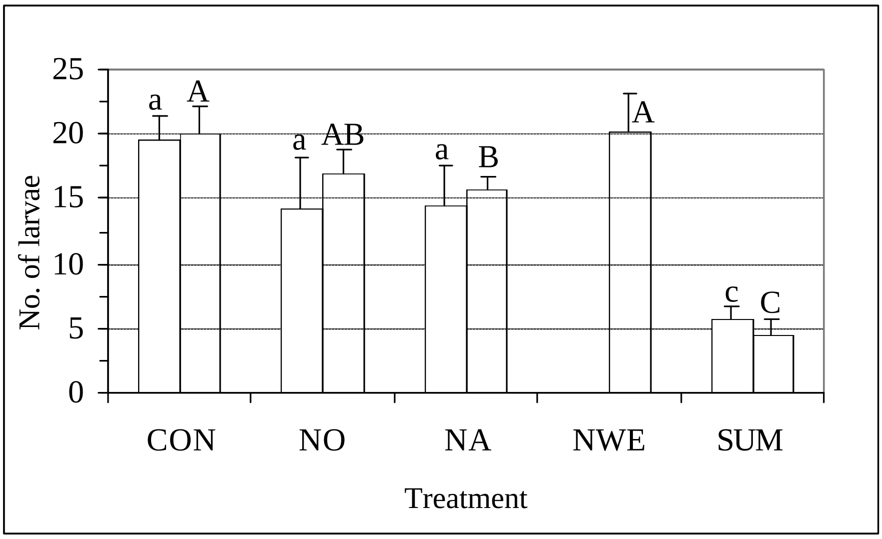

Fig. 19: The population density (mean ± SD) of *Scymnus sp*. per plot of eggplant (5 x 5 m) grown during winter 1998/1999 (white bars) and 1999/2000 (hatched bars), treated with Sumicidin and three neem formulations. The different character on the top of bars indicates a significant difference ($P < 0.05$, Tukey's HSD test). The T-shaped beams represent the standard deviations.

There was no significant difference among the populations of the coccinellid beetle counted in all treatments in the two winter seasons of the study. The control also exhibited no significant difference between the two seasons of the study (Student's t-test, t = 0.3461, $P > 0.05$).

4.2.2.6.3.3 The syrphid fly *Xanthogramma sp*. (Diptera: Syrphidae)

The average number of syrphid fly larvae was 12.50 ± 1.73 in the untreated plots in the 1998/1999 winter season compared with 7.25 ± 0.96, 8.00 ± 0.82 and 2.25 ±0.50 counted in the plots treated with neem oil, NeemAzal-T/S and Sumicidin respectively. The three means were significantly less than the control (Table A14a and A14b). The effect of neem oil and NeemAzal-T/S was more or less equal, where the statistical analysis showed no significant difference ($P < 0.05$, Tukey's HSD multiple range test). The above results are shown in Fig. 20. A significantly negative influence on the population density of this predator was recorded in the neem treated plots in the 1999/2000 season. The population of syrphid fly was 18.50 ± 2.52 in the control and 12.50 ± 1.29, 14.75 ± 1.71 and 12.00 ± 0.82 in the plots treated with neem oil, neem water extract and NeemAzal-T/S respectively. No significant differences were detected among the mean numbers of larvae counted in the plots treated with the three different neem formulations ($P > 0.05$), however, these means were significantly less than the mean number of larvae found in the untreated control plots (Tables A15a and A15b). The least mean population was found in the plots treated with Sumicidin (3.25 ± 1.26). The above mentioned results are illustrated graphically in Fig. 21 and combined with the data obtained during the 1998/1999 season in Fig. 22 for comparison purposes.

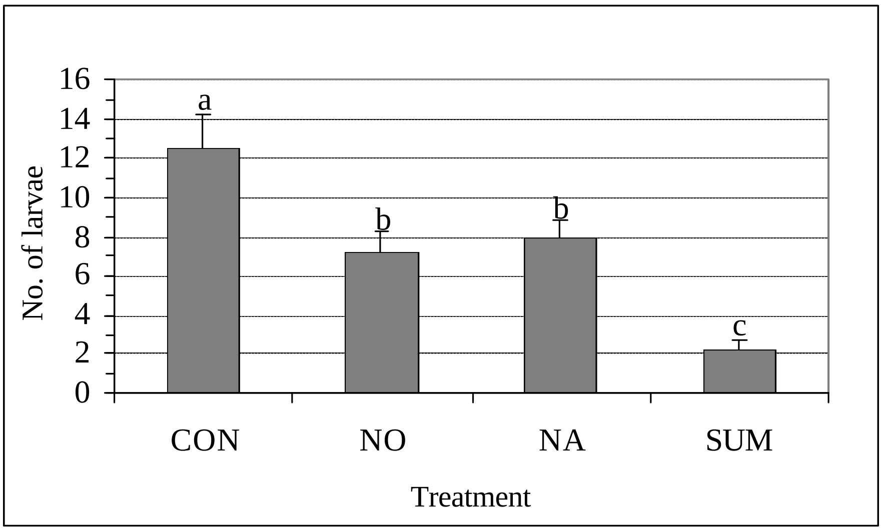

Fig. 20: The population density (mean ± SD) of syrphid fly (*Xanthogramma sp.*) per plot of eggplant (5 x 5 m) treated with Sumicidin and two neem formulations (winter season 1998/1999). Means sharing the same letter do not differ significantly ($P > 0.05$, Tukey's HSD test). The T-shaped beams represent the standard deviations.

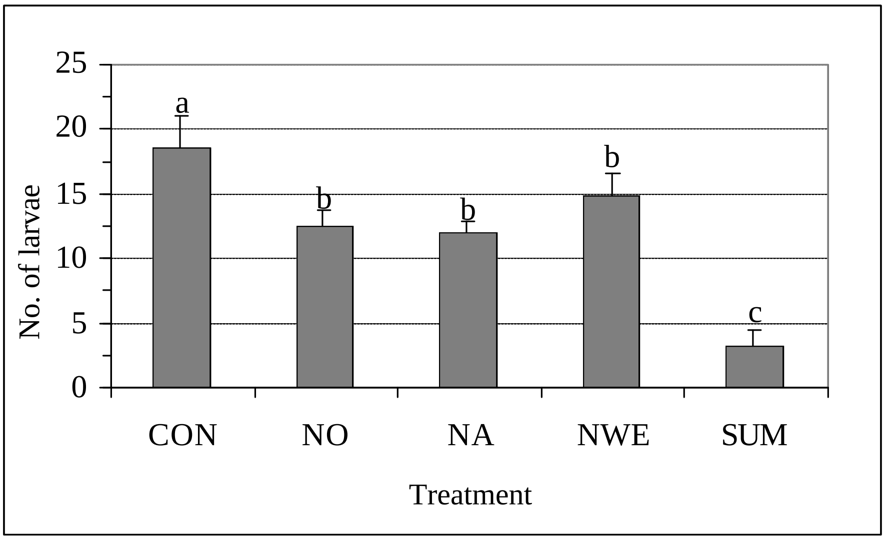

Fig. 21: The population density (mean ± SD) of syrphid fly (*Xanthogramma sp.*) per plot of eggplant (5 x 5 m) grown in the 1999/2000 winter season and treated with Sumicidin and three neem formulations. Means sharing the same letter do not differ significantly ($P > 0.05$, Tukey's HSD test). The T-shaped beams represent the standard deviations.

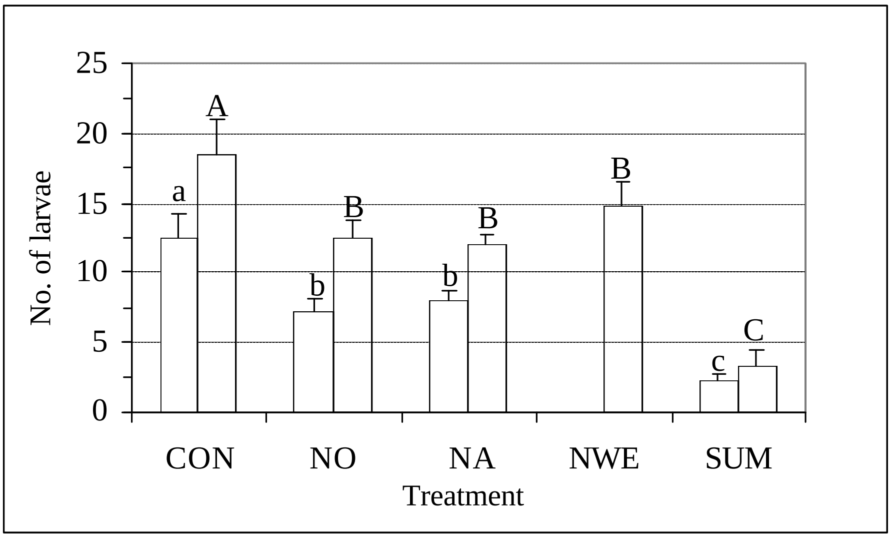

Fig. 22: The population density (mean ± SD) of syrphid fly (*Xanthogramma sp.*) per eggplant plot (5 x 5 m) counted during winters 1998/1999 (white bars) and 1999/2000 (hatched bars) after application of Sumicidin and three neem formulations. Means sharing the same letter do not differ significantly ($P > 0.05$, Tukey's HSD test). The T-shaped beams represent the standard deviations

The populations of syrphid fly in the control, neem oil and NeemAzal-T/S treated plots were significantly higher in the season 1999/2000 compared to the winter of 1998/1999 of the study (t = 3.9198, 6.5328 and 6.928 respectively, $P < 0.01$). The Sumicidin treated plots showed no significant difference in the population of this predator between the two seasons (t = 1.477, $P > 0.05$).

4.2.2.7 The efficacy of neem seed water extract applied with different spraying techniques

4.2.2.7.1 The effect of neem water extract on the population of jassid

Table 21 summarizes the effect of NWE application with different techniques on the population densities of cotton jassid. All treatments reduced the population of jassid significantly in autumn 1999 compared to the untreated check (F =340.225; df = 3,12; $P = 0.000$). The same trend was found in the 1999/2000 season (F = 639.627; df = 3,12; $P = 0.000$). The treatments of the eggplant with the knapsack sprayer reduced the infestation of jassid by 44174.83 and 48293.12 insect-days in autumn 1999 and winter 1999/2000 respectively i.e. 77.87% control for autumn population and 78.63% for the winter population. The application of the same product with ULVA+ sprayer and PLB resulted in 62.59 and 69.28% control of the jassid population in autumn and 60.05 and 66.92% control for the winter population respectively.

Table 21: Percentage reduction (control) in cumulative insect-days of jassid on eggplant treated with NWE applied with different spraying techniques (autumn 1999 and winter 1999/2000)

Treatment	Autumn 1999		Winter 1999/2000	
	C.I.DS.*	% control	C.I.DS.*	% control
Control	56729.8 ± 3220.8 a	—	61418.5 ± 1643.6 a	—
KSS	12555.0 ± 730.6 b	77.9	12555.0± 730.6 b	78.6
ULVA+	21220.7 ± 1117.7 c	62.6	24535.4 ± 1692.5 c	60.1
PLB	17432.1 ± 2632.1 c	69.3	20316.5 ± 2117.5 d	66.9

* Insects per 100 leaves based on 7 counts per the cropping season.
Means within a column followed by different lower case letters are significantly different (Tukey's HSD test, $P < 0.05$).
KSS = Knapsack sprayer, ULVA+ = Ultra low volume sprayer, PLB = Palm leaf brush

The application of neem seed water extract with Knapsack sprayer resulted in significantly higher percentage of control than both ULVA+ sprayer and palm leaf brush in both seasons of the study. No significant difference was detected between the performance of ULVA+ sprayer and PLB in autumn 1999, on the other hand their performance differed significantly in the winter of 1999/2000.

4.2.2.7.2 The yield

The data presented in Table 22 shows the average yield obtained from plots of eggplant treated with neem seed water extract in two different seasons. The neem product was applied with different application techniques. The application of the product with a pre-pressurized knapsack sprayer increased the yield significantly by 2.59 and 2.65 ton/feddan in the autumn (kharif) season of 1999 and winter season 1999/2000 respectively. The performance of the knapsack sprayer was superior to both ULVA+ sprayer and palm leaf brush (PLB) method (Tables A16a, A16b, A17a, and A17b). The ULVA+ sprayer and PLB techniques gave a significantly higher yield than the control in the autumn (kharif) season ($P < 0.05$). A comparison of yield obtained from plots treated with PLB with those sprayed with ULVA+ sprayer revealed no significant difference in both seasons. The plots sprayed with ULVA+ sprayer produced a significantly higher yield than the control in autumn but their yield was not significantly different from that of the untreated plots during the winter season.

The data available in Table 22 strongly suggest that the net effect of neem seed water extract applied with ULVA+ sprayer and PLB was similar.

Table 22: The average yield of eggplant treated with neem seed water extract applied with different spraying techniques in autumn 1999 and winter 1999/2000.

Treatment (application techniques)	**Yield (ton/feddan)*** Autumn 1999	Winter 1999/2000
Knapsack sprayer	6.66 ± 0.34 a	7.64 ± 0.35 a
ULVA+ sprayer	5.46 ± 0.29 b	6.16 ± 0.58 bc
Palm leaf brush	5.90 ± 0.29 b	6.74 ± 0.82 ab
Untreated control	4.07 ± 0.30 c	4.99 ± 0.21 c

* Means (± SD) within a column followed by a common letter are not significantly different.($P > 0.05$; Tukey's HSD test).

The effectiveness of neem water extract as a home-made insecticide seems to vary with the season (Table 20), the method of application used (Table 22) and the type of the crop (Table 23).

Table 23: The average yield of eggplant and potato grown in the winters of 1998/1999 and 1999/2000, treated with Sumicidin and different neem formulations applied with Ultra Low Volume sprayer.

Treatment	Yield (ton/feddan)*			
	Winter 1998/1999		Winter 1999/2000	
	Eggplant	Potato	Eggplant	Potato
N-Azal-T/S®	9.80 ±1.15 a	5.12 ±0.57 a	11.74 ±0.79 a	6.09 ±0.38 a
Neem oil	5.92 ±0.43 b	3.92 ±0.34 b	7.75 ±1.46 b	4.04 ±0.46 bc
NWE	------------	------------	7.36 ±1.69 b	4.32 ±0.44 b
Sumicidin®	9.47 ±1.22 a	5.37 ±0.59 a	11.64 ±1.34 a	6.35 ±0.36 a
Control	4.36 ±0.11 b	3.36 ±0.20 b	5.63 ±0.28 b	3.36 ±0.38 c

*Means (± SD) within a column followed by the same letter are not significantly different ($P > 0.05$; Tukey's HSD test).
NWE = Neem seed water extract
--- Neem seed water extract was not applied in this season.

The yield of eggplant obtained from the control as well as the plots treated with NWE applied with the knapsack sprayer was significantly higher in winter 1999/2000 (t = 4.4203 and 3.5393, respectively, $P < 0.05$) compared with autumn 1999. The plots sprayed with PLB and ULVA+ sprayer using the same product produced yields which were not significantly different in those two seasons of the study (t = 1.6393 for PLB and 1.8670 for ULVA+ sprayer, $P > 0.05$).

5 DISCUSSION

5.1 General

Vegetables growing for the local market in the Sudan is mostly developed in Khartoum state and for this reason that state was chosen as experimental site to carry out the present work. It is the largest urban center in the country and with the highest living standard of its population, concomitant with high levels of education and sophistication, high per capita incomes, having large european community and other nationalities. By all means, it is the largest vegetable market in the country, where vegetables are grown mostly as intensive crops with high agricultural inputs such as fertilizers, irrigation facilities, and pesticides. They are cultivated continously in small and limited areas with very narrow or no crop rotation. This system of management avails optimum condition for breeding and rapid developement of insect and other arthropod pests.

In Sudan, potato, *Solanum tuberosum* L. and eggplant, *Solanum melongena* L. (Solanaceae) are important vegetable crops. The former is grown exclusively in winter and the latter can be grown almost throughout the year. These two crops are rapidly gaining popularity and they rank third and fourth after tomato and onion. They are attacked by many foliage pests, among them, the jassids, whiteflies and aphids are most important (SIDDIG 1987). These homopterous pests upsurged as a result of the wide use of synthetic insecticides in the late 1950s (DITTRICH et al. 1990a).

In this investigation, neem products were applied as prime candidates for possible use in the management of these pests. The evaluation of the performance of these products in the field was based on the insect counts in the treated plots as well as the yield obtained at the end of cropping cycle of each crop.

High efficiency of neem products against homopterous pests was proved in both laboratory as well as field experiments (COUDRIET et al. 1985b; SCHMUTTERER 1985 , 1990 ; JACOBSON 1990; LOWERY et al. 1993 and OSSIEWATSCH 2000).

5.2 The effects of neem products on the different developmental stages of the geenhouse whitefly

Although it is not always easy to extrapolate laboratory results to field application, nevertheless, they give a solid base for the field trials. The application of NeemAzal-T/S, neem oil and Rimulgan with a paint air-brush resulted in a reduction of the egg hatchability of the greenhouse whitefly by 9 upto 25%. These finding seems to be in line with that of COUDRIET et al. (1985b) who stated that 2% of neem seed extract reduced egg hatch of the sweetpotato whitefly on day 6 by 29% and caused ca. 90% mortality of the larvae by day 20.

This study demonstrated a high mortality of the larvae; but the egg and adult stages were the least among the developmental stages of this insect to be seriously affected by the application of neem products. DORN et al. (1987) reported that the hatchability of the eggs from large milkweed bugs injected with AZA was close to normal. Earlier instars of sweetpotato whitefly were more susceptible to Margosan-O compared to later instars and there was little mortality to eggs or adults (PRICE and SCHUSTER 1990).

There was no significant difference between the effect of NeemAzal-T/S and Rimulgan on the egg stage. The deformity of eggs resulted from the application of Rimulgan alone was similar to that produced by NeemAzal-T/S. The fact that Rimulgan contained no AZA in its formulation strongly support the assumption that the effect of neem oil formulations on the egg stage is primarily through the physical properties of the oil. SCHMUTTERER (1997) attributed the effect of neem oil on the egg-parasitoids to some physical properties of the oil. It has been demonstrated in this study that NeemAzal-T/S and neem oil prolonged larval development. This finding is similar to those obtained by STEFFENS and SCHMUTTERER (1982); ZEBITZ (1984); COUDRIET et al. (1985b) who used *Ceratitis capitata* and *Aedes aegypti* respectively in their studies, and GOVINDACHARI et al.(2000), who experimented with *Spodoptera litura.*

This prolongation of developmental period together with the reduction of fecundity of the adult females (SCHMUTTERER 1990) will reduce the number of generations of this pest and other pests with several generations per cropping cycle as well as the reduction of individuals in each generation and thus neem products will enhance the management of this homopterous pest in the agroecosystem.

5.3 The systemic effect of neem products (greenhouse experiment)

The experiment was intended to study the systemic effect of neemAzal-T/S and of neem oil on the cotton jassid on potato seedlings in an stage-dependent greenhouse experiment. Folimat (a well known organophosphorous systemic insecticide) was included for comparison. The second and third nymphal instars of the jassid were selected for the study. It is a vulnerable stage and its population could be checked by the environmental factors as well as the biotic factors such as natural enemies. The fourth and fifth instars might be too old to demonstrate an obvious effect of growth regulating action of neem in the same experiment i.e. a time lag is needed until they reflect this effect. Observable effect of these products might appear later in the adult stage as a reduction of fecundity or reduced fitness (SCHMUTTERER 1990). The second and third instars represent the most interesting and damaging stages in the life cycle of the jassid and there is also no technical problems concerning the handling of the insects without injury. Moreover, they consume large amount of sap and thus increase the probability of picking more active principles of neem. SCHMUTTERER (1969) stated that the higher the proportion of young instars of jassid then the more likely that the infestation will continue for sometimes and the more likely that control measures are urgently needed.

It has been observed during this study that Folimat had a very quick knock down effects on the jassid nymphs demonstrated by the fact that most of the tested animals have died the day after the start of the experiment, unlike neem products which allowed the insects for some more times before they could exerted their effect. There was no significant difference between the efficiency of Folimat and NeemAzal-T/S. These results could put a solid argument that neem products especially the standardized commercial ones could prove to be equally effective and efficient as the synthetic chemicals when applied with sophisticated equipments. NeemAzal-T/S showed more effect on the second nymphal instar of jassid than on the third (Fig 8).

These findings are confirmed by that of PRICE and SCHUSTER (1990) who demonstrated that earlier instars of the sweetpotato whitefly *Bemisia tabaci* (Gennadius) were more susceptible to Margosan-O compared with the late instars. It is very important to realize, that the mortality caused by neem products occurs too late to prevent the transmission of viruses by *Bemisia tabaci* (BERNAL VEGA 2001). MAHESHKUMAR et al. (2000) studied the systemic effect of 8 neem formulations including neemAzal-T/S on the green leafhopper (*Nephotettis virescens* Distant.) on rice seedlings. They sprayed the leaves of the potted seedlings with different concentrations of NeemAzal-T/S (100, 250, 500 ppm.) and then, they confined the second nymphal instar of the leafhopper on unsprayed part of the plant to demonstrate the downward translocation of AZA. In another experiment, their results demonstrated that only six hours are enough for the seedling roots dipped in neemAzal-T/S to prove the upward translocation and efficiency against the green leafhopper nymphs.They stated that significant mortality of the insects was observed in all treatments. LAREW (1988) demonstrated the movement of a neem extract ingredient from a sprayed bean leaf to an unsprayed leaf on the opposite side of the plant.

Foliar spray on potato seedlings carried out with ULVA+ sprayer in the current investigation clearly demonstrated the systemic activity of neem products against the nymphal instars of cotton jassid. Such conclusion has been confirmed by many authors who studied the systemic effect of neem products on different plants and insects. SCHMUTTERER (1985) stated that lower concentration of the neem seed extract in foliar applications are thought to result in insufficient uptake and translocation of compounds to control aphids. NISBET et al.(1993, 1994) reported that by lowering the concentration of AZA applied to the crop, food intake by insect pests with low chemoreceptor sensitivity to AZA e.g. aphids will not be initially affected by the primary antifeedant effects. The fact that neem products can be translocated systemically in the plant will give such products an additional advantage of protecting the hidden parts of the plant canopy which are out of reach of the application equipments and also the new flush of growth will have some degree of protection. The active principles will escape the degradation by the environmental factors. In addition, a big plus will be added in favour of neem which is the safety to egg-parasitoids and predators resulting from avoidance of the contact action.

Two important aspects will be of great interest in this respect, the fate of AZA in the plant system and its threshold level to exert both antifeedant and growth regulating effects on the sap sucking insects. The enzymetic activity of the different plants is different as well as the pH. This difference in the acidity and alkalinity might play an improtant role in the determining the fate of AZA and other neem principles in plant sap (SCHMUTTERER pers. comm.). Until now not enough informations are available and more research in needed in this area (NRC 1992).

5.4 Pest density/yield relationship (semi-field or cage experiment)

The effect of the different jassid densities on the yield of potato was studied in cage-experiment conducted under semi field conditions. The results of the present study have demonstrated that 40 jassid/100 leaves caused yield losses which were still below 10% when the insects were kept on the potato crop in the semi field cages and 231-246 jassid/100 leaves were critical threshold for the initiation of practical control purposes in the open field. The potato crop seems to be very susceptible to infestation by jassid in this cage experiment. The results of the current study are supported by the findings of AHMED et al. (1986) who demonstrated that 0.5 of the jassid (*Amrasca devastans* Dist.) per leaf of cotton caused significant yield losses in the field cages and BINYASON (1997) who determined an economic threshold for jassid on eggplant in field cages at 0.5 jassid/leaf or 50 jassids/100 leaves and 200-300 jassid/100 leaves in the field.

The leafhopper or jassid being sap-feeder on potato foliage, causes occlusion of the vessel in the leaf leading to cell death in the region of feeding puncture. The hatchlings or the early nymphal instars are usually found between two small veins feeding on the main and secondary veins of the leaf. At low levels of jassid density i.e.1.5 jassid per leaf, the symptoms produced on the potato were not conspicuous and it was very difficult for the farmer to observe. Curling of the leaf margins and yellowing of the leaf lamina between veins are associated with the infestation of jassid. This symptom could be proved by the presence of nymphs on the under side of the leaf. The hopperburn symptom is only observable at high level of infestations of 5 or more jassid per leaf and even this symptom is confused most of the time with the symptom of the leaf spot produced by *Alternaria sp.* which is common in poor soil associated with water stress and low nutrients.

The interviewed farmers could not decide their sprayable levels from the photographed symptom obtained from the caged plants. For this reason the participation of the farmers in developing an action threshold against jassid was not possible in this investigation and it was determined on the percent loss of yield and the significant linear regression model. The photographed symptoms have been used by some entomologists to indicate the extend of damage on some crops due to different levels of infestations by various pests and hence the determination of the actin threshold (HART and MYERS 1968; BINYASON 1997).

This method of determining the AT (the action threshold) might be the simplest method to the farmers away from the tedious insect counting adopted by insect researchers, but it depends solely on the clarity of the symptoms produced and the technical possibilities of photographing it. The jassid produced very clear symptoms on cotton and eggplant compared to potato where the symptoms might not be clear.

The proposed AT for jassid on potato in the field could be supported by the fact that the potato crop in the field had maintained a significantly higher yield than the control although it harboured a population density of around 200 jassid per 100 leaves. The microclimate of potato in the cages was different from that of the open field environment and this might account for the wide difference of the ETLs in the field and the semi field cages.

The economic threshold was calculated using the formula adopted by STONE and PEDIGO (1972) and FAKI and STAM (1989) who used the cost/benefit ratio in their calculations. They multiplied the price of the crop by the regression coefficient which represent the slope of the linear equation that determine the relationship between the yield of the crop and the infestation levels by a certain insect pest. The benefits are affected by the infestation of the pest and hence they were represented by the price of the crop multiplied by the regression coefficient.

The decision to apply a pesticide should be determined by the cost/potential benefit ratio, i.e. the cost of control measures balanced against the increase value of the crop that can be recovered or protected and the lack of knowledge on the yield/pest density ratio has lead to unnecessary control measures (STERN 1973).

ETLs are dynamic and the farmers could not depend totally on them unchanged for a long period to obtain profitable yield in their fields. The changes in the market value of the crop depending on the supply and demand, the change in the price of pesticides and the labour cost of their applications due to increasing inflation will determine such ETLs.

The AT is an immediate action which could be taken irrespective of whether the outcome will be economic or not (BINYASON 1997). Based on this background an action threshold of 200 jassids/100 leaves is proposed for the management of the cotton jassid on potato under field conditions. The management should be started at an early stage of infestation. As has been shown in the current study, promising results were obtained with neem pesticides when the population of the insect pests was low.

This of course is a simple-minded approach to the complexity of interactions that determine the ETL for a certain pest in an agroecosystem, but nevertheless, it could provide a useful, adaptable action threshold for the local farmers which should be revised continously when circumstances change.

5.5 The performance profile of neem products under field conditions

In the present investigation, NeemAzal-T/S applied with ULVA+ sprayer (spray volume of 10 l/ha) proved to be as effective as Sumicidin in combating the homopterous key pests of potato and eggplant and increased the yield of potato significantly in both seasons of the study.

The eggplant yield was also substantially increased. Similar results are well documented in the literature. LOWERY et al. (1993) found that neem seed extract and neem oil were as effective as the botanical insecticide Pyrethrum for the control of aphids on pepper and strawberry. Neem seed kernel extract was also found to be as effective as Decis in protecting all the crops treated against their major pests (FAGOONEE 1987). REDKNAP (1981) sprayed aqueous neem seed kernel extract on cucumber against *Epilachna chrysomelina* which was effective as Malathion.

The application of neem water extract with the Knapsack sprayer proved to be very effective and practical against homopterous insect pests. This simple formulation was not applied in the winter season of 1998/99 because of the unavailability of freshly collected neem seeds at the beginning of the experiments which was started in November 1998 and a fresh harvest of neem seeds is usually collected in June. A handful of investigators have successfuly used neem water extract to control some homopterous pests on potato and eggplant in Sudan and Togo (SIDDIG 1987 and DREYER 1987).

The observed difference of potato yield in the two winter seasons of the study (Table 16) could be explained by many factors. The infection of the seedpotato in stores by the soft rot due to bad storage conditions which were caused by the fluctuation of power supply and its lacking most of the time during the summer months of 1998, the relatively high temperature during December-January of 1998/99 could also contribute to the poor growth, establishment and yield of potato in this season. Nevertheless, the yield obtained from these field trials was higher than the yield obtained by the average farmer in Khartoum area in this year. The majority of the farmers ended with very poor yield and in some cases the yield could barely cover the cost of harvest. For this reason some farmers have left their crop even in the ground.

The seasonal variation in the mean number of jassid, aphid and whiteflies beside other minor pests constituting the ecosystem could have similarly affected the yield. Higher yield of eggplant were obtained in winter crop compared with autumn (Table 20). The phenology of the crop together with environmental factors could explain the observed difference in the yield of eggplant in winter and autumn, although it is not at all easy to quantify the contribution of individual factors operating simultaneously with each other in a complex ecosystem.

The efficacy of neem water extract as a home-made insecticide varied with the crop, the season and method of application. These findings concur with the results of many neem researchers. SCHMUTTERER (1990) stated that the control of the whitefly with neem is influenced by the host plant. JACOBSON (1990) reported that soil drenches of Margosan-o reduced the number of adult leafhoppers on marigold and chrysanthemum, but not on zinnias.

The effectiveness of neem appear to be influenced by the hostplant, the insect species, nymphal instar treated and weather conditions (PRICE and SCHUSTER 1990; LOWERY and ISMAN 1994,1996). Two factors are likely to be responsible for the loss of performance of NWE when applied with ULVA+ sprayer. First, the small droplets produced by the sprayer might exposed the active principles to rapid degradation by the different environmental factors especially in this study where no antioxidant, synergist or stabilizer was added to the formulation compared with the commercialized neem products. It is worth mentioning in this respect that UV light, rainfall and temperature are important environmental factors affecting the neem seed kernel extract (SCHMUTTERER 1985). Second, the solubility of neem active ingredients in water could also affect the performance. The water as a polar solvent is able to extract AZA and more of it is expected to be found in large volume of water. Polar compounds are closely associated with the non-polar active compound and hence helping in the solubility (MEISNER et al. 1987). The authors found that the order of efficacy of extraction of AZA by different solvents is as follows: ethanol > methanol > water > acetone. The percent of AZA in the NWE formulation used in the present investigation was unidentified, but it is generally known that the crude neem extract is a complex mixture consisting of few major and numerous minor compounds all of them very similar in polarity (KRAUS 1995).

The systemic activity of neem products differ from plant to plant and formulation to formulation and also differ with insect type. It is not effective on some aphids which are phloem-feeders where the concentration of AZA is very low (for unknown reasons), on the other hand, leafhopper and planthopper, that feed at least half the time on the xylem could be easily controlled (NRC 1992).

The efficacy of the neem products could be further improved and their performance be boosted under field conditions by addition of synergists. A laboratory study carried out in Germany showed that sesamex (sesoxane or sesoxan) and piprotal (Tropital) improved the effectiveness of the neem kernel extract about 3-fold when tested against the mexican bean weevil (*Epilachna varivestis* Muls.). The pupal mortality rate was considerably higher than the untreated insects. Piperonyl butoxide and S-421 were ineffective (LANGE and SCHMUTTERER 1982; LANGE and FEUERHAKE 1984). OLAIFA et al. (1993) added 0.1 percent propyl paraben and 0.1 percent octylgallate to an emulsifiable concentrate from neem oil which prevented microbial spoilage and oxidation of the emulsion. FEUERHAKE and SCHMUTTERER (1985) developed a cheap, standardized formulation for small-scale farmers by using crude neem kernel extract, solvent glycol ether and propyl gallate benzophenone.

With all the possibilities of improving the performance profile of neem pesticides mentioned above, the use of sesamex seems to be the most suitable for the situations of the Sudan since sesame is grown in large areas in the country and the sesame oil is available and affordable for the local farmers. The oil of castor bean which is available in the country could also be used in boosting the efficacy of neem water extract (SCHMUTTERER, pers. comm.).

The efficacy of synthetic chemicals is also affected by the host plant and the species concerned. Responses of the cotton jassid to spraying with different insecticides vary with the season, the variety and locality (SCHMUTTERER 1969). The data obtained from the field trial conducted during the present study in the two seasons demonstrated clearly that jassid was the easiest among the three studied homopterous pests to be controlled with neem products as well as with Sumicidin followed by the whitefly and aphids. This might be explained by the fact that jassids move (adults and nymphs) during the night and come on the upper surface of the leaves (SCHMUTTERER 1969). This mobility might help in bringing the insects in contact with the chemicals sprayed on the plants.

The whitefly seems to be more difficult to control with sumicidin than the cotton jassid. The reason of the relatively low performance of this commonly used pesticide could be attributed to the resistance of this pest to organophosphates and pyrethroids which is well documented in the strains of sudanese cotton whitefly (DITTRICH and ERNST 1983; DITTRICH et al. 1990a, 1990b; DEVINE and DENHOLM (1998). CAHILL et al. (1995) stated that both immature and adults of the whitefly *Bemisia tabaci* are difficult to control with insecticides because of their preferred habit to remain on the under surface of the leaves, their rapid reproduction rate and their occurrence on a wide host range within and between seasons.The short generation time of the whitefly, the high rate of fecundity, the stage specificity and the greater mobility of the adults are advantageous to the insect and thus enhance the evolution of insecticide resistance (PRABHAKER et al. 1985).

The percent control obtained with NeemAzal-T/S on this same pest on potato was in the range of 60 to 70% in the winter season of the study. This performance may be considered appreciable for a pest well known for its resistance even to conventional insecticides. The remaining 30 to 40% of the population could be controlled by the surviving natural enemies and hence a satisfactory manegement of this homopterous pest could be achieved.

5.6 Seasonal fluctuations of jassid, whitefly and aphid in the study area

The understanding of the phenology and the population dynamics of homopterous pests is a prerequisite for their management and will help in the formulation of an effective control decision making agaist each intra-seasonal population.

The seasonal fluctuations of jassid and whitefly populations are indicated clearly by the results shown in Fig. 10. Peak populations of jassid occurred at the end of December and start to decline as the winter faded away. These results are confirmed by those of many authors (COWLAND 1947; JOYCE 1961; SCHMUTTERER 1969 and BINYASON 1997).

Many environmental factors exerted their influence on the population of jassid. Rainfall and temperature may have an effect in this respect. HANNA (1950) indicated that heavy rainfall of more than 10 mm causes mud splash killing a large number of leafhopper located up to 30-40 cm high on the cotton plant in July and August. The velocity of the shower, rain drop size, the soil type and the direction of the shower play an important role in the reduction of the jassid nymph on the under side of the cotton leaf. On the other hand, JOCE (1961) could not find a correlation between the population of jassid and rainfall. The season, plant age and temperature influence the jassid population. HABIB et al. (1972) reported no egg-hatch when temperature dropped below 10°C and similarly an increased mortality was well documented above 27°C (KLEIN 1947). Similar effects of rainfall and temperature on the population have been reported by EVANS (1963).

The nitrogen content of the plant could be another factor influencing the jassid population on eggplant. The nitrogen level in the leaves is an important factor affecting fertility and biology of insects (JOYCE 1961). The nitrogenous fertilizers like urea which are commonly used by vegetables growers could lead to an increase hopper population due to high nitrogen content of the leaf. On the other hand, McNEIL and SOUTHWOOD (1978) found that the available nitrogen in the grass artificially or naturally induced, has little effect on the growth and nitrogen accumulation rate of the leafhopper nymphs.This is achieved by a compensatory increase in the feeding rates on low nitrogen food, with a consequent rapid decrease in the assimilation efficiency as measured either in energy or nitrogen terms.

The population of jassid was about 400/100 leaves in autumn as reflected by the results of the present study .This number could be easily brought below the economic threshold level which was set up for jassid on eggplant at 300 insects/100 leaves (BINYASON 1997). The population in winter was around 600/100 leaves. This inter-seasonal variation in the jassid population might account for the seasonal variation in the efficacy of neem water extract and difference in yield obtained in the two different seasons.

The whitefly reached its peak population in December which was followed by a rapid decline during January and Febraury (Fig 10). The population remained very low during summer (April-June). These findings are not different from that obtained by ABDELRAHMAN (1986) who stated that the infestation of cotton by *Bemisia tabaci* started in early September and increased gradually in October, peaked in mid November and decline slowley again in December and January. The same author reported that the whitefly and its parasitoids resort to the green host plants in garden, vegetable fields, canals and river banks during summer time or the dead season in the Gezira (200 km south of Khartoum). *Ipomea cordofana* (Convoluvalaceae), a wide spread weed is considered as very important alternative host for the whitefly where up to 34% of the pupae were found during September (VAN GENT 1982).

Practically no aphid was found during summer time. *Aphis gossypii* spends the hot summer months in central Sudan in small colonies on weeds and irrigated crops. The aphid is often very small during this period, even in the adult stage. Yellow forms are predominant during the summer months in the central Sudan. The winged aphids give birth to a first generation which is mostly dark green in colour, late in the season when the host plants become woodier and the level of amino acids in the leaves and twigs decreases, the insects may be smaller and yellowish green to yellow in colour (SCHMUTTERER 1969). This changes in colour and size of the aphid are advantageous mechanisims to overcome the scarcity of food during summer and the small size is also known to reduce the loss of water through the integument. The change in the relative abundance of herbivore insect from year to year, appear to be dependent on the large variations in plant phenology and nutritional status within and between seasons (McNEIL and PRESTIDGE 1982).

The present findings are supported by the study of CLOUDSLEY and IDRIS (1964) who investigated the adaptations of desert arthropods to life under extreme conditions of aridity and heat in Khartoum region. They stated that the majority of coleopterous and lepidopterous larvae were found during the month of August and the present of dead beetles during the dry season suggest that the older generations tend to die off at this time of the year while the younger adults burry themselves deep in the ground and remain dormant. This developemental arrest to cope with the unfavorable environmental conditions is also known in homopterous pests .

MÜLLER (1979) emphasized the important of temperature and photoperiod fluctuations in producing dormancy periods which allow the develpoment of the leafhoppers to coincide with seasonal changes in the environment and hence to escape the conditions of extreme coldness, dryness and hunger with the ultimate aim of survival and continuation of the population. Cicadellids can overwinter in egg, larva and adult stages as a response to unfavourable environmental conditions i.e. cold spill, deficiency of food, dryness and high temperature (WITSACK 1993).

Whiteflies overwinter in the temperate regions as nymphs or adults (BYRNE et al. 1990). In the tropics, overwintering or oversummering of the aphids take place either in the wingless or winged parthenogenetic, viviparous forms (SCHMUTTERER 1969), whereas in the temperate many aphids spend the winter in the egg stage (SCHMUTTERER 1969 and EASTOP 1977).

The results of the current study have demonsrated that the newly expanded leaves of eggplant near the apex of the main stem or side branches are preferred for oviposition by the cotton jassid. This was demonstrated by the present of large numbers of young nymphs or hatchlings on this portion of the plant. The maximum number of jassid counted on eggplant in a single count was 65 jassids/leaf compared with 32 jassids/leaf on potato. SCHMUTTERER (1969) stated that the numbers of jassid may be as high as 40 jassid per cotton leaf in heavy jassid incidence.

The presence of this very high numbers of individuals in a very small ecological niche (the plant leaf) will raise a big question of how far is this species capable of coping with the intraspecific competition which is very important biotic factor regulating the population dynamic of the species. WITSACK (1993) stated that the cicadellids being polyvoltine, lead to the overlapping of generations with all developmental stages living together. This situation has the disadvantage of intraspecific competition between these different stages. Because they use the same source of food (the plant sap). Some insect species avoid such competition by assuming a different source of food in the immature and adult stages. Lepidopterous insects and hoverflies are classical examples. Whiteflies were mostly found on the lower leaves of the plant as they prefer shelter places.

The aphids were mostly found in the middle of the plant. This vertical distribution of the three homopterans on eggplant together with the fact that aphids exploit the upper and lower side of the leaf, the whiteflies confine themselves only to the lower side of the leaf and jassid could move freely betweeen these two sites but mostly on the lower side might help reduce the effect of interspecific competition among these species. This knowledge of distribution of these pests in both time and space will help practically in their sampling.

A lot of weeds act as oversummering developmental host for jassid and whitefly and the destruction of these alternative hosts might help in the management of the populations of these homopterans. COUDRIET et al. (1985a) had another opinion, they suggested the use of permanent weeds host sites of the cotton whitefly for the release of introduced as well as indigenous natural enemies to obtain a long-term benefit for the management of this pest. The same authors stated that development of *Bemisia tabaci* was completed in 30% less time on lettuce, cucumber, eggplant and squash than on broccoli or carrot. BERNAL VEGA (2001) reported that weeds could also act as a reservoir for parasitoids of *B. tabaci*.

The availability of oversummering hosts, abundance of winter hosts, moderate winter temperature, low rainfall, and development of resistance to the most commonly used insecticides are among the factors which lead to the recent increase in the population of whitefly and jassid. Their biological and behavioral characteristics of high rate of fecundity and mobility of adults enhance their success in colonizing a wide varieties of niches. This recent increase of homopterous populations in potato and eggplant ecosystems will justify the more attention being paid to them.

Using the eggplant as suitable developmental host at least for the whitefly, predictive life table models as well as day-degree models could be developed to determine the optimum spraying time of the neem products or the evaluation of their efficacy under field conditions.

5.7 Other economically important pests of potato and eggplant

The survey carried out during the present investigation reaveled that more than 25 and 28 insect pest species exist in the ecosystems of potato and eggplant, respectively. Since the main purpose of the current study is to manage the economically important homopterous pests inflicting damage on these crop, it does worth to have an insight look into the whole pest complex. As stated earlier in this work that the economic damage is caused only by 3-5 key pests. The presence of seemingly large number of other pests causing no appreciable damage might even be considered essential for the biodiversity and balance in the agroecosystems.

DISNEY (1999) stated that biodiversity has become a fashionable notion and its conservation a concern with growing popular support. He reported that when population ecologists discuss diversity they are usually concerned with two aspects, species richness (i.e the number of species in a set of samples) and equitability e.g. the number of individuals of each species in a sample, such that 10 each represented by 5 individuals is considered more diverse than sample of 10 species in which one is represented by 40 individuals, 1 by 2 individuals and 8 species are represented by a single individual.
Based on this explanation, the eggplant ecosystem was more diverse than that of potato and both systems were more diverse than others ecosystems where rigorous programs of pesticides are common practice as in the case of cotton ecosystem.

The presence of termite damage in the experimental plots of eggplant and potato was observed sporadically scattered as indicated by the wilting of the infested plants. The damage was not serious and was connected with a dry spell caused by lack of irrigation due to a defect in the pumping machine, but such damage was ephemeral and was over as soon as the crops were irrigated. EL KHIDIR (1976/77) stated that damage by termite on wheat was reported to him from heavy clay soil plots around Shambat Agricultural Institute (approx. one kilometer away from the experimental site of the current study).

Two underground pests that inflict serious damage on potato tubers were found during the present investigation., the tuber moth (*Phthorimaea operculella* (Zeller)) and the black cutworm (*Agrotis ipsilon*) and the cutworm (*Agrotis segetum*). Both species attack the tubers and render them unfit for the market which is a great loss for the farmers. The cultural practice of earthing up to cover the developing tubers with the neem leaves will be suffice to control them (SIDDIG 1987, 1991). Neem products were reported to very effective against the tuber moth in Sudan and Egypt (SIDDIG 1987; KELANY et al. 2000).

Two other sucking arthropods, the red spider mite (*Tetranychus sp.*) and the tingid bug (*Urentius hystricellus*) were encountered inflicting damage on eggplant during the current study. Some plots were infested with the red spider mite which produce considerable webs that capture dust leading to severe damage on the crop. The infestation with the mite spreaded over a strip of about 3-ridge wide. Such kind of infestation pattern might be associated with the epidemiology of the mite and its passive spread from plant to plant by wind. The severity of the mite was high in summer crop compared to that of winter. It is worth while mentioning that the plants infested with the mite tended to show less number of other insects and in severe mite infestation there was no jassid, whitefly or aphid on the infested plants. This could raise a question of interspecific competition, but further investigations are needed before a conclusion could be reached.

The Abutilon plant (*Abutilon figarianum*) a weed commonly found in and arround eggplant fields serve as an alternative host for the tingid bug where a large population is found which might migrate to infest the eggplant. The tingid bug is also one of the pests listed to be sensitive to neem products (SCHMUTTERER and SINGH 1995). The castor bean plant, the main reservoir of the *Tetranychus* mite is also found in the area as a volunteer harbouring a large population of this pest. This mite has been reported to be successfully controlled with neem products in the laboratory

(SANGUANPONG 1992), but TAPPERTZHOFEN (1995) could not find promissing results of reducing the population of the mite under field conditions in the Dominican Republic. This findings agree with the current observations where infestation was recorded in all experimental plots treated with different neem formulations.

5.8 The effect of neem products on the natural enemies

Natural enemies play a fundamental role in integrated pest management programs (MICHELS et al. 1997). In Sudan, coccinellids, syrphid flies and lacewings are important groups of predators in most winter vegetable crops and their role is not fully appreciated yet because of the lacking of quantitative information on them as natural enemies. Apart from some limited laboratory experiments, there is no extensive field reseach in the Sudan to determine the deleterious impact of neem on this group of beneficial insects. In the past very little work has been published on the deleterious side-effects of neem products on natural enemies and other beneficial insects (OSMAN and BRADLEY 1993). During the last few years more reliable results were published on this topic (SCHMUTTERER 1997). It has been generally stated that neem has only little effects on parasitoids or predators (STARK et al. 1990a; SCHMUTTERER 1992).

5.8.1 The coccinellid beetle (*Scymnus sp.*)

As shown by the results presented in Fig 19, NeemAzal-T/S, neem oil and neem water extract proved to be harmless or with slight effects on the aphidophagous coccinellid, *Scymnus sp*. when applied with ULVA+ sprayer to control the homopterous pests on eggplant grown under field conditions. The same results were obtained by other investigators on the same as well as on other species of coccinellids particularly *Coccinella septempunctata* L (KAETHER 1990 ; BANKEN and STARK 1997). This species of predator has been intensively studied in comparison with others. HOELMER et al. (1990) reported no mortality of the coccinellid beetles *Delphastus pusillus* and *Scymnus sp*. reared on leaf disc dipped in Margosan-O and kept in a sealed petri dishes and glass vials for two weeks. The fecundity of the beetles was not drastically affected by feeding on neem-treated eggs of *Bemisia tabaci* for several days. On the other hand, high mortality of the larvae of *Coccinella septempunctata* has occurred in the laboratory when the insects were dipped in a neem water extract (OSSIEWATSCH 2000).

Generally more work has been carried out under laboratory and semi-field conditions on this important group of insects. It is uncommon to find literature on this topic in the Sudan and the results of field trials elsewhere is difficult to be compared with the present findings due to the different concentrations of neem product used, the different methods of application and the different environmental factors prevailed during the conduction of the trials.

5.8.2 The green lacewing (*Chrysoperla carnea*)

The findings of the current study suggest that neem water extract has no deleterious effect on the larvae of the green lacewing, *Chrysoperla carnea* under field conditions when applied with ULVA+ sprayer compared with the two other formulations, NeemAzal-T/S and neem oil. The NeemAzal-T/S resulted in a significant reduction of the population of the lacewing (compared with the control) in an eggplant ecosystem during two consecutive winter seasons. The significant reduction of the lacewing observed in the neem oil treated plots in 1998/1999 season, could not be confirmed in the second season. Although a substantial reduction in the absolute number of predators occured in the neem-treated plots compared with the control, the ratios of predator/prey in the control and neem-treated plots remained unchanged, suggesting no harmful effect on this predator due to application of neem products. Moreover, the observed reduction in the absolute number of predators in the neem-treated plots is very small when compared with the reduction in the Sumicidin-treated plots. Thus neem products seem to be the most suitable alternative for sustainable pest control.

These findings agree with the results obtained by VOGT (1993), VOGT et al. (1996) and HERMANN et al. (1997) who reported no negative effect of NeemAzal-F and NeemAzal-T/s on *Chrysoperla carnea* under field and semi-field conditions. The same authors reported high mortality and developmental disruption of the larvae and pupae of this predator under laboratory conditions. SCHMUTTERER (1997) stated that the formulation of neem products can influence the deleterious side-effect on predaceous or parasitic insects. He pointed out that if neem oil is applied, high degree of mortality may occur especially among egg-parasitoids as compared with oil-free formulations. He attributed this effect to some physical properties of oil. MAHESHKUMAR et al. (2000) reported that neem oil was highly toxic against the velid predator *Microvelia douglasi atrolineata* killing all exposed adults of the predator within one hour of exposure but, they pointed only slight effect of neem formulations on the degree of parasitism and the adults emergence of the egg parasite *Trichogramma japonicum.*

5.8.3 The syrphid fly (*Xanthogramma sp.*)

The population of syrphid fly counted in the neem-treated plots in this investigation were significantly less than that of the control (Fig 22). Again, the predatory/prey ratios were not significantly different between treated and untreated plots. EISENLOHR et al. (1992) reported no effect on syrphid larvae in an orchard of peach trees treated with NeemAzal-F against the green peach aphid *Myzus persicae*. These authors did not mentioed the species of the syrphid used in their trials. Strong negative effect has been reported in the laboratory experiments on the larvae of the aphidophagous syrphid *Epistrophe balteata*, and an unidentified species of syrphid larvae due to treatment with different neem products (SCHAUER 1985; EISENLOHR et al. 1992 and OSSIEWATSCH 2000).

The syrphid flies are the least among the beneficial insects studies with respect to the side-effect of the neem products and scant literature is found on this topic. The present results are in line with the findings of SCHMUTTERER (1997) who stated that the larvae/pupae of syrphid flies seem to be more sensitive to neem products than those of other predators. LOWERY and ISMAN (1995) evaluated the effect of field applications of 1% neem oil and 15% neem seed extract emulsion as well as Pyrethrum on aphid predators and parasitoids. There was fewer syrphids, cecidomyiids, coccinellids and neuropterans on plant treated with neem oil or Pyrethrum compared with control. Neem seed extract sprays reduced the numbers of syrphids and cecidomyiids only indicating that these two groups represent the more neem-sensitive groups of predarors. The Forficulidae are also sensitive to neem products (SCHAUER 1985).

It is not arguable that the reduced numbers of the selected predators observed in the neem treated plots during the current study is attributed to the direct effect of the neem products. It should be due to the indirect effect through the reduction in the population of their prey as the ratios of predator/prey remained unchanged.

Apart from the aforementioned main predators, some role, although not quantified, was being played by the praying mantid (*Mantis religiosa* L.) by feeding on homopterous and other insect pests. Numerous cocoons of this predator were found attached to stems and branches of potato and eggplant and a large number of hatchlings as well as old nymphs in different growth stages were seen roaming on the above mentioned plants during the period of the study, but their number was higher on potato compared with eggplant for a reason which is unknown. The adult beetles of other coccinellids were seen voraciously feeding on aphid colonies on eggplant and potato. EL KHIDIR 1976/77 observed syrphid and coccinellid larvae on wheat feeding on aphids during peak infestation.

5.9 Potentialities and prospects of using neem products for the management of insect pests of potato and eggplant in the Sudan

5.9.1 Potentialities

The neem tree was probably introduced to Sudan from India in 1916 by colonial forester who knew its value for producing shade, fuel, wood and oil for lamps and the first trees appeared in Shambat (NRC 1992) where the present investigation was carried out. The tree might also be introduced to the country in 1921 (SCHMUTTERER 1995) for landscaping, to provide shade and to protect banks of the main watering canals. Now the tree is found in Kasala in the east, in towns and villages along the blue and white nile, in the north part of the country from El-gali to Wadi halfa, in the irrigated central Sudan, Gezira and rainfed areas in the western Sudan, Darfur and Kordofan provinces. The number of the tree in the Sudan is not exactly known but a conservative estimate could be around several millions (FÖRSTER and MOSER 2000). More information on silvicultural characteristics and propagation of the tree as well as afforestation in Sudan have been given by BADI et al. (1989).

The value of neem as pesticides has been known in the country for nearly 30 years but its potentialities as an environmentally friendly one is not fully exploited up to now. It is also interesting to mention that the first inspiration for an intensive global research on the tree was initiated in the Sudan by Heinrich Schmutterer (a German entomologist) at the end of 1950s. It is well known from the literature on the use of neem as pesticide that 50g/l water are needed for the treatment of general field pests (DREYER 1985; FÖRSTER and MOSER 2000). Based on this information, 10-20 kg of neem seeds are needed for the treatment of one hectare of field crops (one treatment). For the annual protection of one hectare about 100 kg are needed (min. of 5 sprayings per season, if we consider the upper limit of the range.

The area under cultivation of vegetable in the Sudan is estimated at 36.000 hectare (BAUDOIN 1992). This area will need annualy 36.000 x 100kg or 3.600 ton of neem seeds. Reliable information on the yield of fruit of the neem tree is scarce (SCHMUTTERER 1995), but the average yield of a single tree can range between 5-50 kg annually (FÖRSTER and MOSER 2000). If we take the lower limit of the range as the average production per tree in the Sudan and we assume that there is only one million tree in the country, the annual production will be 5.000 ton of neem seeds which is greater than the annual need for the treatment of vegetables. The surpus could compensate for the relatively low percent of AZA in the seeds as estimated by ERMEl et al.(1987) to be 2.53 ± 0.60 based on 9 samples collected from different areas. The authors stated that high temperature and exposure to sunlight while the fruits/seeds were on the ground could have reduced the AZA content before or after harvest. The AZA content of the neem seed in the Sudan could be more than this if proper handling of the freshly collected seeds would be done and the best ecotypes of trees grown under congenial conditions were selected for the analysis.

The main harvesting time of the neem fruits in the Sudan does not coincide with the main activities of growing season of vegetables and hence farmers and their family members have enough time to collect more seeds for their own use. The collection of neem seeds could also generate extra income for some farmers, and it is only the question of time until a niche is found in the market of pesticide for the neem seeds and their products. The farmers should be informed about the technical aspects of seed collection, depulping, storage and final processing into a home-made insecticide.

5.9.2 Prospects

Generally, small farmers tend to use less pesticides on potato and eggplant compared to other vegetable crops. They are inclined towards application of defined programs of chemical control against pests and diseases in these two crops. This attitude might be attributed to so many reasons, the following are preeminent. First of all, the high cost of chemicals and their application. Secondly, the damage on potato due to pest and diseases may only be obvious to them late in the cropping season when the application of chemical will not be justified. The cropping cycle of the potato crop is relatively short especially for the farmers who harvest their crops earlier to catch the market where the price of the potato is high. Such crop contains a high percent of water and does not store well. Thirdly, and most important is that majority of farmers today (generation of sons) have a great experience gained during the many years of potato growing and they have got some level of education at least the secondary school unlike their illiterate fathers. This merit of schooling put them in a position to be able to appreciate the countless problems emanating from the unwise use of pesticides on their vegetables crops. On the other hand, eggplant is considered by many growers as a hard prennial crop with vigorous growth which could withstand the attack of many pests and diseases. However, still some eggplant and potato growers spray their crops with Folimat (organophosphorous insecticide) against both sucking and biting insects. Sumicidin (pyrethroid insecticide) is also frequently used. Furdan as an granules is commonly used by the eggplant grower applied in the soil 2 weeks after transplanting as a preventive measure against stem borer. The use of fungicides is uncommon, perhaps because of the unavailability of effective ones in the local market at present time.

The eggplant growers have inherited some cultural practices (technical packages) from their fathers and grandfathers like chopping the plant severly in the case of senescence or high infestation of jassid or spider mite. They also used to give nitrogenous fertilizers and irrigate frequently. This practice will allow the crop to give a new flush of growth and the farmers could harvest 3 to 4 pickings before the population of the insects builds up again. This cultural practice is a type of pest management adopted by the barefoot scientists or the local farmers. The above mentioned reasons are encouraging to incorporate the long experience of these farmers with the uses of neem products in an integrated approach (which can be readily accepted by the farmers) to manage the key pests in these two crops.

A number of merits can be mentioned in favour of neem in this respect, a) the availability and wide geographical distribution of the trees in the Sudan and the possibility of using it in a simple way with simple technology; b) the proved efficacy of the neem products under field conditions; c) its environmentally friendly characteristics coupled with its harmless or minimal side-effects on the main natural enemies in potato and eggplant; d) the great enthusiasm of the farmers for available unexpensive pesticide and their willingness to use it in their vegetable fields; e) the increased activities of the universities, research centers and NGOs in disseminating knowledge about the neem and its uses as well as the technical know-how among farmers and rural population.

To promote the practical use of neem products in pest management of vegetables in the sudan the following recommendations are proposed a) setting up of a pilot neem processing plant (on small scale) to produce ready-to-use neem pesticides; b) encouragement of small enterprises to install extraction plants and units to process neem into finished or half-finished products such as oil, cake and powder; c) conduction of extensive field trials in collaboration with the vegetable growers and extention workers; d) the use of neem products as preventive measures when the populations of the pests are still below the economic threshold level; e) dissemination of more technical information about the use of neem like collection, depulping, drying, proper storage and processing. The outcomes of the present investigations are intended to add only a little to the main stream of exploiting the huge potentiality of the neem tree in the Sudan as a renewable resource for the management of vegetable pests in a benign way and to put the fine concept of sustainable agriculture in practical implementation.

5.10 Implementation of IPM paradigm in vegetables in the Sudan

The adoption of IPM in vegetable sector in Sudan started in 1990/91 growing season. It was first implemented in cotton (the number one cash crop in the country) in the main two growing areas of Gezira and Rahad schemes (DABROWSKI et al. 1994). Apart from the joint activities of the GTZ and the department of plant protection of the ministry of agriculture which worked in Khartoum province, most of the activities of IPM were concentrated in the central Sudan with the farmers in the Gezira and Rahad as the main target group. DABROWSKI et al. (1994) initiated the IPM farmer`s field schools to teach the farmers about how to implement IPM in an on-farm interactive research. The farmers in these areas were accustomed to use much more pesticides on their crops and some of them used to spray their vegetables every 3 to 4 days (ABDELRAHMAN 1994). The success of the adoption of IPM in such areas where the farmers have strict program and calender of pesticide application will depend on their abilities to prefer the risk that might occur from the adoption of a new system of pests control which might reduce their economic returns (SZMEDRA et al. 1990).

More emphasis was given to the farmer as the main element of success in all strategies of IPM implementation (BRADER 1979; SZMEDRA et. al. 1990; DABROWSKI et. al. 1994; SCHULTEN 1994 and ESTOLAS 2000).

In the Sudan, vegetable production and protection are carried out by small farmers with limited resources with only few expectional cases where some farmers own relatively large farms, and they use fertilizers, pesticides and other production inputs. In the far north of the country vegetables are produced without the use of synthetic fertilizers and pesticides. In the west part of the country, potato can be grown all year round and the Immatong mountain in the south still represent a potential area for the production of potato where the crop can be grown twice per year, one from April to August and the other from June to October. In these areas the agroecosystems have not been subjected to the use of pesticides, and the farmers have no definitive program of pests control. They adopt the „no action" strategy, and they will not risk any loss in their yield if they adopt one or two packages of IPM program which could be started right from the very beginning with step-by-step development as advocated by BRADER (1979) who pointed out the importance of research suitable to the small farmers and local agroecosystem. SCHULTEN (1994) stated that a holistic approach including production and protection should be used when implementation of IPM is considered, and the farmer should be involved in the development of an IPM package that meets his needs rather than to depend on one which is developed by a research institute and brought to him to adopt. With all the arguments mentioned above, it seems likely that the time has come and the conditions are congenial to adopt IPM in vegetable production in the Sudan with the application of neem as principal management tactic.

6 GENERAL CONCLUSION

Nowadays potato and eggplant are very important vegetables produced by local farmers in the Sudan. Commercial as well as home-made insecticides from the seeds of the neem tree (*Azadirachta indica* A. Juss; Meliaceae) were tested against homopterous pests attacking these two crops. Both laboratory and field experiments were carried out. NeemAzal-T/S (applied with ULVA+ sprayer increased the yield of potato by 1.49 and 2.73 ton/feddan in the winters of 1998/99 and 1999/2000 respectively. Its performance profile was also superior on eggplant where it increased the yield by 5.44 ton/feddan. This industrially refined and commercially formulated neem products proved to be as effective as the synthetic one (Sumicidin), but it is unlikely that it will be frequently used in the Sudan at the present time due to its high price which is unaffordable by the local farmers.

The efficacy of aqueous neem seed kernel extract against the same pests was enhanced when it was applied with pre-pressurized knapsack sprayer and palm leaf brush. A significantly higher yield than the control was obtained. At the present time, one could hardly find a raw, half-finished or finished neem products on the shelves of agrochemical shops which have mushroomed in Khartoum state during the last decade. This reason together with the lack of information might explain why vegetable growers do not use neem products in their fields.

The percent control based on cumulative insect-days has the merit of combining the magnitude and duration of the insects that survive treatment in a single expression (RUPPEL 1983). This method was used to measure the efficacy of neem products under field conditions .The insect population in the neem-treated plots might not have given a clear picture of the efficacy of these products. There are two likely explanations for this, some of the insects observed on the plants may have a reduced fitness and appetite (characteristics of neem products) and it is difficult to measure this effect under field conditions or the deterrent effect might enforce them to migrate to adjacent untreated plots or nearby fields (SCHMUTTERER 1985). This phenomenon was presumably occurring during the present study, where high populations of insects were found in the untreated control compared with treated plots. Yield was also used as a criterium for the evaluation of the performance of these products.

The action threshold specified for jassid on potato in the present study whether in the field cages or under open field conditions is considered as an ad hoc threshold calculated on simple data and needs to be modified periodically when necessary. In many cases, a useful threshold can be developed from relatively simple data (CAMMELL and WAY 1987). Such thresholds are suitable for preventive treatments.

In addition to coccinellids, chrysopids and syrphids as insect predators, the faunistic analysis of other epigeal predatory arthropod including spiders (Araneae) was also studied. Small sized plant-dwelling, web-building spiders were monitored in the field of eggplant and potato by means of visual observations. Although some jassid (adults and nymphs) and aphids had been observed caught in the webs, the predation and economic impact of this group of predators have yet to be quantitatively determined. The epigeal predatory arthropods were also studied in a field of eggplant (farmer field) grown in the study area and managed conventionally.

The present investigation addressed a set of tactical components of integrated pest management with emphasis on the basic decision rule or the action threshold level, the enhancement of natural enemies (density-dependent factors) and cultural methods (density-independent factors) as preventive tactics, the use of biorational neem products as remedial tactics. All of which share a common merit of managing the pests in an ecologically benign way.

The cultural tactic of pest control used in some fields of eggplant was mostly developed empirically from the long experience of the farmers and has not been evaluated to meet the standards of today's crop husbandry as tactical component to be recommended for adoption in IPM programs. The practice of chopping the eggplant at the time of senescence or high infestation of spider mites or insect pests may also have an adverse effect on the population of the natural enemies and hence the whole practice need to be evaluated through scientific studies before a judgement can be reached. Nevertheless, the pest control system adopted in this study comprises the minimum set of tactical components to qualify it as IPM program. Such program is at the first level of integration i.e. the integration of methods for the control of a single species or species complex (species/population) as defined by KOGAN (1998) who classified IPM according to the level of integration into three categories. The second level is the integration of impact of multiple pest categories (insect, pathogen, weeds) and the methods for their control (community level integration). The third level is defined as the integration of multiple pests impacts and the methods for their control within the context of the total cropping system (ecosystem level integration). At present, the adoption of IPM programs in the vegetable production in the Sudan at the first level of integration is recommended. The adoption at higher level of integration will be possible only after the accumulation of experience and a thorough understanding of the different factors governing the structure and dynamic of the agroecosystem (KOGAN 1998). The pest control program adopted in the current study was based on local needs and possibilities and to my opinion will be accepted by the local farmers who produce for the local consumption where the criteria for cosmetic quality of the products may not be as extreme as in the case of production for export. We believe the practice of pest management to be absolutely essential to the future of pest control (METCALF and LUCKMANN 1982). This statement emphasizes the importance of using wise methods of controlling pests in agriculture with great concern being given to the environment and thus seems to be very suitable to conclude this chapter.

7 SUMMARY

1. The present work was carried out during the period from 1.4.1998 to 28.3.2000 to evaluate the potentialities of neem products as home-made insecticide and to examine their role in the management of three homopterous pests: jassid, whitefly and aphid i.e. *Jacobiasca lybica* (de Berg), *Bemisia tabaci* (Gennadius) and *Aphis gossypii* Glover on potato (*Solanum tuberosum*) and eggplant. (*Solanum melongena*). The side-effect if any of these products on the natural enemies was also studied. The establishment of an action threshold for the cotton jassid on potato adaptable to the local farmer was another objective of the study. NeemAzal-T/S® (standardized commercial neem product) and Sumicidin® were used as yard sticks to judge the performance of the local materials. The work is divided into two parts, laboratory/greenhouse experiments (conducted in Germany and Sudan) to construct a base for the second part, which was concerned with semi-field and field trials and has taken place entirely in the Sudan.

2. The laboratory experiments dealt with the effects of NeemAzal-T/S, neem oil and Imidacloprid on the different developmental stages of the greenhouse whitefly *Trialeurodes vaporariorum* Westwood. The tested products were sprayed with paint air-brush device on potted cabbage plants which were kept in the laboratory at temperature of 23.0 ± 2.1 °C, 40.6 ± 3.0% RH and artificial illumination of 16 h per day. Treatments were arranged in a completely randomized design and each treatment was replicated 4 times. Potted potato plants were used to study the systemic effect of neem products on the nymphal stages of the cotton jassid. Field cages were used to study the effect of artificial infestation of potato with jassid on the yield. Five treatments; 0, 1, 3, 5 and 10 jassid/leaf were used with each treatment replicated 4 times. The field experiments represent the main part of the work. The area allotted for each crop was divided into square shaped plots (5 x 5 m). The application of the tested products was done with ULVA+ sprayer (Ultra Low Volume technique). All experiment were arranged in a completely randomized design. Treatments were replicated 4 times and each experiment was repeated at least for two growing seasons. In one experiment, neem seed water

(NWE) extract was applied with knapsack sprayer and palm leaf brush (PLB) in addition to ULVA+ to compare its performance on eggplant in each case.

3. Under laboratory conditions, foliar application of NeemAzal-T/S, neem oil + Rimulgan retarded the hatchability of the eggs of the greenhouse whitefly by 9.0 ± 1.5%, 10.2 ± 2.0% and 25.4 ± 1.7 %, respectively. The effect of Rimulgan (an emulsifying agent made from the castor bean oil with no azadirachtin) was not significantly different from that of NeemAzal-T/S. This result would suggest that the effect observed on the egg stage due to application of the afore-mentioned products might be due to the physical properties of oil in the three formulations. On the other hand, Imidacloprid (applied in the soil), NeemAzal-T/S and neem oil resulted in a mean mortality of 97.5 ± 2.9%, 95.7 ± 3.8% and 91.8 ± 4.2 % respectively on the 2^{nd} and 3^{rd} larval stages (L_2 & L_3) of the greenhouse whitefly. The adult stage seems to be less affected by the neem products (10.5 ± 1.4 % and 18.4 ± 1.8 % mortality for NeemAzal-T/S and neem oil respectively) compared with 100 ± 0.0 % mortality for Imidacloprid.

4. NeemAzal-T/S, neem oil and Folimat resulted in a mean percent mortality of 91.88 ± 3.50, 90.36 ± 2.95 and 100 ± 0.00 % respectively on the 2^{nd} nymphal stage of the cotton jassid in greenhouse experiment, while a mortality of 78.13 ± 3.95, 59.38 ± 2.71 and 93.75 ± 2.58 % was obtained on the 3^{rd} nymphal instar by application of the above mentioned formulations, respectively, on potted potato plants. This demonstrates clearly the systemic effect of neem products and their stage-dependent efficacy.

5. In the field cages, the potato crop could not withstand a level of jassid infestation above 40 insects/100 leaves. Under field conditions, 200 jassids/100 leaves was the critical level for the initiation of practical control.

6. The study has demonstrated clearly that the yield of potato as a dependent variable and the density of jassid as independent variable are almost perfectly linearly related. This is reflected by the high value of r^2 (0.995). With an increase in jassid density there was a corresponding decrease in the yield of potato, emphasizing that the negative impact of the cotton jassid *Jacobiasca lybica* on this crop should not be underestimated.

7. A survey of the arthropod fauna of potato ecosystem revealed more than 25 different phytophagous species. The economic crop damage however, is caused by only 3-5 key pests. The faunal diversity of eggplant comprised about 28 species from different orders. Jassid, whitefly and aphid were the most important foliage pests on these two crops.

8. An array of plant-dwelling and soil-dwelling predatory arthropods was shown to exist in potato and eggplant ecosystems but their role as potential control factors is yet to be determined.

9. Twenty three different species of weeds were found in potato ecosystem representing 15 different families. The pentatomid bug (*Calidea sp.*) and the flea beetle (*Phyllotreta sp.*) were associated preferably with the weeds (*Phyllanthus niruri* L. and *Aristolochia bracteolata* Lam.), respectively. *Solanum dubium* Fresen (the same family of potato and eggplant) was harboring a large population of the gray blister beetle (*Epicauta aethiops*) which is notorious for its severe damage on the seedlings of potato. The weed composition of eggplant ecosystem consisted of 14 species belonging to 10 different families. *Abutilon figarianum* was found to provide food and shelter for the tingid bug which sometimes inflicts serious injury to eggplant. Jassid, whitefly and aphid were also found on these weeds and some of them are considered as wild breeding hosts for these pests. These examples reflect the importance of weeds and their influence on the population dynamic of harmful and beneficial insects, and hence a weight should have to be given to them in the adoption of any insect pest management program.

10. The NeemAzal-T/S proved to be more or less similar to Sumicidin in its performance profile under field conditions. Its application with ULVA+ sprayer resulted in an increase of potato yield by 35.48 and 65.00 dt/ha in the winter seasons of 1998/99 and 1999/2000 respectively, compared with Sumicidin which has increased yield by 41.42 and 71.19 dt/ha simultaneously in the two seasons of study. No significant different was observed in the performance of the two products. Their effectiveness was also more or less the same on eggplant, where an increase in yield of 129.52 and 121.67 dt/ha was obtained when the crop was sprayed with NeemAzal-T/S and Sumicidin, respectively, in the winter season of 1998/99. The same trend was obtained in the following growing season of 1999/2000 where the application of NeemAzal-T/S resulted in an increase of yield of 145.48 dt/ha while Sumicidin accounted for 143.10 dt/ha.

11. Neem water extract applied with ULVA+ sprayer resulted in no significant difference in eggplant yield during winter of 1999/2000 while it resulted in significantly higher yield of potato in the same growing season. A significant effect of NWE was obtained on eggplant during the autumn of 1999 (an increase of 43.57 dt/ha). The same product increased the yield of eggplant significantly when applied with the pre-pressurized knapsack sprayer (an increase of 61.67 dt/ha in autumn 1999 and 63.10 dt/ha in the winter 1999/2000), and palm leaf brush (43.57 dt/ha higher than the control in autumn 1999, and 41.43 dt/ha in the winter of 1999/2000). Thus, the efficacy of the neem water extract seems to be dependent on the type of crop, the season, and method of application.

12. The average yield of eggplant and potato obtained from these field experiments was equal to or more than that produced by the average farmer in the study area.

13. The crop marketability of the eggplant and potato yields was not affected by the application of neem products, i.e. the cosmetic quality of the products was not different from that which have been treated with conventional products.

14. Sumicidin resulted in a percentage reduction in the cumulative insect-days of 90.18, 76.65 and 82.15 for the jassid, whitefly and aphid on eggplant, respectively, in the winter season of 1998/1999. NeemAzal-T/S achieved a reduction of 84.55, 63.16 and 79.66 for the three insects, respectively, in the same season of the study. The performance of neem oil was, however, less than the two mentioned products when applied with ULVA+ sprayer, where 67.18 reduction occurred in the cumulative insect-days for the jassid, and 49.12 and 59.38 for the whitefly and aphid, respectively. The same calculations were carried out for the effect of the tested products on the three insects on potato and eggplant grown in the different seasons of the study. The close examination of the percentage reduction in the cumulative insect-days due to the application of different treatments revealed that the three studied homopterous pests could be arranged according to their easiness to be controlled with neem products as follows: jassid, whitefly, and aphid

15. The mean population of the whitefly (adult insects/100 leaves) was 29.35 ± 11.52 in summer, 203.10 ± 27.12 in autumn and 210.92 ± 32.84 in the winter season. The mean jassid population was 179.51 ± 40.19, 421.80 ± 65.73 and 671.66 ± 120.18 in summer, autumn and winter, respectively. No aphid was observed during the summer and autumn seasons. The aphid population reached a peak point in late winter and then virtually disappeared as the summer advanced. Thus, the inter and intra-seasonal population dynamics of homopterous pests as has been demonstrated in this study, which could help a lot in making decision rule for the management of these pests on eggplant and potato.

16. Among the other tested formulations, the NWE had the least negative influence on the population densities of beneficial insects. This was judged by the reduction in the absolute numbers of predators in the treated plots compared with the untreated check. The examination of predator/prey ratios however, suggest that neem products, even the commercial ones, are not harmful to predators at least under field conditions. The following example will explain this; the average ratio of the number of aphids/the number of syrphid fly was 4.05 in the untreated check or the control while it was 5.75 and 5.27 in the neem oil and neem water extract treated plots respectively. Both ratios were not significantly different from that of the control (t-test; $P > 0.05$). Thus the observed negative effects should have been due to the indirect action of the products through the reduction of the number of the sucking insects or the prey (density-dependent).

17. The possible implementation of the results obtained into system of Integrated Pest Management under the specific Sudanese conditions is discussed.

8 ZUSAMMENFASSUNG

1. Die vorliegende Arbeit wurde in der Zeit von 1.4.1998 bis 28.3.2000 durchgeführt mit den folgenden Zielen: a) Bestimmung der Auswirkung von verschiedenen Niemprodukten auf die wichtigsten saugenden Schädlinge an Kartoffeln (*Solanum tuberosum*) und Auberginen (*Solanum melongena*). b) Untersuchungen zu den Nebenwirkungen von Niemprodukten auf die natürlichen Feinde c) Versuche, die ökonomische Schadenschwelle der Zikaden an Kartoffeln für den lokalen Bauern zu ermitteln. Das kommerzielle Niemprodukt, nämlich NeemAzal-T/S und das Insektizid Sumicidin (Pyrethroid) wurden als Vergleich angewendet. Die Arbeit wurde in zwei Teilen durchgeführt: Versuche im Labor und Gewächshaus zum Zweck, die Auswirkung von verschiedenen Niempräparaten auf die verschiedenen Wachstumsstadien der weißen Fliege *Trialeurodes vaporariorum* (Westwood) und der Zikade *Jacobiasca lybica* (de Berg) zu studieren, um eine Basis für die Feldversuche zu haben. Die Labor- und Gewächshausversuche wurden in Deutschland und im Sudan durchgeführt. Die Halbfreiland- und Freilandversuche wurden nur im Sudan durchgeführt.

2. Die Auswirkung von NeemAzal-T/S, Niemöl und Imidacloprid auf die Wachstumsstadien der weißen Fliege wurde im Labor studiert. Die Präparate wurden mit Farbsprühgerät auf getopfte Kohlpflanzen ausgebracht. Die Pflanzen und die behandelten Wachstumsstadien wurden bei einer Temperatur von 23.0 ± 2.1 °C, 40.6% ± 3.0% relativer Luftfeuchtigkeit und Beleuchtung von 16 h pro Tag. Die Behandlungen wurden mit vierfacher Wiederholung und randomisierter Verteilung durchgeführt. Die getopften Kartoffelpflanzen wurden im Gewächshaus benutzt, um die systemische Wirkung von Niem auf Zikaden zu studieren. In den Halbfreilandversuchen wurde die Auswirkung von verschiedenen Populationsdichten von Zikaden auf den Ertrag von Kartoffeln getestet. Zwanzig Käfige wurden benutzt. Fünf Behandlungen, nämlich 0, 1, 3, 5 und 10 Jassidenlarven pro Blatt wurden benutzt, jeweils mit vier Wiederholungen. Die Feldversuche stellten den Hauptteil der Arbeit dar. Die Kartoffel und die Aubergineflächen wurden in 20 etwa 25 m^2 große, quadratische Parzellen aufgeteilt,

mit vierfacher Wiederholung und randomisierter Verteilung. Jedes Experiment wurde in zwei Vegetationsperioden wiederholt. Auf die Parzellen wurden die Präparate mit einer ULVA+ Spritze ausgebracht (Ultra-Low-Volume-Technik, Aufwandmenge von 10 Liter/ha).

3. Unter Laborbedingungen konnten hoch signifikante Verringerungen der Eierschlupfrate von *Trialeurodes vaporariorum* um 9.0 ± 1.5, 10.2 ± 2.0 und 25.4 ± 1.7 % durch der Blattapplikation von NeemAzal-T/S, Niemöl und Rimulgan (Emulgator) festgestellt werden. Es gab keinen signifikanten Unterschied zwischen den mit Rimulgan und NeemAzal-T/S behandelten Eiern. Der Einfluß von Niemölhaltigen Produkten auf das Eistadium konnte daher auf die physikalischen Eigenschaften der Präparate zurückgeführt werden. Auf der anderen Seite führte die Applikation von Imidacloprid, NeemAzal-T/S und Niemöl zu signifikanten erhöhten Mortalitäten von 97.5 ± 2.9%, 95.7 ± 3.8% und 91.8 ± 4.2% bei den Larvenstadien der weißen Fliege. Die Mortalität der Adulten war geringer (10.5 ± 1.4% und 18.4 ± 1.8%) bei Niempräparaten (NeemAzal-T/S und Niemöl) als bei Imidacloprid (100%ige Mortalität).

4. Im Gewächhausversuch mit der Jasside *Jacobiasca lybica* (de Berg) konnten hohe Mortalitäten von 91.88 ± 3.50, 90.36 ± 2.95 und 100 ± 0.00% auf das zweite Larvenstadium durch Besprühen von getopften Kartoffelpflanzen mit NeemAzal-T/S, Niemöl und Folimat erzielt werden. Die gleichen Präparate verursachten Mortalitäten von 78.13 ± 3.95%, 59.38 ± 2.71% und 93.57 ± 2.58% beim dritten Larvenstadium. Dieser Versuch zeigte deutlich die systemische Wirkung von Niemprodukten auf die verschiedene Larvenstadien von *Jacobiasca lybica*.

5. Die Kartoffelpflanzen zeigten in Feldkäfigen erste Schäden bei einer Populationsdichte von mehr als 40 Jassiden/100 Blätter. Unter Freilandsbedingungen, war eine Populationsdichte von 200 Jassiden/100 Blätter das kritische Niveau für die Einführung von Bekämpfungsverfahren, um die Steigerung der Jassidenspopulationen und deren Schäden an Kartoffeln zu vermeiden.

6. Die Untersuchung hat deutlich gezeigt, daß der Ertrag von Kartoffeln als abhängige Variable und die Populationsdichte von Zikaden als unabhängige Variable beinahe vollkommen in Beziehung zueinander stehen. Dies wurde mit dem hohen Wert von r^2 (0.9959 demonstriert. Je höher die Populationsdichte von Zikaden, desto geringer ist der Ertrag von Kartoffeln. Daher ist zu betonen, daß der negative Einfluß der Jasside *Jacobiasca lybica* auf die Kartoffeln nicht unterschätzt werden sollte.

7. Es wurden 25 verschiedene phytophage Insektenarten im Kartoffelökosystem ermittelt, aber ökonomische Schäden verursachten davon nur 3-5 Schlüsselschädlinge. Achtundzwanzig Insektenarten befanden sich im Auberginеökosystem darunter sind Zikaden, weiße Fliegen und Aphiden von großer Bedeutung als Schädlinge an den Blättern.

8. Es gibt eine große Menge von Nutzarthropoden in den Ökosystemen von Kartoffeln und Aubergine, die sowohl auf den Pflanzen als auch im Boden existieren, aber ihr Potential in der Bekämpfung von Schlüsselschädlingen ist noch nicht festgestellt.

9. Dreiundzwanzig verschiedene Wildpflanzen wurden im Kartoffelökosystem ermittelt aus 15 verschiedenen Familien. Viele diese Wildpflanzen können alternative Wirtspflanzen für Schadinsekten sein. Dazu dienen die folgenden Beispiele: Die Wanze *Calidea sp.* und der Käfer *Phyllotreta sp.* wurden in große Anzahl auf die Wildpflanzen *Phyllanthus niruri* L. und *Aristolochia bracteolata* Lam. beobachtet. Eine hohe Population des grauen Blasenkäfers *Epicauta aethiops* wurden auf der Wildpflanze *Solanum dubium* (die gleiche Familie von Kartoffeln und Auberginen) festgestellt. Dieser Käfer ist sehr bekannt für die große Schäden, die der an Kartoffelkeimlingen verursacht. Das Auberginenökosystem enthielt 14 Wildpflanzen aus 10 verschiedenen Familien. Die Wanze *Urentius hystricellus* wurde in hoher Anzahl auf die Wildpflanze *Abutilon figarianum* gefunden. Diese Wanze verursacht manchmal erhebliche Schäden an Aubergine. Zikaden, weiße Fliegen und Blattläuse wurden auch in große Anzahlen auf dieser Wildpflanzen gefunden. Die vorherige Beispiele zeigen, daß der Einfluß von Wildpflanzen auf die Populationsdynamik von Schad- und Nutzinsekten sehr wichtig ist. Deshalb sollten

Wildpflanzen bei der Durchführung von integrierten Bekämpfungsprogrammen der Schädlinge völlig studiert werden.

10. Das Wirkungspotential von NeemAzal-T/S war unter Freilandbedingungen mehr oder weniger ähnlich wie Sumicidin. Durch Applikation von NeemAzal-T/S mit ULVA+ Spritze konnte ein erhöhter Ertrag von Kartoffeln gegenüber die Kontrolle um 35.48 und 65.00 dt/ha im Winter 1998/1999 und 1999/2000 erzielt werden. Im Vergleich mit Sumicidin, das den Ertrag um 41.42 und 71.19 dt/ha erzielte. Es gab keinen Fall signifikanten Unterschied zwischen den Erträgen. Das Wirkungspotential von beiden Präparaten war auch ähnlich, wenn Sie auf die Aubergine ausgebracht wurden. In der Saison 1998/1999 und, auch 1999/2000 erhöhte die Applikation von NeemAzal-T/S den Ertrag von Aubergine gegenüber die Kontrolle um 129.52 und 145.48 dt/ha. In Winter von 1998/1999 erzielte die Applikation von Sumicidin einen hohen Ertrag um 121.67 dt/ha und der Ertrag war um 143.10 dt/ha höher als die Kontrolle im Winter von 1999/2000.

11. Durch die Applikation von Niemsamen-Wasserextrakt (NWE) mit ULVA+ Spritze auf Aubergine im Winter 1999/2000 konnte kein signifikanter Ertragsunterschied festgestellt werden. Es führte aber zu einem signifikant erhöhten Ertrag auf Kartoffeln. Einen signifikant erhöhten Ertrag von Aubergine gegenüber der Kontrolle um 43.57 dt/ha wurde im Herbst 1999 erzielt. Eine Effektivitätssteigerung von NWE durch Applikation mit der Rückenspritze konnte im Herbst 1999 und Winter 1999/2000 festgestellt werden. Die Erträge wurden gegenüber der Kontrolle um 61.67 und 63.10 dt/ha in den Jahren 1999 und 1999/2000 erhöht. Die Applikation von NWE mit einer Bürste, die aus Dattelpalmenblätter gemacht wurde (PLB) konnte zur Erhöhung des Ertrages um 43.57 und 41.43 dt/ha im Herbst 1999 und Winter 1999/2000 führen. Dies läßt darauf schließen, daß das Wirkungspotential des Niemsamen-Wasserextrakts von vielen Faktoren abhängt, darunter sind die Saison, die Kulturpflanze und die Applikationsmethode zu nennen.

12. In den Freilandversuchen konnte ein durchschnittlicher Ertrag von Kartoffeln und Auberginen erzielt werden, der gleich oder höher war als der durchschnittliche Ertrag, der durch die Bauern in der Region erzielt wurde.

13. Die Applikation von Niemprodukten hatte keine negative Wirkung auf die Ernte oder die Marktfähigkeit der Produkte, d.h. die Handelsklasse der Produkte war ähnlich wie bei konventionellen Insektiziden.

14. Durch die Applikation von Sumicidin auf Aubergine wurde eine Verringerung der kumulativen Insektentagen für Zikaden, Weiße Fliegen und Aphiden in den Jahren 1998/1999 um 90.18, 76.65 und 82.15 signifikant reduziert. Die Applikation von NeemAzal-T/S konnte zu einer Verringerung der kumulative Insektentagen um 84.55, 63.16 und 79.66% für die Testtiere führen. Das Wirkungspotential von Niemöl war niedriger im Vergleich mit Sumicidin und NeemAzal-T/S. Das Niemöl führte zur Verringerung der kumulative Insektentage um 67.18, 49.12 und 59.38% für Zikaden, Weiße Fliegen und Blattläuse. Die gleiche Berechnungen wurden durchgeführt für die drei Homopteren an Kartoffeln und Aubergine, die in verschiedenen Versuchsjahren angebaut wurden. Basierend auf den kumulativen Insektentagen nimmt die Möglichkeit der Bekämpfung der Testtiere mit Niempräparaten unter Freilandsbedingungen folgendermaßen ab: Zikaden, Weiße Fliegen und Blattläuse.

15. Die Population von Weißen Fliegen (Adulte/100 Blätter) war 29.35 ± 11.52 im Sommer, 203.10 ± 27.12 im Herbst und 210.92 ± 32.84 im Winter. Die Population von Zikaden war 179.51 ± 40.19, 421.80 ± 65.73 und 671.66 ± 120.18 im Sommer, Herbst und Winter. Keine Aphiden wurden im Herbst und Sommer beobachtet. Die Population von Aphiden im Winter war am höchsten und ging zurück, als der Sommer kam. Deshalb könnte die Kenntnis der Populationsdynamik von Homopteren (inter- und intra-seasonal) zur sinnvollen Bekämpfungsentscheidung von diesen Schädlingen an Auberginen und Kartoffeln verwendet werden.

16. Der Niemsamen-Wasserextrakt führte zur geringsten negativen Wirkung auf die Populationen von Nutzinsekten im Vergleich zu den anderen Präparaten. Die Anzahl von Predatoren war geringer in den mit Niem behandelten Parzellen im Vergleich zur Kontrolle, aber das Verhältnis zwischen der Anzahl von Predatoren und Beute blieb unverändert. Das bedeutet, daß die Niempräparate im Freiland keine direkten Schäden an den Nutzarthropoden verursachen. Das folgende Beispiel erklärt dies: das Verhältnis zwischen der Anzahl von Syrphidlarven und Aphiden lag bei 4.05 in der Kontrolle, bei den mit Niemöl und bzw. Niem-Wasserextrakt behandelten Parzellen lag die Anzahl bei 5.75 und 5.27. Es konnte kein signifikanter Unterschied zwischen den mit Niempräparaten behandelten Parzellen und der Kontrolle festgestellt werden (t-test, $P > 0.05$). Daher konnte es nachgewiesen werden, daß die Population der Nützlingen von vorhandenen Population der Beute abhängig sind, und nicht von der Behandlung.

17. Die Bedeutung der erarbeiteten Befunde für die Gemüseproduktion und den integrierten Pflanzenschutz im Sudan wird diskutiert.

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10 ANNEX

The tables in this annex from A1 to A17 illustrate the ANOVA procedure as well as separation of means for the data of the different experiments carried out during the study period. Some explanations of statistical abbreviations are given below:

df.	Degree of freedom
F or F calculated	The ratio of MS of treatments to MS of experimental error
MS	Mean squares.
n	Number of samples or replications
SS	Sum of squares

Table A1a: The effect of NeemAzal-T/S®, neem oil and Folimat® on the 2nd nymphal instar of the cotton jassid (*Jacobiasca lybica* de Berg) on potato during winter season 1998/99.

Source of variation	df.	SS	MS	F	Significance
Treatments	3	24500.00	8166.67	163.33	0.000
Experimental error	12	600.00	50.00		
Trial (total)	15	25100.00			

Table A1b:

Treatment	n	Duncan grouping for ∝ = 0.05*	
		a	b
Folimat®	4	100.00	
NeemAzal-T/S®	4	91.88	
Neem oil	4	90.63	
Control	4		5.00

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A2a: The effect of NeemAzal-T/S®, neem oil and Folimat® on the 3rd. nymphal instar of the cotton jassid (*Jacobiasca lybica* de Berg) on potato during winter season 1998/99.

Source of variation	df.	SS	MS	F	Significance
Treatments	3	16850.00	5616.67	70.95	0.000
Experimental error	12	950.00	79.17		
Trial (total)	15	17800.00			

Table A2b:

Treatment	n	Duncan grouping for ∝ = 0.05*		
		a	b	c
Folimat®	4	93.75		
NeemAzal-T/S®	4	78.13		
Neem oil	4		59.38	
Control	4			6.25

* Means within the same group i.e. under the same lower case letter are not significantly different.

Table A3: Linear regression analysis for the effect of jassid density on the yield of potted potato (winter 1998/1999).

	df.	SS	MS	F	Significance
Regression	1	17.207	17.207	706.395	0.000
Residual	18	0.438	2.436E-02		
Total	19	17.646			

Table A4: Linear regression analysis for the effect of jassid density on the yield of potted potato (winter 1999/2000).

	df.	SS	MS	F	Significance
Regression	1	16.999	16.999	1858.175	0.000
Residual	18	0.165	9.148E-03		
Total	19	17.163			

Table A5a: The average yield obtained in potato plots during the winter season of 1998/99.

Source of variation	df.	SS	MS	F	Significance
Treatments	3	8.92	2.98	14.09	0.000
Experimental error	12	2.53	0.21		
Trial (total)	15	11.46			

Table A5b:

Treatment	n	Tukey grouping for ∝ = 0.05*	
		a	b
NeemAzal-T/S®	4	5.12	
Neem oil	4		3.92
Sumicidin®	4	5.37	
Control	4		3.63

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A6a: The average yield obtained in potato plots during the winter season of 1999/2000.

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	4	27.81	6.95	41.69	0.000
Experimental error	15	2.50	0.18		
Trial (total)	19	30.31			

Table A6b:

Treatment	n	Tukey grouping for ∝ = 0.05*		
		a	b	c
NeemAzal-T/S®	4	6.09		
Neem oil	4		4.04	4.04
Neem water extract	4		4.32	
Sumicidin®	4	6.35		
Control	4			3.36

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A7a: The average yield obtained in eggplant field treated with Sumicidin® and 2 different neem formulations during the winter season of 1998/99

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	3	85.73	28.58	38.03	0.000
Experimental error	12	9.02	0.75		
Trial (total)	15	94.75			

Table A7b:

Treatment	n	Tukey grouping for ∝ = 0.05*	
		a	b
NeemAzal-T/S®	4	9.80	
Neem oil	4		5.92
Sumicidin®	4	9.47	
Control	4		4.36

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A8a: The average yield obtained in eggplant field treated with Sumicidin® and 3 different neem formulations during autumn 1999.

Source of variation	df.	SS	MS	F	Significance
Treatments	4	58.65	14.66	51.30	0.000
Experimental error	15	4.29	0.29		
Trial (total)	19	62.94			

Table A8b:

Treatment	n	Tukey grouping for ∝ = 0.05*			
		a	b	c	d
NeemAzal-T/S®	4	8.79			
Neem oil	4			6.59	
Neem water extract	4			5.64	
Sumicidin®	4		7.69		
Control	4				3.81

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A9a: The average yield obtained in eggplant field treated with Sumicidin® and 3 different neem formulations during winter season 1999/2000.

Source of variation	df.	SS	MS	F	Significance
Treatments	4	119.82	29.96	19.98	0.000
Experimental error	15	22.49	1.49		
Trial (total)	19	142.31			

Table A9b:

Treatment	n	Tukey grouping for ∝ = 0.05*	
		a	b
NeemAzal-T/S®	4	11.74	
Neem oil	4		7.75
Neem water extract	4		7.36
Sumicidin®	4	11.64	
Control	4		5.63

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A10a: The effect of 4 different treatments on the population density of the green lacewing (winter 1998/1999)

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	3	429.50	143.17	64.83	0.000
Experimental error	12	26.50	2.21		
Trial (total)	15	456.00			

Table A10b:

Treatment	n	Tukey grouping for ∝ = 0.05*		
		a	b	c
Control	4	18.00		
NeemAzal-T/S®	4		12.50	
Neem oil	4		13.75	
Sumicidin®	4			3.75

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A11a: The effect of 3 different neem formulations and Sumicidin on the population density of the green lacewing (winter 1999/2000)

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	4	834.70	208.68	39.37	0.000
Experimental error	15	79.50	5.30		
Trial (total)	19	914.20			

Table A11b:

Treatment	n	Tukey grouping for ∝ = 0.05*		
		a	b	c
Control	4	22.00		
Neem water extract	4	20.75		
NeemAzal®	4		15.00	
Neem oil	4	21.00		
Sumicidin®	4			4.75

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A12a: The effect of 2 different neem formulations and Sumicidin on the population density of the coccinellid beetle *Scymnus sp*. on eggplant (winter 1998/1999).

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	3	390.50	130.17	18.27	0.000
Experimental error	12	85.50	7.13		
Trial (total)	15	476.00			

Table A12b:

Treatment	**N**	Tukey grouping for ∝ = 0.05*	
		a	b
Control	4	19.50	
NeemAzal®	4	14.50	
Neem oil	4	14.25	
Sumicidin®	4		5.75

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A13a: The effect of 3 different neem formulations and Sumicidin on the population density of the coccinellid beetle *Scymnus sp*. on eggplant (winter 1999/2000).

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	4	664.50	166.13	44.11	0.000
Experimental error	15	56.50	3.77		
Trial (total)	19	721.00			

Table A13b:

Treatment	n	Tukey grouping for ∝ = 0.05*		
		a	b	c
Control	4	20.00		
Neem water extract	4	20.25		
NeemAzal®	4		15.75	
Neem oil	4	17.00	17.00	
Sumicidin®	4			4.50

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A14a: The effect of 4 different treatments on the population density of syrphid fly (winter 1998/99)

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	3	211.50	70.50	58.35	0.000
Experimental error	12	14.50	1.21		
Trial (total)	15	226.00			

Table A14b:

Treatment	n	Tukey grouping for ∝ = 0.05*		
		a	b	c
Control	4	12.50		
NeemAzal®	4		8.00	
Neem oil	4		7.25	
Sumicidin®	4			2.25

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A15a: The effect of 4 different treatments on the population density of syrphid fly (winter 1999/2000)

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	4	505.70	126.43	48.01	0.000
Experimental error	15	39.50	2.63		
Trial (total)	19	545.20			

Table A15b:

Treatment	n	Tukey grouping for ∝ = 0.05*		
		a	b	c
Control	4	18.50		
Neem water extract	4		14.75	
NeemAzal®	4		12.50	
Neem oil	4		12.00	
Sumicidin®	4			3.25

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A16a: The average yield of eggplant treated with NWE applied with different spraying techniques (autumn 1999).

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	3	10.65	3.55	38.38	0.000
Experimental error	8	0.74	0.092		
Trial (total)	11	11.39			

Table A16b:

Treatment	n	Tukey grouping for ∝ = 0.05*		
		a	b	c
Knapsack sprayer	3	6.66		
ULVA+ sprayer	3		5.46	
Palm leaf brush	3		5.90	
Untreated control	3			4.07

* Means within the same group i.e. under the same lower case letter are not significantly different

Table A17a: The average yield of eggplant treated with NWE applied with different spraying techniques (winter 1999/2000).

Source of variation	**df.**	**SS**	**MS**	**F**	**Significance**
Treatments	3	11.15	3.72	12.76	0.002
Experimental error	8	2.33	0.29		
Trial (total)	11	13.48			

Table A17b:

Treatment	n	Tukey grouping for ∝ = 0.05*		
		a	b	c
Knapsack sprayer	3	7.64		
ULVA+ sprayer	3		6.16	6.16
Palm leaf brush	3	6.74	6.74	
Untreated control	3			4.99

* Means within the same group i.e. under the same lower case letter are not significantly different

ACKNOWLEDGMENTS

The entire work has been carried out under the auspices of Prof. Dr. Thies Basedow to whom I am indebted for his suggestion of the topic, keen supervision and guidance during the study period. His valuable advice and final correction of the manuscript are greatly appreciated. My sincere thanks and gratitude extend to my second supervisor Prof. Imam El khidir who kindly arranged for my field work in the Sudan. His deep knowledge and experience helped me a lot to come out with this work.

I would like to extend my thanks to Prof. Dr. B. Honermeier for his willingness to be my co-referee. His kind assistance and help during my stay in Germany is sincerely acknowledged. The author would like to extend his special thanks to so many peoples the following are pre-eminent; Prof. Dr. H. Schmutterer for the information on neem and pest control, Dr. Hollenhorst for his assistance in statistical analysis, Dr. Juan Bernal for the unlimited assistance in statistical analysis and computer work, Mr. Curt von Boguslawski for his kind help in computer technicalities, all members of the Institute of Phytopathology and Applied Zoology (University of Giessen) for their cooperation during the conduction of the laboratory work. Many thanks are extended to Dr. Masum Ahmed for his kind assistance of reading the manuscript.

The support I have received from the Dean of the Faculty of Agriculture, the members of the department of crop protection, the University of Khartoum is much appreciated.

My cordially thanks are due to Mr. El sir Abdel haleem, Mr. Abdel Gafar, Ishag, Awad, Mudathir and Adam khatir for their assistance in the conduction of the field trials.

My special thanks extend to my close friend Hamid Ahmed Hamid for his support during the period of research in the Sudan.

The financial support of the German Academic Exchange Service (DAAD) is much appreciated and sincerely acknowledged. Without this generous scholarship it would have been impossible to accomplish this work.

Last but not least I would like to thank my family very much indeed for the moral support and my wife Nawal for the lonely days she endured patiently during the preparation of the manuscript.

CURRICULUM VITAE

Personal data

Name	:	Hamadttu Abdel Farag El Shafie
Date of birth	:	1962
Place of birth	:	Gilas (a village in the north of Sudan)
Marital status	:	Married

Educational backgrounds

1969-1975	:	Primary school (Gilas)
1975-1978	:	Intermediate school (Um boukol)
1978-1982	:	High school (Korti)
1982	:	Sudan high school certificate
1982	:	Admission at the Faculty of Agriculture, University of Khartoum
1988	:	B.Sc. (Agric. Honor), University of Khartoum
1993	:	M.Sc. (Agric.), University of Khartoum, majoring in entomology
1997-1998	:	The German language course in Bremen (October-March)
1998	:	Ph.D. candidate (DAAD scholar), University of Giessen

Practical experience

1988	:	Teaching assistant at the department of crop protection (University of Khartoum) since 1988
Since 1993	:	Promoted to the status of lecturer