EVALUATION OF NEEM FORMULATIONS FOR THE CONTROL OF SELECTED PESTS OF FRENCH BEANS (*Phaseolus vulgaris.* L.).

By

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DECLARATIONS

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

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DEDICATION

TO MY BELOVED HUSBAND

GATHU KARIUKI.

OUR LOVELY CHILDREN

JOAN NJERI GATHU

&

EDGAR KAHUTHIA GATHU.

MY PARENTS

BEDAN KAHUTHIA & LILIAN MUTHONI

FOR HAVING INSPIRED ME THROUGH THE HYENAS' MOTTO OF

"NGONE KANA NGONE"

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ABSTRACT

Evaluation on efficacy of neem seed oil (NSO) and neem kernel cake powder (NKCP) as compared to synthetic pesticides against *Aphis fabae*, *Megarulothrips sjostedti* and *Frankliniella* species and their effects on natural enemies was conducted at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Thika District, Central Province of Kenya, between August 1998 and June 1999. NKCP/wannin and Gaucho (imidochloroprid) were applied as seed treatment, NKCP and Furadan (carbofuran) as soil amendment, while NSO, neem kernel cake powder water extract (NKCP/WE) and Karate (lambda-cyhalothrin) as foliar sprays, replicated four times in a Randomized Complete Block Design (RCBD).

The parameters involved were seed germination, leaf damage, flower drop, crop yield, pod quality, thrips and aphid infestation, parasitoid and predator populations. NKCP/wannin had the highest germination and differed significantly from NKCP soil amendment. There was no significant difference (P>0.05) in leaf damage and infestation by *Frankliniellla* species amongst the treatments. There was significant difference in aphid, adult thrips and larvae population amongst the treatments. However, treatments with Karate resulted with the lowest infestation by thrips and aphids. There was a significant difference in the population of *Megarulothrips sjostedti* among the treatments during the reproductive stage, with NSO and NKCP/WE treated plots having significantly low population. The mean number of flower drops differed significantly among the treatments. The parasitoid and predator population compared within the plots sprayed with NKCP/WE, NSO and control, but differed significantly from plots sprayed with Karate an indication that Karate adversely affected the population.

Although there was no significant difference ($P>0.05$) in pod yield among the treatments, the pod quality differed significantly ($P<0.05$) amongst the treatments. High percentage of unblemished pods was obtained in plots sprayed with NSO, NKCP/WE and Karate. The high percentage difference in pod quality was attributed to high infestation of thrips. The amount of NKCP used, as a soil amendment is not economical due to the large quantities required. Thus seed treatment using NKCP could be used instead of the conventional pesticides as it is cheap and little amounts are required. NSO and NKCP/water extract could also be used as alternatives to Karate as they reduced thrip population thus reducing the extent of pod damage and had no adverse effects on the natural enemies.

CHAPTER I

1.0 GENERAL INTRODUCTION

1.1. Vegetable production in Kenya

Export vegetable cultivation is emerging as an important source of income generation for small-scale farmers in Kenya. The national annual export of vegetables in Kenya during the year 1995-96 was worth about US $ 24-25 million, accounting for 35-40 % of foreign exchange earnings from horticultural exports (Sithanantham *et al.,* 1997). The vegetable exports rose from 50,000 tons in 1991 to 70,000 tons in 1995, and the figure is expected to increase to 100,000 tons by the year 2000 (Hortec, 1996). French beans (*Phaseolus vulgaris* L) occupy second position after cut flowers with 18% of the total value of horticultural export (MoALDM, 1995). In 1985 and 1994, they had an export volume of 7,000 and 13,678 metric tonnes (MT) respectively, with an export value of close to US $ 20 million (Löhr and Michalik, 1997), while in 1995, 14,694 tons were exported (Sithanantham *et al.,* 1997). It is therefore evident that the prospects for increase in export market are good and there is also a high demand from the processing industry. It is estimated that nearly 250,000 farm families earn significant income through cultivation and marketing of export vegetables (Ouko, 1997). Furthermore, record shows that almost 100,000 people earn major income directly from exports of French beans (Swanberg, 1995).

One of the major constraints to the successful production of export vegetables has been damage caused by pests and diseases. One third of the world's potential food supplies are estimated to be lost mainly to pre- and post-harvest pests and diseases. According to FAO estimates, potential losses world-wide are 35% in the field and 14% in storage bringing total loss to 50% while in Eastern and Southern Africa, these losses are estimated to be even higher (Odhiambo, 1985).

Chemical control of thrips in French beans accounts probably for most of the pesticide applied on the crop. The use of pesticides on thrips is thus, responsible for the residue problem on French beans, which has gained special importance since the introduction of new regulations for maximum pesticide residue levels (MRL's) by the European Union (EU) in January 1994 and with partial enforcement since January 1995 (Löhr, 1996). Consequently, there is urgent need to reduce pesticide application and also to change plant protection methods and come up with methods that would minimise the risk of exceeding these residue levels for the benefit of mankind and maintenance of high quality domestic and export produce. This calls for concerted effort in generating suitable and environmental friendly technologies for continued production of these crops. Unless policies and alternative technological packages are availed, most Kenyan fresh produce may be blocked out from the export markets like the European Union within the next few years (Agong, 1997).

1.2. French beans, *Phaseolus vulgaris* L.

1.2.1. Production and utilisation of French beans

French beans, (*Phaseolus vulgaris* L) are important legumes in Kenya (Davis, 1994). The crop is mainly grown for the immature green pods and is also referred to as Snap beans, Green beans, Horticultural haricot beans and "miciri" (Kikuyu) and belongs to the Leguminosae family. They are consumed as immature fresh pods preferably in fibreless state (Silbernagel, 1991).

French beans are mainly grown for fresh export market and they constitute one of the country's most important export crop. Besides the fresh export market, there is high demand for French beans especially in the processed form through dehydration, freezing and canning. The demand for French beans in the local market, and for processing (canning) is still relatively limited, but the latter is increasing and might become a major market outlet, in addition to the export market (HCDA, 1996). French beans rank among the most preferred vegetables, and the demand is at par with that of broccoli, cauliflower, eggplant, peas and tomato. A characteristic of these vegetables is that their demand is income dependent. Like other pulse legumes, French beans are a major source of proteins, energy, minerals, vitamins and roughage.

French beans are mainly grown as mono crop mostly by small-scale farmers on farm sizes of between 0.25 to 1.0 ha (Nderitu *et al.*, 1995). They are labour intensive, especially at harvesting, and require well-trained farmers because only high quality grades can be exported. Thus, smallholder production is more suitable in view of the labour management problems, which often occur on large-scale farms. The steady increase in acreage under French bean in Kenya over the last few years can be attributed to its high monetary return per unit area and demand abroad. Large demands for suitable varieties of these beans in both fresh and processed forms are popular especially in Western Europe thus, creating a stable industry in Kenya. French beans from Kenya are mainly exported to France, United Kingdom, Germany and Netherlands (HCDA, 1996). Furthermore, local consumption of French beans has also steadily increased over the last few years providing a local market.

1.2.2. Ecological requirements

Optimum temperature for good growth and yield of French beans ranges from 16°C to 25°C (Bunting, 1961). French beans develop a higher fruit percentage in cooler weather, therefore areas with extreme high temperatures are not suitable as they lead to poor flower development and pod set. Frost, persistence of dry winds, long periods of rain and fog are also harmful.

French beans require an optimum rainfall of about 500mm per season. High rainfall towards the end of the growing season is undesirable, because this leads to high incidence of pests and diseases. The minimum rainfall requirement is around 300mm per cropping cycle. Thus, during off-season, irrigation is essential to maintain continuous production. Either furrow or overhead irrigation may be used to supply up to 50mm water per week.

French beans can be grown in a wide range of soil types, ranging from light sandy loam to clay. They however grow best on friable, medium loam soils that are well drained and have a lot of organic matter content and which are slightly acidic to slightly alkaline. The optimum soil pH is 6.5 to 7.5, but beans can tolerate a low pH of 4.5 to 5.5. However, below pH of 4.5, plant growth is impaired (HCDA, 1996; MoALDM, 1995). French beans are very sensitive to excessive soil moisture or waterlogged conditions hence, good drainage is essential.

1.2.3 Distribution

The suitable areas for French bean production fall within the lower midland to lower highland zones, with moderate rainfall and between altitudes 900 and 2100m above sea level (ASL). French beans can be cultivated in most areas of Kenya, except along the coastal strip where temperatures are too high. The main growing areas are Nairobi, Kiambu, Murang'a, Embu, Meru, Naivasha, Nakuru, Machakos, Makueni, Nyeri, Bungoma, Trans Nzoia, Vihiga and Kericho (HCDA, 1996).

1.2.4 Agronomy

Monel is the main and most popular variety grown in Kenya. It has a high yielding potential of 9 to 12 tons per hectare, with a long picking duration and is tolerant to bean rust (HCDA, 1996). Pods are greyish green in colour, straight, long, rounded in cross section and quite fleshy. Monel variety is more preferred since the development of seed and strings appear in a mature stage such that the pods harvested late qualify as "extra fine" grade and can still be offered to the fresh markets as "fine" grade beans. Flowers and seeds are purple and black respectively. Other varieties commonly grown are Vernadon, Gloria, Claudia Super Monel (Super Miciri), Groffy, Skill, Paulista, Samantha, Amy and Listel.

The seeds should be planted at a spacing of 60cm between rows and 15cm within rows, and a single seed placed in each hole. During planting, 200kg DAP/ha should be applied in the furrow and mixed with the soils thoroughly before placing the seed. For top-dressing, 100 kg CAN/ha should be applied at the trifoliate leaf stage and again at the onset of flowering. Use of farmyard manure is recommended especially where the soils are low in organic matter. The field should be kept clean from weeds. Weeding should be done carefully, preferably hand weeding to avoid damaging of the shallow roots. The first weeding should be done 2-3 weeks after emergence followed by the second one 2-3 weeks later. For large-scale farmers, the use of herbicides is probably advisable. Picking of the fresh pods begins about nine weeks after sowing and should be done at regular intervals preferably when the weather is dry to maintain high quality (Personal observation).

1.3. Constraints to production and yield

French bean production is constrained by high pest and diseases loads, moisture deficit, poor agronomic practices and low soil fertility (Muigai and Ndegwa, 1991). These stresses inflict severe reduction in yield as well as quality of the vegetable produce (Agong, 1997). Various workers have identified pests as one of the major yield reducers in bean production, accounting for 50% of the total losses (Nderitu and Anyango, 1993). Moreover, pests and diseases attacking French beans are among the major problems confronting the farmers in the production process thus provoking over application of pesticides on the crop. The severity and incidence of pest attack varies depending on the location, varieties used and season.

1.3.1. Pests

Pests of major economic importance that attack French beans in Kenya, in the order of importance are Bean flies *Ophiomyia phaseoli* Tryon, and *O. spencerella* (Greathead) (Diptera: Agromyzidae), Bean flower thrips *Frankliniella* sp. and *Megalurothrips sjostedti* Trybom. (Thysanoptera: Thripidae), Aphids *Aphis fabae* Scopoli. (Homoptera: Aphididae), African bollworm, *Helicoverpa (Heliothis) armigera* Hub. (Lepidoptera: Noctuidae) and Red spider mite, *Tetranychus* sp. (Acarina: Tetranychidae) (Nderitu and Anyango, 1990).

Other pests considered to be of lesser economic importance, but would be a threat to French bean production incude Foliage beetles *Ootheca bennigseni* Weise (Coleoptera: Chrysomelidae), Pollen beetles *Coryna apiccornis* Guern (Coleoptera: Meloidae), Legume pod borer *Maruca testulalis* Geyer (Lepidoptera: Pyralidae), Striped bean weevil *Alcidodes leucogrammus* (Coleoptera: Curculionidae), Whitefly *Bemisia tabaci* (Geun.) (Homoptera: Aleyrodidae), Leafminer *Liriomyza* sp. (Diptera: Agromyzidae), Pod sucking bug *Clavigralla* sp. (Hemiptera: Coreidae), Cutworm *Agrotis* sp. and *Spodoptera* sp. (Lepidoptera: Noctuidae) (Nderitu, 1990; Nderitu and Anyango, 1990).

Insect pests are a major constraint to successful production of French beans. They often cause significant losses both directly and indirectly through plant mortality, reduction in plant vigour, yield and produce quality, thus affecting the export produce. Sap sucking insects such as thrips and aphids are known to transmit viral diseases such as Tomato Spotted Wilt Virus (TSWV) and bean common mosaic virus (BCMV) respectively, which leads to heavy losses, apart from affecting plant growth. Thrips damage is mainly caused by the larvaes and adults which feeds and puncture flower structures and the developing pods. Aphids suck plant sap causing stunting of the plants. Bean fly damage, is caused by the larvae which mine down the stem causing the plant to be stunted and the stems crack at the soil level and may at times lead to the plant dying (Hill, 1975; Nderitu, 1990).

1.3.2. Diseases

French beans may be affected by a number of fungal diseases such as, Anthracnose *Colletrotrichum indemuthianum*, Rust *Uromyces appendiculatus,* powdery mildew *Erysipe polygoni*, Angular leaf spot *Phaeoisariopsis griseola,* (Hocking, 1967), Rhizoctonia root rot *Rhizoctonia solani*, Ashey stem blight *Macrophomina phaseolina,* Southern blight *Screlotium rolfsii*, Ascochyta blight *Ascochyta phaseolorum*, Pythium root rot *Pythium* sp., Fusarium root rot *Fusarium solani* and *F. phaseoli,* (Nderitu, 1990; Nderitu and Anyango, 1990). Simirarly, they may be affected by bacterial diseases which include Halo blight *Pseudomonas phaseiolicola,* Common blight *Xanthomonas campestris* pv. *phaseoli,* Fuscous blight *Xanthomonas phaseoli* var. *fuscans,* and Bacterial Brown Spot *Pseudomonas syringae.* The two viral diseases, Bean Common Mosaic Virus (BCMV) and Yellow

Bean Mosaic Virus (YBMV) are also important (Silbbernagel *et al*., 1986).

1.3.3. Nematodes

Root knot nematodes *Meloidogyne javanica* and *M. incognita* often attack roots, causing lesions; thus making them more susceptible to fungal and bacterial attack (HCDA, 1996).

1.4. Pest control options

Various methods have been recommended for the control of pests. They include use of chemicals, biological, physical (hand picking of insects) and cultural methods (early planting, spacing, mulching, proper sanitation, deep ploughing, flooding,) and use of host plant resistant crops. High pesticide use has resulted in development of pesticide resistance in target pests, pest resurgence and emergence of secondary pests. Thus, insecticide use should be kept minimum because of the development of pesticide resistance (Immaraju *et al*., 1992), and the possible incompatibility with biological control agents and increasing consumer concern about chemical residue on fresh vegetables (Clarke *et al*., 1994). French beans have been rejected in the export market due to high pesticide residues above the accepted Maximum Residue Limits (MRL' s) for Green beans.

1.5. Potential for using neem products in managing pests.

Use of neem formulations would be most welcome to consumers and producers at large. It would reduce the level of pesticide residues in French beans and at the same time, might be cheaper than the conventional pesticides used by the farmers to control the pests. Neem is a botanical, a broad-spectrum biopesticide, with over 200 insects registered as being susceptible. Neem is non-toxic to human beings and other biota. It is biodegradable hence less prone to pest resistance and resurgence and poses low risk against non-target organisms (Rembold, 1988). Neem is also relatively cheap and might usher a new era in pest control (National Research Council, 1992).

CHAPTER II

2.0 LITERATURE REVIEW

2.1 General French bean entomology

French bean is attacked by a wide variety of pests (MOA, 1976-1979). Surveys carried out have identified thrips, bean fly and aphids as the most widely and economically important pests of French beans in Kenya (Nderitu, 1990).

2.1.1 Bean flower thrips: *Frankliniella* sp. and *Megalurothrips sjostedti* Trybom (Thysanoptera: Thripidae)

2.1.1.1 Distribution

The western flower thrips, *Frankliniella occidentalis* (Pergande), and the palm thrips, *Thrips palmi* Karny are examples of thrips species spreading worldwide very quickly. *Frankliniella occidentalis,* is a polyphagous species attacking a wide range of vegetable, ornamental and orchard crops (Yudin, 1986). They are becoming important pests in many green houses and field crops, especially on vegetables and ornamentals (Tommasini and Maini, 1995). Bean flower thrips are wide spread in sub-Sahara Africa where they attack and feed on many hosts, including over 50 plant species representing over 20 taxonomic families depending on thrip species (Wang and Chu, 1986). Thrips have a wide range of host plants, ranging from monocotyledons to dicotyledons (Ingram, 1969a; Hill, 1975). The host crops reported to be damaged often severely are in the family Solanaceae: eggplant, pepper, Cucurbitaceae: bittermelon, cucumber, watermelon, muskmelon, squash and

Leguminosae: French beans, kidney bean, broad bean, cowpea, common beans and soybean (Ingram, 1969b; Hill, 1975). Although primary damage to the plants and fruits is physical, *F. occidentalis* is known to be a vector of several pathogens and thus causes substantial economic damage (Ananthakrishnan, 1979).

2.1.1.2 Description and biology of thrips

Thrip is the common name given to the insects of the order Thysanoptera (thusanos, a fringe; pteron, a wing). There are over 5000 species in the order thysanoptera. The small size of thrips is an important factor contributing to the success of the order and their status as pests (Lewis, 1973). The adults are tiny, shiny black, about 2mm long with yellowish band across the pronotum and a distinct head (Palmer *et al.*, 1989). Morphology of the mouthparts differ from one family to another but feeding behaviour is generally the similar, being characterized by rasping, puncturing and sucking (Borden, 1915).

Thrip is a bisexual species, with no males and reproduction is mainly through parthenogenesis. The females lay over 200 eggs in the course of their two months life span. The life cycle has the egg, two larval instars, two pupal instars and the adult, are therefore the egg, larvae and adults are usually found on the same host plant. The eggs are small, kidney shaped, yellowish-white, measuring approximately 1/100 inch in length and less than 1/100 inch in diameter. They are generally deposited into the leaves, flowers and fruits and hatch into larvae in 3 days. The larvae are similar to adults in body form but lack wings and has smaller eyes. The larvae vary in colour from pale cream to orange and are similar in appearance except for the smaller size. There are two actively feeding larval stages within the flowers. The first stage is approximately 1/50 inch in length and the second 1/35 of an inch. The second larval instar crawl into the ground three days after hatching when fully fed. They remain there for 1 to 2 days before pupation, which occurs in the soil or among leaf litter. There is no feeding during this stage. The pupal period is divided into prepupa and pupa stages. The prepupae has a backwardly flexed free moving antennae and two short wing buds or incompletely developed wings and this stage lasts a day. After a moult, the pupa emerges which differs from the prepupae by having antennae fused to the body and has considerably longer wing buds. Their poor mobility and lack of feeding during this stage makes them vulnerable to desiccation in drought conditions. The pupa period lasts for 3 days and pupation takes place in the soil. Therefore, the life cycle takes 10-14 days depending on the temperatures (Ingram, 1969b).

Under field conditions, it is difficult to identify thrips to species level. To the naked eye, adult thrips are black in colour and measure approximately 1/25 inch long while the larvae are yellow to cream in colour. Adults are good flyers but their small size makes their dispersal susceptible to influences of wind and weather. Their ability to disperse widely either naturally by flight within vegetation in commercial agriculture and horticulture has greatly contributed to their pest status. Their activity peaks during the hot weather when updrafts may carry them for greater distances.

2.1.1.3 Pest status and nature of damage by the bean flower thrips

The status of thrips as pests differs greatly between crops, seasons and geographical areas. Thrips are a major pest of French beans accounting for 50 % yield loss and quickly build up heavy infestations causing severe injury (Kibata and Ong'aro, 1997). They are frequently found in pockets, cracks or crevices on host material. Both larvae and adult bean flower thrips *Frankliniella* sp. and *Megalurothrips sjostedti* Trybom feed gregariously on leaves, stems, flowers, flower buds, small pods and fruits leaving silvery marks called 'baridi' by Kenyan farmers. Loomans *et al.* (1995) reported that thrips indirectly affect plant vigour by feeding on leaves and flowers. Heavily infested plants are characterised by silvered or bronzed appearance of leaves, stunted leaves and terminals, scarred and deformed pods. Individuals may be found on all parts of the plant during outbreaks.

High incidence of thrips leads to abortion of flowers, pods do not open and abort prematurely, reducing yields significantly and/ or leading to total crop failures (Karel *et al*, 1981; Singh, 1990; Kibata and Ong'aro, 1997). Yield loss has been estimated to be about 14.5 kg/ha per individual thrip per plant (CIAT, 1996). Feeding and oviposition punctures lead to poor growth, deformed and poor quality pods at harvest (Hill, 1975; Sithanantham *et al.*, 1997). The farmers have been known to discard 40-60% in pre-sorting at the farm and up to another 20% at the collection points by exporters (Löhr, 1996). This is entirely due to thrips feeding marks on otherwise normally developed pods. Infestation by thrips is reported to be severe during the hot period and/ or during vegetative and flowering stages (Tagangin *et al.*, 1980; Karel and Mghogho, 1985). The type of damage caused depends on the structure infested, plant growth stage and the degree of toxicity of saliva of the species considered in relation to host plant characteristics.

Thus, bean flower thrips is the most important pest affecting the quality of export produce and leads to heavy losses of French beans due to quality reduction from feeding marks on pods. It also transmits viral diseases through contact and feeding (Pittman, 1927; Hansen, 1929; Sakimura 1947; Trevor, 1973). Infection of plants with Tomato Spotted Wilt Virus (TSWV) may likewise be costly to growers (Lewis, 1973). Therefore, efforts to identify effective and sustainable options for thrips management are of high priority.

2.1.1.4 Predators of Thrips

Many arthropods are known to be predators of thrips. They include Anthocoridae, Miridae, Syrphidae, Cecidomyiidae, Chrysopidae, Sphecidae and Araneida (Ananthaklrishnan, 1979). Most species belong to the family Gryllidae, Chrysopidae, Anthocoridae, Nabidae, Lygaeidae and order Acari Thysanoptera, Coleoptera and Diptera. The Anthocoridae are known as active general insect predators, and are effectively used in biological control programmes (Sohm, 1981; Schmitt and Goyer, 1983; Ananthakrishnan and Sureshkumar, 1985).

Several natural enemies have been reported for melon thrips. A flower bug of genus *Orius* (Heteroptera: Anthocoridae) was observed by Johnson (1986) preying on melon thrips on watermelon in Hawaii. Other flower bugs have been observed preying on *Thrips palmi* in India (Kumar and Ananthakrishnan, 1984) and

China (Wei *et al.*, 1984). These bugs are general feeders. Two species of mite predators namely *F. occidentalis* may be controlled by biological control agents (predatory mites and anthocorids) and insecticides (Kumar and Ananthakrishnan, 1985; Shipp and Gillespie, 1993). Pesticide control is required because of the occurrence of secondary pests such as the plant bugs, *Lygus* sp., which are not effectively controlled with biological agents.

2.1.1.5 Parasitoids of thrips

Parasitoids of thrips belong to the order Hymenoptera, superfamily Chalcidoidea. Most of them are solitary endoparasites of eggs (Mymaridae, Trichogrammatidae) or larvae (Eulophidae). A few species in the genera *Psilogaster* and *Orasema* belonging to the family Eucharitidae have been reported as ectoparasites of thrips larvae (Johnson, 1988). Larval parasitoids are found in four closely related genera: *Ceranisus, Goetheana, Thripobius* and *Entedonastichus* (Eulophidae: Entedontinae). They are all solitary, internal parasitoids of the larval stages although sometimes the prepupae and/or pupae may be attacked.

Ceranisus menes (Walker) (Hymenoptera: Eulophidae) is the most serious parasitoid of thrips. The size of the females ranges from 0.66 mm (Desantis, 1961) to 1.06 mm (Buhl, 1937), the males are somewhat smaller (Ishii, 1933). They reproduce by both arrhenotoky and thelytoky. *Ceranisus menes* is characterised by black thorax, all yellow legs and the hyaline wings can be distinguished from the other *Ceranisus* species by the characteristic bare space below the subcubital vein strongly sinuately curved upwards. The distribution of *C. menes* can be considered have developed resistance to organophosphate, carbamate, and pyrethroid insecticides (Helyer and Brobyn 1992; Immaraju *et al.*, 1992; Brodsgaard, 1994). A typical practice for control of thrips is the application of a systemic insecticide such as Aldicarb at planting and then weekly applications of Acephate or Carbofuran through the season (McPherson *et al.*, 1992). To date, there are few cultural control methods known that are highly effective in controlling thrips. Mulching and the use of reflective material on the field have given some control while plants are small. Similarly, mulching combined with irrigation may help reduce adult emergence from pupation in the soil. No host plant resistance has been recorded.

2.1.2 Black bean aphid: *Aphis fabae* Scop. (Homoptera: Aphididae)

2.1.2.1 Distribution

Aphid is a common name for a group of insects sometimes called plant lice or green flies. Aphids belong to the family Aphididae in the order Homoptera. *Aphis fabae* insect is completely cosmopolitan and is known to be present in Australia, Africa, and America, but absent only in parts of Canada and Asia. The aphids are found all over the world parasitizing on roots, leaves and stems of plants. They frequently do great damage, cause heavy losses by feeding and transmitting viral diseases. *A. fabae* is an important pest of French beans and is widely distributed in Kenya and they prevent farmers from obtaining high yields. They attack wide variety of plants and mainly attack common beans wherever they are grown. Economically important plants that are attacked include common beans, French beans, cowpeas, eggplant, spinach, turnips, cabbage, tomato, watermelon, apples and pears. Aphids often attack crops and reduce the yields either directly or indirectly (Dixon, 1987).

2.1.2.2 Description and biology

The adult of *Aphis fabae* is minute, a soft bodied, dull black minute (1-2.6 mm long) plant sucking insect, often with powdery white secretion on the abdominal segments. These pear-shaped insects have antennae, which are shorter than their bodies and a pair of cornicles (tailpipe-like appendages). Though smaller than adults, larvaes resemble the wingless forms in shape and are dark green in colour with rounded bodies. The last instar has five to seven pairs of white spots on the back of its abdomen.

The mouthparts of *A. fabae* are modified for piercing, and sucking and consisting of four long, sharp stylets inside a proboscis. Two projecting cornicles, or horn-shaped tubes at the posterior end of the body emit a sweet glutinous substance called honeydew, which attracts ants and other insects. Ants may protect aphids from predators. The legs are long and slender but are not adapted to running quickly. *A. fabae* has a short life cycle of about 7 days. The time of development is so short that the eggs sometimes hatch before they are laid (Hill, 1975).

Several or all generations comprise of parthenogenetic females, which do not require fertilisation and are viviparous. Reproduction does not involve mating or egg laying and the females give birth to live larvae. Because of this type of reproduction, the population is composed solely of females. Some species show cyclical parthenogenesis where asexual reproduction alternates with sexual reproduction.

This parthenogenesis and telescoping of generations enable aphids to achieve very high rates of increase. The winged aphids are known as alatae while wingless aphids are apterae. The alates usually develops under overcrowded conditions or when food quality deteriorates (Hill, 1975).

2.1.2.3 Pest status and nature of damage on French beans

The wingless aphids occur in colonies especially around the stems, growing points and lower parts of the leaves where they feed by sucking the sap from their hosts. The undersides of leaves are preferred, other leaf surfaces and flower buds are its next choice but the entire host may be covered when populations are large. Aphids feed by inserting their stylets into the plant tissues and exploiting the turgor pressure within the plant cells. Aphids feed in colonies disrupting the continuous flow of sap even from the tissues not directly attacked by them (Kennedy and Stroyan, 1959) thus, leading to serious plant damage and consequently crop losses. Young plants may have stunted growth or become desiccated hence wilt and die. Heavy infestations may result in the infested leaves often becoming cupped downwards or otherwise distorted and may appear wrinkled (Hill, 1975). They cause direct damage through sap sucking, mechanically injuring the plant tissues or indirect damage through transmitting several viral diseases.

Aphids transmit over thirty viral diseases, which adversely affects the fitness of plants (Hill, 1975; Dixon, 1987). Both apterae and alate aphids are able to transmit viruses. Non persistent transmission occurs when the virus is taken up into the aphid's mouth while feeding on an infected plant and transferred to a healthy plant during the next feeding or probing using mouthparts. The virus reproduces in the plant and the aphids simply aid in transporting the virus. The viral diseases include Common Bean Mosaic Virus (CBMV) and Yellow Bean Mosaic Virus (YBMV) which reduces yield (Dixon, 1998). Viral disease infection on young bean plants causes malformation and discoloration of leafves, reduces plant growth and leads to severe yield loss (Wallace, 1941; Khaemba and Ogengo, 1984). Aphids can inflict severe losses of up to 46% on broad bean crops (Way and Heathcore, 1966). They reduce the number of seeds produced by bean plants by 86% and also the average weight of faba bean (*Vicia faba)* by 45% (Banks and Macaulay, 1967).

Aphids produce honeydew, which serves as a medium on which sooty mould grows. Sooty mould blackens the leaf and decreases photosynthetic activity (Elmer and Brawner, 1975). Presence of honeydew and sooty mould on the fresh pods, reduces the marketability of the produce. The extent of damage is governed by level of infestation, disease, plant developmental stage, growing conditions of the crop, growth stage attacked and environmental conditions (Ogenga-Latigo and Khaemba, 1986; Mueke, pers. Comm.). Aphid infestations are more important during the dry spells. The effects are severe when the plants are infested during the early vegetative stage of growth, when aphid infestation levels are high or when the conditions of crop growth are poor (Ogenga-Latigo, 1983; Ogenga-Latigo and Khaemba, 1986).

2.1.2.4. Predators of aphids

Natural enemies, particularly insect predators, exert an important influence on field populations of many aphid pests (Hagen and van Den Bosch, 1968; Minks and Harrewijn, 1987). Aphids are preyed on by a number of predatory species, which include insects in the order Hemiptera, Neuroptera, Diptera, and Coleoptera (Hagen and van Den Bosch., 1968). Coccinelids or ladybird beetles (Coleoptera: Coccinelidae) are the most abundant and most effective group of aphid predators (Hagen and van Den Bosch, 1968; Hagen, 1974). Insect predators are considered more effective in the preventing outbreaks of *A. fabae* than all the other groups of biotic mortality agents (Hagen and van Den Bosch. 1968). The effectiveness of predators is due to their high individual rate of prey consumption, their great abundance, activity and their closer synchronization with aphid populations and the fact that both adults and larvae feed on the aphids (van Emden, 1967; Gilbert, 1981). They also show strong numerical and reproductive responses to high prey populations (Bryant and Wratten, 1984). Coccinelids are considered the most important enemies of aphids (Tamaki and weeks, 1972; Luff, 1983) and have, in some Temperate counties, been effectively utilized in the integrated control of aphid pests (Hagen, 1974; Neuenschwander *et al.*, 1975) thus, the need to conserve them.

2.1.2.5 Parasitoids of aphids

Very little information is provided on the parasitoids of *Aphis fabae*. A number of parasitoids found on *A. fabae* include *Diaeritiella rapae, Eretmocerus* sp., *Aphilinus* sp. and Alloxysta sp. and they have been found on different host plant. Hymenopterous parasitoids are believed to mature on one aphid and therefore would appear to be potentially more likely to regulate aphid abundance. Their effectiveness, however, is reduced by their longer developmental times relative to their hosts and by the action of their hyperparasitoids, which are less specific than the primary parasites (Mackauer and Völkl, 1993).

2.1.2.6. Control

Aphids are pests of world-wide importance and cause heavy crop losses by feeding and transmitting viral diseases. Birds, spiders, parasite wasps, hover-fly larvae and ladybird beetles destroy great numbers of aphids. The control of aphids is a serious problem because many aphid populations are insecticide resistant. Certain insecticides e.g. Pirimicarb, Dimethoate, Diazinon, Formothion and Karate applied before flowering has been found effective against aphid infestation (Bardner *et al.*, 1978). Their use prevents damage and transmission of CBMV and YBMV and enhances high yields (Mueke, pers. Comm.). Use of chemicals in the control of pests, especially the foliar sprays pauses a serious problem to the pollinators, parasitoids and predators (Way, 1966). Therefore, it is necessary to find new methods of control, preferably with agents that are nontoxic to humans. Thus, there is need to look for alternative bio-pesticide that will not affect the beneficial insects. One such alternative is the use of derivatives from the neem tree.

2.1.3 Neem tree

2.1.3.1. Taxonomy and economic importance

Adrien Henri Lawrent De Jussien (1830) named the neem tree as *Azadirachta indica.* Neem is a native to Burma and the arid regions of the Indian sub-continent, where it has almost been semi-domesticated and it is well known for its medicinal and insecticidal properties. It is a botanical cousin of mahogany, a member of Meliaceae family (Schmutterer, 1995). Neem is widely distributed throughout tropical Africa in both dry and humid areas. It is grown in many western African countries such as Niger, Sierra Leone, Ghana, in plantations in Sudan, Ethiopia and Eastern and Southern Africa with predominance in the Swahili dominated areas along the coast. Today, it is grown in many Asian countries, in tropical regions of the New World, in several Caribbean and in some Mediterranean countries. During the last century, neem was introduced in arid zones of Africa. In Kenya, it is mainly grown along the coast where it is commonly known as "Muarubaini" in Kiswahili, meaning a reliever of 40 disorders (Ketkar, 1976). Neem has potential application in agriculture, animal care, public health, and even for regulating human fertility.

Neem is an ornamental, evergreen, tall, hardy fast-growing shade tree, which grows to a height of 8-25 metres and 2.5 metres in girth with deep green foliage and masses of honey-scented flowers. It grows in lowland tropics as well as arid and semi-arid areas, in poor soils, stony, well drained sandy soil with pH value of 6.2-7.0 and tolerates long spells of drought and salinity (Schmutterer, 1995). It grows in areas with annual rainfalls of 450 mm up to 1,200 mm. The tree can tolerate high to very high temperatures between 21°C and 35°C. However, the tree is unsuited to growing in cooler and mountainous areas above 1000 metres above sea level. Neem is propagated by use of seeds and fruiting begins from 3 to 5 years. In coastal Kenya, fruiting occurs in March and April, but some off types also fruit in November and December. The fruit is about 2 cm long, with a yellow fleshy absorbed into the plant, carried throughout the tissues, to be ingested by insects when they feed on the plant. For systemic use, neem can be applied either as a foliar spray or soil drench. Soil drenches are more effective than foliar applications when systemic activity is desired. Systemic action is more effective against certain foliage-feeders that cannot be reached through foliar sprays.

2.1.3.3. Effect on pests

Azadirachtin and its analogues have phagorepellency, growth inhibiting, oviposition and egg-laying deterrence, mating disruption, chemosterilizing, anti-feedant and toxic effects on insect pests (Schmutterer and Ascher, 1986; Saxena, 1989; Ascher, 1993; Schmutterer, 1990,1995). In the last decade, *Azadirachta idica* has come under close scientific scrutiny as a natural source of novel pest control materials (Schmutterer and Ascher, 1984; Jacobson, 1989). The well-known insect antifeedant property is associated with the bitter taste of neem leaves, bark and seed. Recent findings have revealed a whole range of behavioural and physiological effects on insect pests (Saxena, 1989; Schmutterer, 1990a; Ascher, 1993). Azadirachtin affects growth, metamorphosis, behaviour of insects through its action on neuroendocrine system, hormonal production and release of molecular synthesis (Schmutterer, 1995). It also interrupts signal transfer from haemolymph to the neurosecretory cells by binding irreversibly to specific receptors, possibly in the neurolemma, thereby impairing the endocrine physiology (Schmutterer, 1995). Except for certain scale insects and mealy bugs (Coccoidae), many homopteran insects particularly planthoppers, leafhoppers and aphids are highly sensitive to neem products (National Research Council, 1992). In the Dominican republic, water extracts of neem seed proved effective against *Aphis gossypii* on cucumber and okra, and *Lipaphis erysimi* on cabbage (Schmutterer, 1990). The effectiveness of neem products depends on the concentration of the active principles, type of formulation, the pest species tested and the crop (Varela, 1998).

2.1.3.4. Phagorepellency

A material is considered repellent when there is an orientated movement away from the stimulus source. Dethier, (1956) and Schmutterer and Hellpap, (1988) found extracts of dried and ground seed kernels to be most potent of all neem preparations. Bhatnagar and Kandasamy (1993) found 1% neem oil to be a better repellent than commercial products against *A. gossypi* on cotton. From the experiments done by Karel and Hongo (1984), *Megalurothrips sjostedti* were repelled from common bean (*Phaseolus vulgaris*) when sprayed with crude extracts of neem leaves and kernels.

2.1.3.5. Growth inhibiting

At comparable concentrations, the growth inhibitory and disrupting effects of neem derivatives on homopteran pests are much more pronounced than either the repellent or the antifeedant effect. Neem products have some growth inhibiting effects on whiteflies, beetles, leafminer, diamondback moth and pink bollworm. The blocking of larvae from moulting is likely to be neem's most important quality especially in bean aphid. Azadirachtin causes morphogenetic defects in pests that come into contact with it and ensure that young insects do not reach adulthood when ingested. It is known to prolong the larval period by upto 45 days.

2.1.3.6. Anti-feedant

Neem oil and neem extracts have been shown to deter feeding in many homopteran insects. Water seed extracts of neem seed proved effective against *Aphis gossypii* on Okra (Schmutterer, 1990). Since azadirachtin is an important antifeedant for aphids, its contribution to reducing virus transmission should not be underrated (Simons, 1981; Wood, 1990). The efficacy of 3 and 5 % of neem seed kernel extract (NSKE) and neem oil was found to be high against *H. armigera* in chickpea (Saxena, 1980). Neem oil sprayed on plant inhibits feeding by insects. Haskell and Schoonhoven (1961) showed that an aqueous extract of neem tree stimulated a neurone in sensilla on the maxillary palps of *Schistocerca gregaria*, which resulted in feeding deterrence. It is possible that neem extract preferentially stimulated deterrent neurones responsible to antifeedant compounds like azadirachtin (Schmutterer, 1995). Azadirachtin can also act indirectly by affecting the centres that control feeding or the hormones that are involved in food metabolism (Barny and Kloche, 1987). Injection of azadirachtin in larvae and adults of *Locusta migratoria* induce inhibition of mid-gut peristalsis and concurrent depletion of serotoninergic cells in the frontal ganglia which results in suppressed feeding and therefore, development (Dorn and Trumm, 1993).

2.1.3.7. Effect on Reproduction

The insects that ingest neem succumb to behavioural and physiological stresses and starvation. Neem oil disrupts normal courtship and mating behaviour, and invariably impairs insect's reproductive physiology. Azadirachtin is an ecdysis inhibitor and affects vitellogenesis, which leads to vitellarium and the oviducts being reabsorbed, thus a drastic reduction in egg laying activity of the adults. Rembold and Sieber (1981a & b) demonstrated that azadirachtin inhibits oogenesis and ovarian ecdysteroid synthesis thereby causing a shift and a decrease in ecdysteroid peaks in *L. migratoria*. Ecdysteroid and juvenile hormone are affected by azadirachtin administration in female *L. migratoria* and vitellogenin synthesis is delayed during the first and second gonadotrophic cycles (Rembold and Sieber, 1989). All these physiological effects of azadirachtin may either result in reduced adult fecundity or reduced viability of the resulting eggs.

2.1.3.8. Effect on virus transmission

Wood (1990) stated that the commercial significance of the antifeedant activity of neem may be limited due to considerable variation between insect species in their sensitivity to bioactive fractions such as azadirachtin. However, he stated that the importance of antifeedant in reducing virus transmission should not be underrated. Simons (1981) emphasised the use of oil formulations with antifeedant properties for control of insect transmitted viral diseases. Recently several workers have confirmed the value of neem derivatives in reducing virus transmission. Spray applications of 3% and 5% neem oil impeded the transmission of a chilli mosaic virus (PVY) by *Aphis craccivora* and *Myzus persicae* in chillies (Mariappan and Samuel, 1993). Likewise, Roychoudhury and Jain (1993) reported that application of 2% neem oil reduced the disease incidence of yellow vein mosaic virus by *M. persicae* and *Bemesia tabaci* in Okra fields. Neem oil also inhibited virus multiplication in the host as evidenced from its effect on mechanically transmitted tobacco mosaic virus in hosts.

2.1.3.9. Soil amendment

Use of neem products as soil amendments has been reported in the control of plant parasitic living nematodes and associated micro-organisms (Schmutterer, 1995). Schmutterer (1995), reported that neem cake as soil amendment can be applied on the basis of nitrogen content of the cake and the crop requirements or on the basis of weight per unit area or unit weight of soil. Neem seed cake when used as soil amendment or added to urea or ammonia containing fertiliser, not only enriches the soil with organic matter but also lowers nitrogen losses by inhibiting nitrification. Neem cake also reduces nitrification rate of the soil by suppressing nitrifying bacteria such as *Nitrobacter* and *Nitrosoma* bacteria. This reduces the need for application of external nutrients. Some studies have shown that mixing neem cake with regularly scheduled applications of manure can almost double yield over manure alone. Neem cake which is richer in plant nutrients than manure, killed damaging nematodes, promoted larger populations of earthworms, helped keep nitrogen in the soil available to the plants, and provided significant protection from insects. This combination of effects provides an almost ideal growing condition for the plants (Vijayalakshmi and Goswami, 1985).

By killing nematodes in the soil, a major plant pest is eliminated. Nematodes suck juices from roots of plants to the point where they are unable to supply sufficient nutrients to the plant. On the other hand, by promoting larger populations of earthworms, neem cake helps keep the soil loose so that the roots can more easily absorb water and nutrients. Earthworms also enrich the soils by creating readily absorbable nutrients as it feeds on decaying plant material.

2.1.4.0. Insect orders affected by neem

Neem compounds affect 400-500 species of insect pests and are most effective against insects belonging to order Homoptera, Lepidoptera, Diptera, Hemiptera, Thysanoptera, Coleoptera, Orthoptera, several species of mites, nematodes, snails and fungi (Schmutterer, 1995; Saxena, 1997). Aphids, leafhoppers, psyllids, whiteflies, scale insects, and other homopterous pests are sensitive to neem products to varying degrees. Phloem feeders, such as aphids, are in general not good candidates for neem used systemically and its effect on some of the insects is as shown in table 2. Results against some bugs, leafhoppers and whiteflies have also been good. Generally, chewing insects are affected more than sucking insects. Insects that undergo complete metamorphosis are affected more than those, which undergo incomplete metamorphosis. Leafhoppers and plant hoppers vary in susceptibility. Aphids and thrips are not highly susceptible to neem, but are sometimes controlled with repeated applications. Larvae of leafhoppers and planthoppers show considerable antifeedant and growth-regulating effects.

From numerous field trials (notably on various moths), it appears that the larvae of most lepidopteran pests are highly sensitive to neem, which blocks feeding, although this effect is usually less important than the disrupting of growth. Neem is very effective on thrips larvae that occur in the soil, and thrips control trials done so far with neem products have provided promising results against *Frankliniella sp* and *Megalurothrips* sp. and oily formulations have shown some success in exploratory trials (Schmutterer, 1995; Saxena and Kidiavai, 1997).

The larvae of all kinds of beetles especially those of phytophagous coccinelids (Mexican bean beetle and cucumber beetle) and chrysomelids (Colorado potato beetle) are sensitive to neem products. They refuse to feed on neem related plants, grow slowly and some are killed on contact especially the soft skinned larvae of Colorado potato beetle. In Orthoptera, antifeedant effect seems important since a number of species refuse to feed on neem-treated plants for several days, sometimes several weeks. Neem has been used to control aphids, diamondback moth, armyworms, cabbage loopers, Colorado potato beetles, mites, corn ear worms, cutworms, corn borers, flea beetles, fungus gnats, flies, grasshoppers, leaf-hoppers, leaf-miners, mites, spruce budworms, tent caterpillars, thrips, white flies and many others.

Table 2. Insect pests affected by neem products that mainly infest French beans.

INSECT	EFFECT
Bean aphid	Reduces fecundity, disrupts moulting
Western thrips	Retards growth
Leafminer	Retards growth, inhibits feeding, disrupts moulting, toxic
Pink Green leafhopper	Retards growth, inhibits feeding
Green leafhopper	Inhibits feeding
Bollworm	Inhibits feeding
Mexican bean beetle	Retards growth, inhibits feeding, disrupt moulting
Whitefly	Repels, retards growth, inhibits feeding

Source: National Research Council, 1992.

2.1.4.1. Effect on other organisms

Neem seems remarkably benign to spiders, butterflies, insects such as bees that pollinate crops and trees, ladybirds and bugs that consume aphids and wasps that act as parasites on various crop pests (Saxena, 1987). This is because neem products have to be ingested to be effective. Thus, insects that feed on plant tissues succumb, while those that feed on nectar or other insects rarely contact significant concentration of neem products (National research council, 1992). In green house trials in Florida, neem products proved essentially nontoxic to predators and parasitoids of cotton aphid and the sweet potato whitefly. Neither the amount of predation nor parasitism was notably reduced (Hoelmel *et al.*, 1990). Recent interest in biological control has shown that some anthocoridae are effective member of the predator complex (Ananthakrishnan and Sureshkumar, 1985; Drukker *et al.*, 1995), thus the need to preserve them.

It is therefore important to explore the potential benefits of natural enemies and in particular, the compatibility of using pesticides in ways that allow natural enemies to contribute significantly to pest control. Integrating these two strategies would allow the balance between pest management based on pesticides and biological control to shift towards the latter as new non-chemical methods become available. A census of natural enemies of aphids collected from seven different field trials indicated that neem has no detrimental effects on either predators (coccinellids, chrysopids, syrphids) or parasitoids (Ichneumonids, braconids). The aphids in the neem-treated plots were actually carrying more parasites than were those in either the control plots or plots treated with insecticide pyrethrum (Isman *et al.*, 1991).

One of the alternatives to synthetic pesticides being studied is the use of ecologically friendly, natural control agent such as neem. Crude extract from neem could even break resistance against commercial insecticides (Schmutterer and Hellpap, 1988). The chances of insects developing resistance to neem seed extracts are remote (Saxena, 1983). However, those could be very valuable in the prevention of resistance development as they act in various modes on different systems in insect pests. Comparative studies between synthetic pesticides and raw material of neem products have shown that this is actually happening (Vollinger, 1992)

Therefore, neem having shown to have broad spectrum properties characterized by antifeedant and antimoulting effects in many agricultural insect pests (Schmutterer, 1990; Simmonds & Blaney, 1996; Isman, 1997) might usher a new era in pest control (Rembold, 1988; National Research Council, 1992). Additionally, azadirachtin is a biologically degradable compound (Bomford and Isman, 1996). It is also less prone to pest resistance and resurgence, low risk against the non-target organisms, non-toxic to human beings and other beneficial biota and is cheaper than conventional pesticides. Neem's systemic qualities affect insects feeding behaviour and disrupt their growth and development (National Academic Press, 1992). Numerous sprays are required to control pests effectively and large quantities of neem powder are required for soil application, which make it relatively expensive. Thus, seed treatment with neem products may prove more economical than any other method because smaller quantities are needed (Schmutterer, 1995).

2.3 OBJECTIVES

2.3.1.General objective:

To investigate the efficacy of various neem formulations in the control for major pests of French beans and examining their effect on some beneficial insects.

2.3.2.Specific objectives:

1. To establish the effect of various neem formulations on seed germination of French beans.
2. To determine the efficacy of various neem formulations on thrips and aphids in French beans
3. To determine the effect of various neem formulations on predators and parasitoids of thrips and aphids.
4. To determine the efficacy of various neem formulations on plant damage and their effect on yield and pod quality.

CHAPTER III

3.0 MATERIALS AND METHODS

3.1 STUDY SITE

The study was conducted at Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Thika district, Central province, Kenya, located 32 km north of Nairobi at longitude 37° 00' E and latitude 1° 05' S and approximately 1,525m above sea level (ASL) (Figure 1). The experimental site receives an average annual rainfall of 856 mm and exhibits a bimodal pattern with over 55% of the total falling in the long rainy season (from March to June), while the short rains fall between October and January. Temperatures are moderate, usually ranging between 13 and 26°C. The area has a problem of high rate of evaporation. The area is relatively flat with a slope of 0-2%. The soils are clay and so are poorly drained and easily get waterlogged. Market gardening is practised in the area because of its close proximity to the urban areas and has the high demand for a variety of crops by the urban population and thus, a variety of crops are grown.

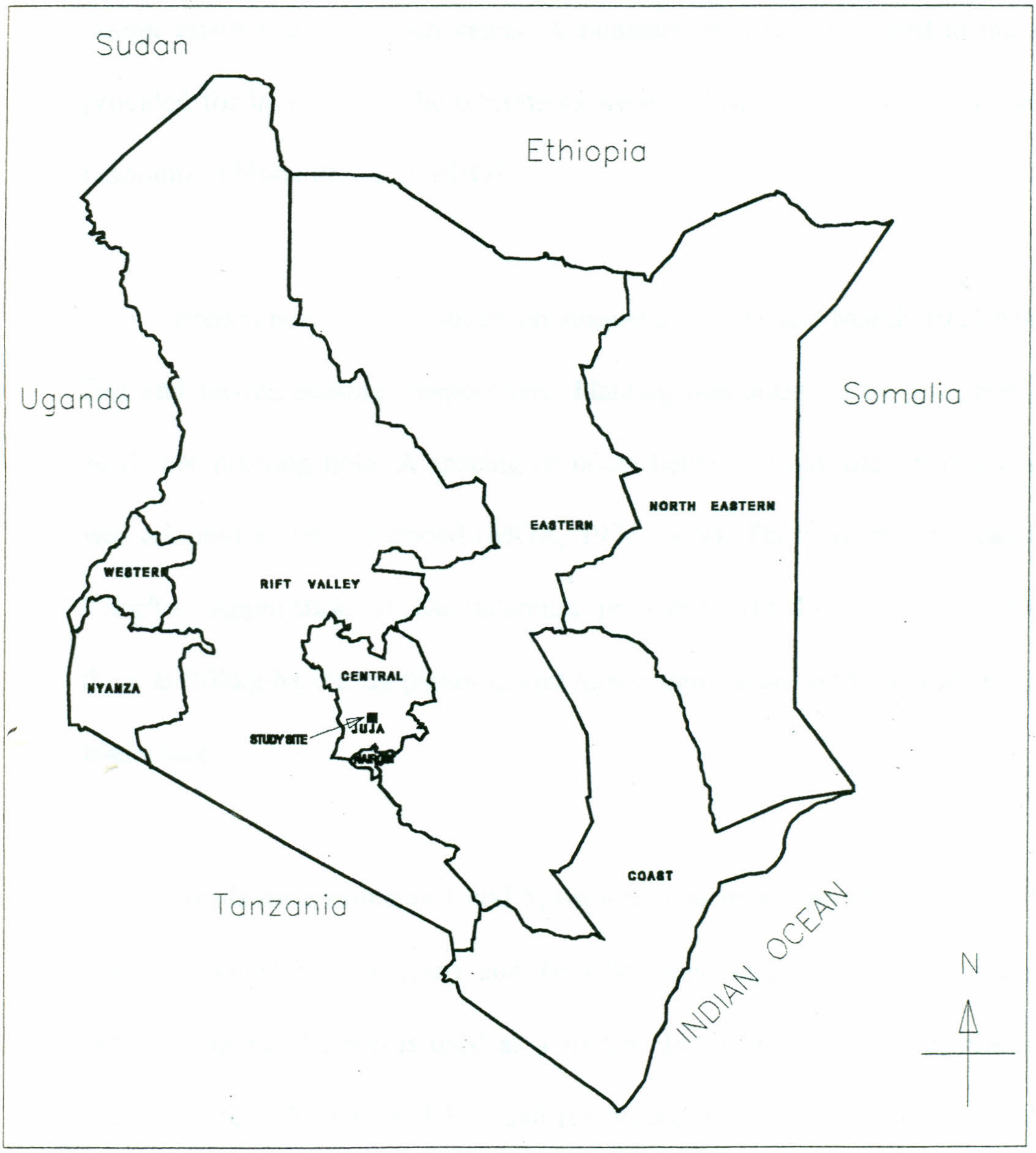

FIGURE 1: Map of Kenya showing study site

3.2. Experimental design and plot layout

Field trials of French bean using variety 'Monel' were laid out (during the months of September-December 1998 and March –June 1999) in plots measuring 4 metres by 5 metres each. The plots were separated by one metre buffer strip of bare ground between different treatments and replicates while, each treatment received 1 border guard row of French beans. A summary of treatments used in the study is provided for in Table 3. The treatments were replicated four times in a completely randomized block design (CRBD).

French beans were planted on August 23, 1998 and March 10, 1999 for the first and second seasons, respectively. Planting was achieved by placement of two seeds per planting hole. A spacing of 60cm between rows and 15cm within rows was adopted as recommended (MOA, 1976-1979). The seeding rate translated to 75kg/ha. Application of Diammonium phosphate (DAP-18%N+40%P2O5) was done at 200kg/ha during planting, and mixed thoroughly with the soils before seed placement.

Seeds for treatments 1 and 5, were treated with Neem Kernel Cake Powder with wannin (NKCP/wannin) and Gaucho (imidochloroprid) respectively a day before planting. Wannin is used as a sticker. In treatments 2 and 6, Neem Kernel Cake Powder (NKCP) and Furadan (carbofuran) respectively were applied within the ridges and mixed thoroughly with soil before planting while treatment 8 received no treatment (control). For treatments 4, 30 grams of NKCP was soaked in water, stirred regularly and left to stand overnight for a period of 10 hours. The mixture was stirred the following morning and allowed to stand before sieving in the afternoon. Sieving was done using a fine muslin cloth before being transferred into a 20-litre knapsack sprayer. Spraying was done late in the afternoon. The NKCP and NSO were supplied by Saroc Company Limited in collaboration with GTZ-IPM Horticulture Project based at ICIPE, Nairobi. Neem seed oil (NSO) has 0.03% azadirachtin and neem kernel cake powder (NKCP) has 0.3% azadirachtin

Hand weeding was done during the second and fourth week of emergence to avoid damaging of the shallow roots. The crop was irrigated throughout the growing period. From planting to two weeks after germination the crop was irrigated twice a week to allow proper growth set-up and from two weeks after germination to the end of cropping season, the crop was irrigated once a week, a day before spraying.

Foliar sprays using neem oil at 30ml/l water, neem powder at 30mg/l water and Karate (Lambda-cyalothrin) at 3ml/l water commenced 2 weeks after emergence and were applied every week for seven weeks. Data collection started two weeks after emergence.

Table 3: Treatments applied in French bean plots during the experimental period

Treatment No.	Treatment.
1	Seed treatment with NKCP/wannin @ 35 g/kg
2	Soil application of NKCP @ 3 g/hill.
3	Foliar spray with NSO @ 25 ml/l of water
4	Foliar spray with NKCP/WE @ 30 g/litre of water
5	Chemical seed treatment with Gaucho (imidochloroprid) @ 8ml/kg.
6	Soil application with Furadan (carbofuran) @ 1g/hill
7	Foliar spray with Karate (lambda-cyalothrin) @ 3ml/litre of water
8	No treatment

3.3 Specific methods

3.3.1 Effect of neem formulations on French bean germination

To test effects of various treatments on seed germination, French beans were subjected to different treatments as outlined in Table 3. They included treatments 1, 2, 5, 6 and 8. After planting, the plots were irrigated twice a week from planting period to two weeks after germination to allow proper germination and growth. Ten days after emergence, the number of germinated seedlings were counted in each plot with the help of tally counters and recorded. Percentage seed germination for each plot was obtained based on the following computation:

$$\% \text{ Germination} = \frac{\text{Number of seedlings emerged x 100}}{\text{Number of seeds planted}}$$

Experiments were conducted in two seasons (August to December 1997 and March to June 1998)

3.3.2. Efficacy of neem formulations on thrips population

Sampling of thrips started two weeks after emergence and continued up to the end of flowering period. The number of larvae and adult thrips were sampled one day before spraying and three days after spraying. During the vegetative stage, weekly counting of individual thrip population was conducted from 10 randomly selected plants per plot. It involved taking a white sheet of paper and placing it below the plant after which the plant was tapped and the numbers collected visually counted and recorded. This is because visual estimation of thrips number is highly correlated with absolute thrips densities r^2=0.83;$P<0.001$ (Edelson, 1985). However, during the reproductive stage, 20 uniformly sized flowers were randomly picked per plot from rows 2 and 8 commencing five weeks after emergence. The flowers were placed in small glass vials containing 70% alcohol for preservation and then taken to the laboratory. In the laboratory, the flowers and flower buds were dissected using a dissecting microscope and scalpels, and washed to separate the insects from the flower parts. Identification and counting of larvae and adult thrips were done using the stereo-binocular microscope and the numbers recorded. The two rows were selected for thrips counting since they were not interfered with during harvesting of pods.

3.3.3 Effect of neem formulations on aphid infestation

To test whether neem as seed treatment, soil amendment and foliar spray was effective in the control of aphids in French beans, aphids were sampled from plots subjected to different treatments (Table 3). Two weeks after emergence, ten plants were randomly selected from rows 4, 5 and 6, examined for aphid infestation and the number of aphids on the growing parts estimated using visual rating score of 1-5 personally developed (Table 4). Counting of aphids was done one day before spraying and three days after spraying.

Table 4: Rating scale for aphid infestation

Visual rating score	aphid infestation/ plant
1	<10
2	11-50
3	51-100
4	101-200
5	>201

3.3.4 Effect of neem formulations on predators and parasitoids of thrips and aphids

In order to assess the effect of neem formulations on predators and parasitoids of aphids and thrips, the population of predators (ladybirds, *Orius* and *Anthocorids* sp.) and parasitoids (*Ceranisus* sp.) were studied under field conditions Visual examination of predators and parasitoids was used in the experiment since it was found to produce a more accurate measure of density than sticky traps or pan traps (Letourneaau and Altieri, 1983). Counting of predators was conducted one day before spraying and three days after spraying from 10 randomly selected plants per plot and the numbers recorded. Sampling was conducted in the morning hours and involved gentle turning of each leaf and recording the number of ladybirds and the anthocorids observed. The population density of ladybird beetles in the two cropping seasons was estimated using the direct counting method (Southwood, 1978). Starting form one of the plot, beetles on the ten plants were counted. This method minimized disturbance and reduced the chances that those beetles already counted might move to the uninspected plants. After counting each species, a few insects per species were collected and preserved in 70% alcohol for later identification at ICIPE.

Five weeks after emergence, the population of thrips parasitoid *Ceranisus menes* was estimated by randomly picking 20 flowers of uniform size from rows 2 and 8 per plot and placing them in small glass vials containing 70% alcohol. The flowers were dissected in the laboratory to separate the flower parts from the parasitoid and later counted with the help of a dissecting microscope and the numbers recorded.

3.3.5 Effect of neem formulations on leaf damage and flower drop

To assess the effect of neem formulations and other chemicals on leaf damage, 10 plants were randomly selected from rows 3, 4, 6 and 7 four weeks after emergence and the leaves were checked for any damage by pests. The extent of damage caused by pests was assessed through examination of the leaves for any defoliation and rated using the visual damage rating score of 1-4 personally developed (Table 5).

To evaluate the effect of neem formulations and synthetic insecticides on flower drop, ten plants were randomly selected from rows 2 and 8, one week after onset of flowering and the flowers that had dropped around the plant collected, counted and the number recorded. The two rows were selected for sampling since they were not interfered with during harvesting of pods. Collection of dropped flowers was done on third and sixth day after spraying and continued for five weeks.

Table 5: Visual rating score for leaf damage

Rating	leaf area damaged (%)
1	0-25
2	26-50
3	51-75
4	>75

3.3.6 Effect of neem formulations on yields and pod quality

Harvesting of fresh pods in the field started six weeks after emergence. This took place on 14 November 1998 and 26 April 1999 for first and second season respectively. The pods were harvested thrice every week. It involved harvesting the pods of fine grade from rows 3, 4, 5, 6 and 7, placing them in crates whose weight had been known and weighing them to the nearest ten grams. To get weight of pods for each harvested plot the weight of the crate was subtracted from the total weight obtained (weight of crate and pods). The harvested pods were turgescent, very tender, seedless, string-less with a minimum length of 10cm and width between 6 and 9mm. After weighing, 50 pods of approximately the same length and size per plot were randomly selected, placed in polythene bags and taken to the laboratory where counting of scars was done. The number of scars were counted, recorded and rated using the visual rating score for pod quality of 1-4 personally developed (Table 6).

Table 6: Visual rating score for pod quality

visual rating scale	Damage extent
1	Unblemished (0 scars),
2	slight damage (1-5 scars),
3	moderate damage (6-10 scars)
4	badly damaged (>10 scars).

3.4. Data analysis

Data collected were averaged for individual plots during each cropping season because of the unequal frequency of samples taken during the seasons. The number of seedlings that germinated were converted to respective germination percentages. Data collected were subjected to actual numbers, log(x+ 0.5) and square root transformation before being subjected to 2-way analysis of variance

(ANOVA) (Snedecor and Cochran, 1980), using the general linear models (GLM) procedure of the statistical analysis systems (SAS, Institute, N. C, 1988). The means were compared using the Ryans-Einot-Gabriel-Welsch multiple range test (REGWQ) at P<0.05 (Rachie, 1985). The means were pooled from the two seasons.

CHAPTER IV

4.0 RESULTS.

4.1 Effect of neem formulations on germination of French beans

The mean percentage seed germination was relatively high in all the treatments. Seeds treated with NKCP/wannin had the highest mean germination percentage of 83.33 ± 2.96%, while the lowest germination percentage of 72.78 ± 3.53 % was recorded in plots where NKCP was applied as soil amendment but the two did not differ significantly (P>0.05) (Table 7). The means obtained were pooled from the two seasons. The control had a higher germination percentage 77.83 ± 4.88% than plots treated with the chemicals Gaucho, and NKCP but there were no significant differences. Although, seeds treated with NKCP/wannin had a higher germination percentage than those treated with Gaucho (75.98 ± 4.94%), there was no significant difference in germination percentage between the treatments. Similarly, seeds treated with Furadan were observed to have a higher germination percentage (77.16 ± 3.22%) than NKCP which were used as soil amendment but the differences were not significant (Table 7). Germination of seeds treated with NKCP/wannin compared well with those treated with Gaucho, which is the recommended chemical for seed treatment.

In comparison, season 1 had a higher germination percentage than season 2. There was no significant difference among treatments in season 2 while in season 1 there was significant difference among the treatments (See Annex 1 and 2). In both seasons, seeds treated with NKCP/Wannin recorded the highest germination percentage while seeds planted in NKCP soil amendment treated plots had the lowest germination percentage.

Table 7: Mean percentage germination of French beans.

Treatment	Mean germination percentage ± SE
NKCP/Wannin	83.331± 2.95
NKCP (SA)	72.79± 3.53
Gaucho	75.98± 4.49
Furadan	77.16± 3.22
Control	77.83± 4.88
Mean	77.42
CV (%)	14.21

4.2 Efficacy of neem formulations on thrips population

There was significant difference ($p<0.05$) among treatments over the days with respect to *Frankliniella* thrips species population during the vegetative phase of French bean development (Table 8). Control plots (without any suppression of the thrips) recorded the highest thrips infestation of over 6 individual thrips per 10 plants. On the other hand, NSO resulted into the lowest thrip population at 21 days after emergence. During the vegetative phase, Karate treated plots had the lowest infestation of thrips throughout the sampling period, which was an indication that the foliar sprays controlled completely the thrips population. It was observed that at 15 and 18 days after emergence, there was no significant difference (P>0.05) in thrips infestation amongst the treatments and the populations remained relatively low. However at 21, 24, 27 and 30 days after emergence (DAE), there was significant difference (P<0.05) in thrips populations among the treatments. The population of thrips in karate treated plots was the lowest as compared to all the other treatments. The control plots had the highest thrips infestation with a mean population of about 6 thrips per 10 plants as compared to that of NSO which had a mean of approximately 3 thrips per 10 plants. The mean number of thrips in Gaucho and NKCP/wannin seed treated plots, did not differ significantly (P>0.05) throughout the sampling period. However, at 24 and 30 days after emergence the mean number of thrips were significantly higher in the control plots than in Gaucho and NKCP/wannin treated plots although the means were relatively higher in the latter than former but comparable. Furadan and NKCP soil amendment treated plots differed significantly from the control at 21,24, 27 and 30 days after emergence. However, the mean number of thrips infestation for Furadan and NKCP were comparable on all sampling dates. There was no significant difference among treatments during the reproductive stage on the mean number of thrips *Frankliniella* species during the reproductive stage (P>0.05) (Table 11). The means were comparable with the control.

There was significant difference among treatments during the reproductive stage on the mean number of thrips *Megarulothrips sjostedti* Trybom (Thysanoptera: Thripidae) and larvae. Thrip larvae population differed significantly

(P<0.05) among treatments throughout the sampling period (Table 9). At 54 days Karate treated plots had the lowest infestation (1.63 ± 0.28) while control had the highest (5.07 ± 0.15). Mean number of larvae on plants treated with NSO were comparable with those treated with NKCP water extract on all days except at 36 days after emergence when there was significant difference between the treatments, but were significantly lower (P<0.05) than in the control plots. The larvae population increased in all the treatments as time went by. The mean number of larvae in the Karate treated plants were significantly lower (P<0.05) than those from NSO and NKCP water extract treated plants at 33, 36, 40, 43, 47, 50 and 54 days after emergence. Mean number of larvae in NKCP/wannin was comparable with Gaucho treated plants and the control on all days, although they had slightly higher means than the control. The mean larvae population did not significantly differ (P>0.05) between control and NKCP (SA) and Furadan treated plots on all days except at 47 days after emergence where the means in the Furadan treated plants differed significantly from control while the means were comparable in all the other days. The seed and soil amendment treated plots reduced the larvae densities below that of untreated plots in all days.

The mean number of adult *M. sjostedti* differed significantly (P<0.05) among the treatments throughout the sampling period (Table 10). However, there was no significant difference at 54 days after emergence. Thrips population in Karate treated plots differed significantly from all the other treatments at 33, 36, 40, 43 47 and 50 days after emergence. There was significant difference between Karate treated plants and the foliar sprays of NSO and NKCP water extract throughout the sampling period. Although the means between plots sprayed with NSO and NKCP water extract were comparable, the former had slightly lower means than the latter. Karate seemed to have complete control of thrips up to 50 days after emergence, with the lowest mean observed at 36 days after emergence. The mean number of thrips in NKCP/wannin seed treated and NKCP soil amendment treated plants were comparable with the control in all days. At 54 days after emergence there was no significant difference among the treatments

The mean number of the foliar thrips *Frankliniella* species during season one were relatively lower than season 2 although there was no significant difference among the treatments. Karate treated plot had complete control of thrips during the two seasons (See Annex 3 and 4). *M. sjostedti* infested the plant during the reproductive stage and the population was relatively high with season 1 having a higher population than season 2. During season 1 the means were significantly different between 33 and 47 days after emergence while in season 2 the means were significantly different throughout the sampling period (See Annex 5 and 6). Karate treated plots had significantly lower thrips infestation from the other treatments during season 1 while in season 2, the control plots differed significantly from all the other treatments between 40 and 54 days after emergence. NSO treated plots had a lower thrips infestation than those treated with NKCP water extract although the differences were not significant. The mean number of thrips larvae were significantly different throughout the sampling period in season 2 while in season 1, the means were comparable at 40 and 50 days after emergence but differed significantly on all the other days (See Annex 7 and 8).

Table 8: Mean number of foliar thrips *Frankliniella* sp. obtained during the vegetative stage.

Treatment	15 DAE Mean±SE	18 DAE Mean±SE	21 DAE Mean±SE	24 DAE Mean±SE	27 DAE Mean±SE	30 DAE Mean±SE
NKCP/wannin	0.71	0.90±0.09	1.19±0.22ab	3.30±0.29b	4.76±0.40ab	4.77±0.53b
NKCP (SA)	0.71	0.71	0.71b	2.87±0.24bc	4.27±0.52bc	4.30±0.44bc
NSO	0.71	0.77±0.06	0.71 b	2.60±0.27bc	3.31±0.31c	3.20±0.35c
NKCP/WE	0.71	0.84±0.08	0.84±0.08b	2.80±0.28bc	3.59±0.19bc	4.12±0.30bc
Gaucho	0.71	0.84±0.08	0.84±0.08b	1.89±0.43bc	3.27±0.24c	3.83±0.35bc
Furadan	0.71	0.84±0.08	0.84±0.08b	3.25±0.21b	3.88±0.26bc	4.04±0.21bc
Karate	0.71	0.77±0.06	0.71 b	0.71 d	0.71d	0.71d
Control	0.71	1.06±0.14	1.49±0.20a	4.40±0.32a	5.63±0.50a	6.27±0.30a
Mean	0.71	0.84	0.91	2.73	3.68	3.91
CV%	0	27.98	36.33	26.48	25.60	22.10

[a] Means within a column followed by the same letter are not significantly different at P=0.05% (REGWQ).

Table 9: Mean number of *Megarulothrips sjostedti* larvae obtained from 20 flowers on different days.

Treatment	33 DAE Mean±SE	36 DAE Mean±SE	40 DAE Mean±SE	43 DAE Mean±SE	47 DAE Mean±SE	50 DAE Mean±SE	54 DAE Mean±SE
NKCP/wannin	3.11±0.28ab	2.90±0.23a	3.10±0.24ab	3.38±0.25ab	3.37±0.38ab	3.38±0.33a	4.79±0.14a
NKCP(SA)	3.26±0.31a	2.65±0.29a	3.30±0.26ab	2.82±0.25ab	3.33±0.25ab	3.62±0.26a	4.53±0.15a
NSO	2.17±0.34b	1.50±0.34b	2.29±0.31b	2.71±0.28ab	2.95±0.43b	3.37±0.41a	4.51±0.08a
NKCP/WE	2.93±0.22ab	2.76±0.16a	2.33±0.39b	2.40±0.39b	3.31±0.32ab	3.98±0.30a	4.58±0.16a
Gaucho	2.64±0.32ab	2.53±0.19a	2.57±0.39ab	3.06±0.20ab	3.45±0.31ab	3.67±0.38a	4.37±0.33a
Furadan	3.22±0.18a	2.92±0.22a	3.06±0.23ab	2.91±0.25ab	2.94±0.51b	3.40±0.17a	4.57±0.17a
Karate	0.27±0.27c	0.46±0.46c	0.46±0.23c	0.17±0.17c	0.78±0.22c	1.42±0.19b	1.63±0.28b
Control	3.35±0.31a	3.70±0.19a	3.69±0.11a	3.73±0.18a	4.20±0.07a	4.29±0.10ab	5.07±0.15a
Mean	2.70	2.60	2.78	2.81	3.12	3.46	4.25
C V%	24.87	27.06	27.50	25.52	25.20	22.28	11.37

[a] Means within a column followed by the same letter are not significantly different at P=0.05% (REGWQ).

Table 10. Mean number of adult *Megarulothrips sjostedti* per 20 flowers obtained from different days.

Treatment	33 DAE Mean±SE	36 DAE Mean±SE	40 DAE Mean±SE	43 DAE Mean±SE	47 DAE Mean±SE	50 DAE Mean±SE	54 DAE Mean±SE
NKCP/wannin	3.28±0.31ab	3.04±0.11a	2.99±0.26ab	3.31±0.25ab	3.26±0.18abc	3.66±0.13ab	3.82±0.31
NKCP(SA)	3.66±0.27a	3.02±1.63a	2.95± 0.18ab	3.53± 0.20ab	3.60± 0.15ab	3.62± 0.25ab	4.06±0.27
NSO	2.54±0.49b	2.17±0.35a	2.48±0.34b	3.02±0.35b	2.79±0.31c	3.39±0.23b	2.73±0.27
NKCP WE	3.40±0.25ab	2.57±0.14a	2.44±0.43b	3.16±0.27ab	3.17±0.21bc	3.59±0.20ab	3.72±0.28
Gaucho	3.23±0.21ab	2.79±0.28a	2.85±0.24ab	3.22±0.36ab	3.49±0.28ab	3.67±0.20ab	3.84±0.29
Furadan	3.53±0.14ab	2.84±0.13a	2.44±0.42b	3.23±0.22ab	3.49±0.21ab	3.33±0.26b	3.65±0.32
Karate	0.91±0.18c	0b	0.82±0.27c	0.66±0.27c	1.25±0.21d	2.28±0.54c	3.63±0.24
Control	3.80±0.12a	3.06±0.18a	3.44±0.11a	3.78±0.09a	3.84±0.11a	3.96±0.06a	4.15±0.14
Mean	3.05	2.68	2.64	3.03	3.19	3.44	3.83
C V%	18.43	18.70	21.74	15.19	12.35	10.54	8.81

[a] Means within a column followed by the same letter are not significantly different at P=0.05% (REGWQ).

Table 11. Mean number of adult thrips of (*Frankliniella* Spp) during the reproductive stage

Treatment	33 DAE	3 6 DAE	40 DAE	43 DAE	47 DAE	50 DAE
NKCP(ST)	0.93±0.21	0.97±0.15	1.14±0.25	1.57±0.31	1.22±0.30	0.99±0.29
NKCP(SA)	1.31±0.09	1.27±0.21	1.26±0.24	1.64±0.32	1.22±0.30	0.93±0.22
NKCP/WE	1.95±0.48	1.70±0.19	1.48±0.16	1.89±0.24	0.97±0.15	1.00±0.29
NSO	1.80±0.07	1.63±0.18	1.35±0.25	1.64±0.32	0.97±0.15	0.97±0.15
Gaucho	1.59±0.40	1.22±0.30	1.05±0.21	1.27±0.21	1.48±0.16	0.71±0
Furadan	1.27±0.21	0.97±0.14	0.84±0.13	1.06±0.21	1.27±0.21	0.84±0.13
Karate	1.05±0.21	1.18±0.18	0.84±0.13	1.27±0.21	0.84±0.13	1.06±0.21
Control	1.56±0.13	1.40±0.10	0.84±0.13	1.06±0.21	1.83±0.23	0.97±0.15
Mean	1.43	1.29	1.10	1.43	1.22	0.93
C V%	38.06	31.18	34.96	32.88	35.53	32.62

4.3 Effect of neem formulations on aphid infestation

Aphid infestation was relatively low in the early growth period but the population increased 5 weeks after emergence (Table 12). There was no significant difference in aphid population amongst the treatments as per sampling at 22, 26, 29 and 33 days after emergence. However, there was significant difference ($P<0.05$) amongst the treatments at 36, 40, 43, 47, 50, and 54 days after emergence. Plots sprayed with karate compared with those of NSO and NKCP water extract at 36, 40, 43 and 47 days after emergence but differed significantly from the control. At 50 and 54 days after emergence, mean aphid population in plots subjected to foliar sprays of karate differed significantly ($P<0.05$) from NSO and NKCP water extract.

Plants treated with NSO had lower aphid infestation than NKCP water extract plots except at 54 days after emergence when the means were the same and compared with those from NKCP/wannin treated plants. Aphid population was comparable amongst plots treated with Gaucho, Furadan and foliar sprays of NSO and NKCP water extract. Aphid infestation from seed treated plants were comparable with the control throughout the sampling period although the means in the control plants was lower. Aphid infestation in NKCP/wannin and Gaucho treated plots were comparable at 36, 43, 47, 50 and 54 days after emergence but differed significantly from the control. But at 40 days after emergence, Gaucho treated plots had significantly lower infestations than NKCP/wannin and the control plots.

Infestation of French beans by aphids was observed as early as three weeks after emergence in plots where NKCP was used as seed treatment and soil amendment. Aphid infestation at 36 and 40 days after emergence in soil amendment treated plots with NKCP compared with the control but was significantly higher than in Furadan treated plots. But at 47 days after emergence, NKCP and Furadan treated plots differed from control with Furadan treated plot having lower aphid infestation. 54 days after emergence, karate treated plants had significantly lower aphid scores (1.00) than all the other treatments.

During season 1, aphid infestation was relatively lower than in season 2 (See Annex 9 and 10). There was significant difference among the treatments at 40, 50 and 54 days after emergence in season 1 unlike in season 2 where there was significant difference at 40 and 54 days after emergence. In season 2 NSO had a better control of aphid than season in 1and it differed significantly from the control.

Table 12: Mean number of Aphid (*Aphis fabae*) obtained from French bean plants under different treatments and days.

Treatment	26 DAE Mean±SE	29 DAE Mean± SE	33 DAE Mean± SE	36 DAE Mean± SE	40 DAE Mean± SE	43 DAE Mean± SE	47 DAE Mean± SE	50 DAE Mean± SE	54 DAE Mean± SE
NKCP/wannin	1.00	1.25±0.16	1.00±0.0	1.25±0.16bc	1.63± 0.18abc	1.75±0.16abc	1.88±0.30ab	2.00±0.33b	2.38±0.38ab
NKCP	1.00	1.25±0.16	1.38±0.18	1.88± 0.13a	2.00± 0.19ab	2.00±0.27a	2.38± 0.26a	2.75± 0.31a	2.88± 0.35a
NSO	1.00	1.00	1.00	1.13± 0.13c	1.38± 0.18cd	1.13±0.13bc	1.50± 0.18bc	1.75± 0.16b	2.00±0.0b
NKCP/WE	1.00	1.00	1.25±0.16	1.25±0.13c	1.50±0.19bcd	1.63±0.18abc	1.75±0.16ab	1.88±0.23b	2.00±0.27b
Gaucho	1.00	1.00	1.00	1.00 c	1.00 d	1.63±0.26abc	1.88±0.23ab	1.75±0.25b	2.00±0.38b
Furadan	1.00	1.00	1.00	1.00 c	1.00 d	1.25±0.13bc	1.38±0.18bc	1.75± 0.25b	1.75±0.25b
Karate	1.00	1.00	1.00	1.00 c	1.00 d	1.00 c	1.00 c	1.00 c	1.00 c
Control	1.00	1.00	1.38±0.18	1.63±0.18ab	2.13±0.13a	1.88±0.23ab	2.38±0.32a	2.75±0.31a	3.00±0.54a
Mean	1.00	1.06	1.125	1.250	1.450	1.516	1.766	1.953	2.125
CV%	-	23.23	28.08	26.95	26.98	33.60	25.28	22.55	23.47

[a] Means within a column followed by the same letter are not significantly different at P=0.05% (REGWQ).

4.4 Effect of neem formulations on predators and parasitoids of aphids and thrips

The mean number of parasitoids of thrips *Ceranisus menes* (Hymenoptera: Eulophidae) previously identified at ICIPE differed significantly (P<0.05) amongst the treatments except at 50 days after emergence (Table 13). Plots sprayed with karate had significantly lower parasitoid numbers than all the other treatments. The means in plots sprayed with NSO and NKCP water extract compared with that from the control except at 40 days after emergence when the means in the control plots differed from the former treatments. The control had relatively higher parasitoid means than the NSO and NKCP water extract treated plots. The parasitoid population in NSO and NKCP sprayed plots were slightly lower at three days after spraying than at six days after spraying. Plots sprayed with karate had the lowest (0.77±0.06) population of *C. menes* while unsprayed plots (control) had the highest (1.71±0.32) at 47 and 36 days after emergence respectively. The population of *C. menes* in plots treated with Furadan treated plots were significantly (P<0.05) higher than control on all days except at 47 and 50 days after emergence. However, the population in control plots compared with the NKCP/wannin and NKCP soil amendment treated plots on all sampling days The population of *C. menes* was comparable in the control, seed and soil amendment treated plots on all days. However, throughout the sampling period, the mean population was slightly lower in the seed and soil amendment treated plots than the control. The mean number of *C. menes* in Furadan treated plots were significantly different (P<0.05) from the control at 36, 40 and 43 days after emergence, while the means in the Gaucho and NKCP/wannin treated plots were not significantly different (P>0.05).

There was significant difference (P<0.05) among the treatments at 33, 36, and 40 days after emergence (Table 14) on the mean number of ladybirds obtained from the crop during the two seasons. The mean number of ladybird beetles in Karate treated plots were comparable with those of other treatments at 29, 43, 47, and 50 days after emergence. However, at 33 and 40 days after emergence the NSO, NKCP/WE and Karate treated plots had significantly lower ladybird numbers than the control. Later observations at 36, 47 and 50 days after emergence confirmed that the treatments had comparable influence on the ladybird population. Karate treated plots had lower population of ladybird beetles throughout the sampling period. The ladybirds appeared during flowering when the aphid population was abundant and were the most abundant group of predators that were observed preying on aphids especially in the control experiment. The ladybird population in seed and soil amendment treated plots was comparable with the control except at 33 days after emergence, when the control had significantly higher ladybirds than the other treatments.

The mean number of predatory bug *Deraeocoris ostentants* (Heteroptera: Miridae) was nearly the same in all the treatments at 15 and 19 days after emergence (Table 15). However, from 22 days after emergence, the mean population differed significantly (P<0.05) amongst the treatments. These early season thrips predators appeared on the crop soon after germination. Their mean population in plots sprayed with karate was lowest throughout the sampling period giving an indication that it had adverse effect on the predator population. The mean number of *D. ostentants* in the plots sprayed with NSO and NKCP water extract were comparable however, both treatments differed significantly from the control 22 days after emergence. The number of the *D. ostentants* in plots treated with NKCP/Wannin and Gaucho compared with those in the control plots except at 36 days after emergence, when there was significant difference between the treated and untreated plots. Similar results were observed on soil amendment treated plots. Thus, seed treatment and soil amendment did not seem to affect the populations of this predator species in the field.

The *Orius insidiosus,* (Hymenoptera: Anthocoridae) which are parasitoids of thrips, were found from the flowers collected in the field and were the late season parasitoid group. At 22 and 26 days after emergence the mean number among the treatments was similar. However, from 29 days after emergence the population of *O. insidiosus,* differed significantly ($P<0.05$) amongst treatments (Table 16). The population of *O. insidiosus,* in the neem seed treated plots compared with the Gaucho treated plots and control throughout the sampling period. The mean population of *O. insidiosus,* in plots spayed with of NSO and NKCP water extract was comparable throughout the sampling period but significantly differed from the Karate treated plots and the control at 36 days after emergence. However, at 50 days after emergence the population of *O. insidiosus* in NSO, NKCP water extract and the control were comparable but differed significantly from Karate treated plots. The mean population of *O. insidiosus* differed significantly between the soil amendment treated plots and the control at

50 days after emergence while in all the other days the populations were comparable. Plots sprayed with Karate had the lowest population of the *O. insidiosus* throughout the sampling period. The *O. insidiosus* appeared when the thrips population was fairly high.

The mean number of *C. menes* species was relatively more during season 1 than in season 2 (See Annex 11 and 12). There was significant difference among the treatments on the mean number of *O. insidiosus* during season 1 but during season 2 no *O. insidiosus* were obtained from the flowers

Table 13: Mean numbers of the thrips parasitoid *Ceranisus. menes* observed from 20 flowers at different days

Treatment	36 DAE Mean±SE	40 DAE Mean±SE	43 DAE Mean±SE	47 DAE Mean±SE	50 DAE Mean±SE
NKCP/wannin	1.41± 0.24ab	1.47± 0.29ab	1.46± 0.29ab	1.17± 0.19a	1.31± 0.24
NKCP (SA)	1.44± 0.20ab	1.50± 0.30ab	1.38± 0.26ab	1.34 ±0.22a	1.27±0.24
NSO	1.54± 0.23ab	1.41± 0.27b	1.35± 0.25ab	1.41± 0.27a	1.34± 0.22
NKCP/WE	1.43± 0.21ab	1.44± 0.28b	1.34± 0.25ab	1.34± 0.25a	1.30± 0.25
Gaucho	1.36± 0.28ab	1.47± 0.29ab	1.32± 0.23ab	1.28± 0.22a	1.49± 0.24
Furadan	1.12± 0.19bc	1.38± 0.60b	1.20± 0.20b	1.14± 0.17a	1.09± 0.21
Karate	0.84± 0.08c	0.84± 0.08c	0.84± 0.08c	0.77± 0.06b	1.01± 0.12
Control	1.71± 0.32a	1.65± 0.36a	1.50± 0.30a	1.50± 0.33a	1.50± 0.27
Mean	1.36	1.39	1.30	1.25	1.29
CV (%)	26.54	9.69	13.57	20.31	30.32

Means within a column followed by the same letter are not significantly different at P=0.05% (REGWQ).

Table 14: Mean number of predatory Ladybird beetles observed from 10 plants at different days

Treatment	29 DAE Mean±SE	33 DAE Mean±SE	36 DAE Mean±SE	40 DAE Mean±SE	43 DAE Mean±SE	47 DAE Mean±SE	50 DAE Mean±SE
NKCP/wannin	1.46±0.16	1.44±0.25ab	1.83±0.23a	2.82±0.11ab	1.26±0.24	1.26±0.24	0.97±0.15
NKCP (SA)	1.22±0.30	1.39±0.16ab	1.72±0.14a	2.42±0.21ab	1.41±0.30	1.41±0.30	1.06±0.21
NSO (FS)	1.06±0.21	1.48±0.17ab	1.54±0.21a	1.95±0.27b	0.93±0.22	0.93±0.22	0.71
NKCP/WE	0.84±0.13	1.27±0.21b	1.42±0.28ab	1.85±0.40b	1.27±0.21	1.27±0.21	0.71
Gaucho	0.93±0.22	1.49±0.29ab	1.82±0.24a	2.74±0.07ab	1.18±0.18	1.18±0.18	0.84±0.13
Furadan	0.97±0.15	1.40±0.10ab	1.92±0.16a	2.66±0.34ab	1.44±0.25	1.44±0.25	0.93±0.22
Karate	0.71	0.84±0.13b	0.71b	0.93±0.22c	0.93±0.22	0.93±0.22	0.84±0.13
Control	1.40±0.10	2.21±0.18a	2.01±0.28a	2.94±0.15a	0.97±0.15	0.97±0.15	1.10±0.13
Mean	1.07	1.44	1.62	2.29	1.17	1.17	0.89
CV%	33.02	28.02	23.36	18.85	38.25	33.25	33.12

[a] Means within a column followed by the same letter are not significantly different at P=0.05% (REGWQ).

Table 15: Mean numbers of predatory bug *Deraeocoris ostentants* under different treatments on different days

Treatment	19 DAE Mean±SE	22 DAE Mean±SE	26 DAE Mean±SE	29 DAE Mean±SE	33 DAE Mean±SE	36 DAE Mean±SE	40 DAE Mean±SE	43 DAE Mean±SE
NKCP/wannin	2.25±0.85	10.00±1.73abc	16.75±3.66ab	29.75±3.17ab	21.50±3.77ab	18.50±2.90b	12.50±1.44ab	7.75±1.54a
NKCP (SA)	2.50±0.96	11.75±3.32abc	11.75±3.33ab	30.50±2.72ab	22.50±3.21ab	5.01±2.61b	10.25±0.48b	5.25±1.49ab
NSO (FS)	1.25±0.48	11.25±1.03abc	14.75±0.63ab	25.50±2.06ab	14.25±2.29c	13.25±2.17b	8.50±0.65b	2.50±0.96bc
NKCP/WE	1.00±0.71	9.25±2.14bc	12.50±2.22b	23.00±1.35b	16.75±2.50bc	13.50±1.76b	8.00±1.73b	4.25±1.32abc
Gaucho	1.75±1.44	10.75±1.32abc	18.75±1.80ab	30.00±0.71ab	20.50±3.33abc	18.50±1.50b	8.25±0.25b	5.50±1.50ab
Furadan	2.50±1.04	15.00±2.52ab	21.75±1.25ab	28.00±1.68ab	18.00±2.16bc	18.00±3.14b	8.754±0.95b	7.25±0.63ab
Karate	1.75±0.25	3.50±1.19c	2.00±0.58c	2.00±0.91c	3.25±1.25d	1.00±0.41c	3.00±0.41c	0c
Control	3.50±1.32	18.75±4.39a	22.50±2.60a	33.50±3.01a	27.00±1.41a	25.25±2.25a	16.25±0.95a	8.00±1.15a
Mean	2.06	11.28	15.72	25.28	17.97	15.36	9.44	5.06
C V%	69.28	34.97	25.69	16.80	17.69	18.51	21.11	43.93

[a] Means within a column followed by the same letter are not significantly different at P=0.05% (REGWQ).

Table 16: Mean numbers of thrips predators (*O. insidiosus.*) under different treatments on different days

Treatment	22 DAE Mean±SE	26 DAE Mean±SE	29 DAE Mean±SE	33 DAE Mean±SE	36 DAE Mean±SE	40 DAE Mean±SE	43 DAE Mean±SE	47 DAE Mean±SE	50 DAE Mean±SE
NKCP/wannin	0	0	5.00±1.41a	5.00±1.41a	12.50±1.44ab	14.50±1.19a	13.00±3.00a	6.50±0.65ab	6.00±0.91ab
NKCP. (SA)	0	0	5.25±1.03a	5.25±1.03a	10.25±0.48b	15.50±2.22a	12.75±1.60a	5.75±0.48abc	4.50±0.50b
NSO	0	0	3.50±1.04ab	3.50±1.04ab	8.50±0.65b	6.00±1.08bc	8.25±1.65ab	2.50±0.29cd	16.00±0.58ab
NKCP/WE	0	0	2.75±0.25ab	3.00±0.41ab	8.00±1.73b	7.25±1.03b	7.00±0.41ab	3.25±1.25bcd	4.75±0.63ab
Gaucho	0	0	3.00±1.73ab	3.00±1.73ab	8.00± 0b	14.00±2.89a	9.67±1.86a	3.67±0.67bcd	4.33±0.67b
Furadan	0	0	3.75±1.32ab	3.75±1.32ab	8.75±0.95b	12.25±1.49a	11.25±1.49a	5.00±0.58bc	3.75±0.63b
Karate	0	0	0.75±0.48b	0.75±0.48b	3.00±0.41c	2.50±0.87c	2.75±1.11b	1.50±0.50d	0.75±0.25c
Control	0	0	5.75±0.95a	5.75±0.95a	16.25±0.95a	16.00±1.68a	11.75±2.02a	8.75±0.63a	7.50±0.96a
Mean	0	0	3.74	3.77	9.45	10.9	9.55	4.65	4.71
CV%	-	-	46.6	45.54	76.65	17.5	30.72	30.65	26.58

[a] Means within a column followed by the same letter are not significantly different at P=0.05% (REGWQ).

4.5 Effect of neem formulations on leaf damage and flower drop

There was no significant difference ($P>0.05$) in leaf damage amongst treatments four weeks after emergence (Table 17). On average there was less than 25 percentage damage on all the treatments.

There was significant difference ($P<0.05$) in mean number of flower drops among treatments at 36, 43, 47, 50, and 54 days after emergence (Table 18). Plots sprayed with karate had the lowest mean number of flower drops throughout the flowering period ranging from 0.5±0.29 to 8.25±1.7. However, there was no significant difference at 29, 33 and 40 days after emergence, although the control had relatively higher means than the other treatments. The number of flower drops was comparable in plots sprayed with NSO, NKCP water extract and the control throughout the flowering period.

Table 17: Mean leaf damage on French beans

Treatment	Mean rating score at 4 WAE
NKCP/wannin	2.00± 0.0
NKCP (SA)	1.75± 0.25
NSO	1.50± 0.29
NKCP/WE	1.75± 0.25
Gaucho	1.75± 0.25
Furadan	1.75± 0.25
Karate	1.50± 0.29
Control	1.75± 0.25
Mean	1.72
CV%	28.48

Table 18: Mean number of flower drops per 10 plants

Treatment	33 DAE Mean±SE	36 DAE Mean±SE	40 DAE Mean±SE	43 DAE Mean±SE	47 DAE Mean±SE	50 DAE Mean±SE	54 DAE Mean±SE	57 DAE Mean±SE
NKCP/Wannin	1.75±0.48	2.50±0.87ab	6.00±1.41	10.25±2.10ab	18.50±2.40a	16.25±1.93a	9.75±0.85a	6.00±0.91ab
NKCP(SA)	1.25±0.75	2.50±0.65ab	5.00±0.82	11.00±2.27ab	16.25±2.53a	16.00±2.48a	7.50±0.96a	4.50±0.29b
NSO	0.75±0.25	1.75±0.48ab	4.25±1.11	9.75±2.56ab	14.50±2.06a	14.00±3.34a	5.50±0.96ab	4.00±0.41b
NKCP/WE	0.75±0.25	1.25±0.75b	4.00±0.82	12.00±2.16a	16.25±2.14a	16.00±2.83a	5.50±1.26ab	4.25±0.95b
Gaucho	2.00±0.71	1.25±0.48b	7.00±0.41	11.50±2.84ab	14.00±1.87a	18.50±2.87a	9.00±0.41a	4.25±0.75b
Furadan	1.00±0.41	1.25±0.48b	6.50±1.76	12.25±2.17a	16.00±3.03a	18.75±1.38a	9.00±1.78a	5.25±0.63ab
Karate	0.50±0.29	1.25±0.25b	3.50±0.65	6.50±2.02b	6.25±1.55b	8.25±1.70b	2.25±0.63b	0.75±0.48b
Control	2.00±0.41	4.25±1.03a	6.75±1.75	12.50±2.53a	19.50±1.32a	19.25±1.65a	9.00±1.29a	8.00±1.15a
Mean	1.25	2.00	5.38	10.72	15.16	15.88	7.19	4.63
C V%	75.59	59.76	45.62	21.56	23.99	18.63	27.51	34.02

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ

4.6 Effect of neem formulations on yield and pod quality

There was significant difference ($P<0.05$) in pod yield among treatments Plots where NKCP was applied as soil amendment had significantly ($P<0.05$) lower yield (7.96 ±1.41) kg than Karate treated plots (11.14±1.90) kg (Table 19). The mean yield in the control compared well with the other treatments.

When the mean yields were compared, it was observed that season 1 had higher yields than season 2 and the means differed significantly in season 1 among the treatments (see Annex 13 and 14). During both seasons Karate treated plots had the highest mean yield while NKCP soil amendment had the lowest.

There was significant difference ($P<0.05$) in pod quality among treatments (Table 19). Plots sprayed with karate had the highest mean percentage of unblemished pods (64.95 ± 6.04%) while the control had the lowest (21.70± 3.57%). At the same time plots sprayed with karate had the lowest (0.45±0.08%) mean percentage of badly damaged pods while control had the highest (13.20±0.42%). The mean percentage of unblemished pods in plots sprayed with NKCP water extract and NSO were 43.25±3.7% and 44.20±2.22% respectively, which compared favourably but differed significantly ($P<0.05$) from that of karate (64.95±6.04%) and the control (21.0 ± 3.57%) plots respectively. Seeds treated with Gaucho had more harvestable yield than those treated with NKCP/wannin and a higher percentage of unblemished pods (35.65±4.25%) than the latter (30.95±3.57%). The percentage pod quality in all the grades were comparable in NKCP water extract and NSO. Pod quality varied a lot, with a difference of over

100% recorded between control and karate treated plots in unblemished pods (Table 20).

The percentage of unblemished pods during season 1 were relatively lower than season 2 with Karate having the highest percentage and control the lowest in both seasons (See Annex 15 and 16). Similarly, control had the highest percentage of badly damaged pods and karate the lowest in both seasons. There was significant difference among the treatments in both seasons and in all the four categories of pod qualities. The mean percentages obtained from different treatments were higher in season 2 than season 1 in all qualities.

Table 19: Mean yield of French beans

Treatment	Mean yield±SE (kg/plot)
NKCP/wannin	9.32 ± 1.69 ab
NKCP (SA)	7.96 ± 1.41 a
NSO	9.25 ± 1.63 ab
NKCP/WE	9.29 ± 1.80 ab
Gaucho	9.40± 1.56 ab
Furadan	9.01± 1.33 ab
Karate	11.14± 1.90 b
Control	8.74 ± 1.53 ab
Mean	9.26
CV%	21.34

[a] Means within columns followed by the same letter are not significantly different at P=0.05% REGWQ.

Table 20. The mean percentage pod damage obtained from different treatments.

Treatment	Unblemished %Mean±SE	Slight damage %Mean±SE	Moderate damage %Mean±SE	Badly damaged %Mean±SE
NKCP/wannin	30.95±3.57c	45.85 ±2.00a	18.15±1.10c	5.05 ±0.23c
NKCP (SA)	24.35±4.06d	39.90± 1.90b	26.30±0.92a	9.45±0.41a
NSO	43.25±3.70b	39.35±2.13b	14.90±1.21cd	2.50±0.19cd
NKCP/WE	44.20±2.22b	41.65±1.50ab	12.85±1.32d	1.30±0.16d
Gaucho	35.65±4.25c	45.25±2.03a	16.85±2.08c	2.25±0.22c
Furadan	33.85±3.14c	45.20±1.91a	16.55±1.24c	4.4±0.21c
Karate	64.95±6.04a	28.35±4.42c	6.25±1.61e	0.45 ± 0.08e
Control	21.70±3.57d	42.95±1.02ab	22.15±1.23b	13.20 ±0.42a
Mean	37.62	41.06	16.75	4.83
CV%	13.04	9.09	16.48	22.23

[a] Means within columns followed by the same letter are not significantly different at P=0.05 (REGWQ).

CHAPTER V

5.0 DISCUSSION

5.1 Effect of neem formulations on germination of French beans

There was no significant difference in germination among the treatments. NKCP/ wannin treated plots had the highest germination. This conforms to the findings of Maundu (1999) who observed no significant difference in germination of French bean seeds after using 7 grams of NKCP as soil amendment. This observation is supported by that of Kareem *et al.* (1988) where germination of rice seeds treated with 10% NSKE was not affected. The results are also in conformity with the findings of Vijayalakshmi and Goswami (1986), who noted that, germination of *Vigna radiata* was unaffected when the seeds were treated with neem cake before planting. NKCP/wannin used in seed treatment seemed to have enhanced germination rate. Thus, NKCP/wannin could perhaps be used as an alternative to the chemicals used in seed treatment and which result to high residue levels. It might be an alternative in seed treatment to the chemical streptomycin, which is unsafe and is known to reduce plant emergence. Germination of seeds in plots where Furadan and NKCP were applied as soil amendment did not significantly differ and no phytotoxic effect was observed. However, the germination in plots treated with NKCP and Gaucho were lower indicating that the dose adopted for placement in soil might have had some slight adverse effect on germination.

5.2 Effect of neem formulations on thrips infestation

Foliar sprays of NSO and NKCP did controlled the populations of thrips and aphids although not as effectively as Karate but significantly reduced the incidence of thrips than in untreated plots. Hongo and Karel (1986) observed that common bean plots sprayed with NSKE had less damage and a significantly lower incidence of pests than in untreated plots.

From the study, it was observed that the *Frankliniella* species infestation recorded at the vegetative stage was generally low in all the treatments. Plots sprayed with Karate had the lowest population of *Megarulothrips sjostedti* throughout the reproductive period while the control had the highest. This is in conformity with the findings of Saxena and Kidiavai (1997), who observed lowest number of adult and larval thrips on Cypermethrin-treated plots of cowpea plants. The population of thrips increased progressively as the plant grew. They were mainly localised on the lower leaves of the plant where punctures of both adults and larvae could be seen. The population of thrips on the flowers comprised mainly of adults and this did not affect the fruit bearing capacity of French beans or cause pod deformation as reported by Loomans *et al.* (1995). However, the population adversely affected the pod quality.

The results indicate that neem is almost as effective as chemical insecticides for the control of thrips. It was observed that the control of thrips by foliar sprays using NSO and NKCP water extract gave better results when compared to the control experiments. Neem appeared to control thrips infestation as evidenced by the lower number of thrips in the sprayed plots when compared to the unsprayed plots. The foliar sprays of neem seemed to have the same effect as Karate in the control of thrips and thus could be used as an alternative pesticide. This result conforms to the findings of Maundu (1999). Therefore, weekly application of neem based pesticides seems to provide relatively good protection to crops against infestation by thrips thus, reducing the extent of leaf damage and pod damage.

The low number of larvae and adult thrips in neem sprayed plots throughout he sampling period may have perhaps led to the reduction in percentage pod damage and an increase in pod yield. During the reproductive phase, the mean larval populations were generally high and this could be attributed to the larvae hiding within the flowers. Neem oil at 3% showed the highest efficacy on thrips and aphids when compared with NKCP water extract, NKCP seed treatment, NKCP soil application and the control. From the results, it appears that if used frequently, neem may be used as an alternative to conventional pesticides since it controlled the pests. Furadan was effective in controlling the pests within the first two weeks of observation. But this chemical may not be recommended for use due to its high residue problem (Seif, 1995).

The azadirachtin in its active form does not last for more than three weeks in the plant system such that thrips and aphids exposed to the treated plants thereafter are not significantly affected. The systemic action of neem during seed treatment and soil amendment may have lasted for about two weeks. This is in conformity with the findings of Okoth (1998), who observed that the effect of neem 10g, 20g, and 30g as seedbed treatment lasted for less than two weeks on cabbages.

5.3 Effect of neem formulations on aphid infestation

The trials on French bean aphids showed that foliar spray with NSO and NKCP water extracts protected the plant from aphid attack, although plants for the latter had a higher aphid population throughout than the former. NKCP water extract at 30g/l water gave protection similar to Gaucho as seed treatment and Furadan as soil amendment. The best results were obtained with NSO and Karate in aphid control. At 36, 40 and 43 days after emergence, the mean number of aphids in plots treated with Furadan and Gaucho did not differ significantly from those treated with Karate. However after that, the former two compared with each other but differed significantly from the latter. This could be an indication that the systemic effects of Furadan and Gaucho were diminished. The control had the highest aphid population, which was similar to the plots, where NKCP was applied as soil amendment. Aphid infestation increased after three weeks in all treatments except for Karate. Similar results were reported by Varela (1997), who observed that the number of *Brevicoryne brassicae* on cabbages and Kale were controlled completely by Karate unlike foliar sprays of NSO and NKCP/WE. Lowest aphid scores were consistently recorded in plants sprayed with neem oil and Karate, followed by Furadan, Gaucho, NKCP water extract, while control plants had the highest aphid scores. The plots sprayed with Karate had the lowest population of aphids throughout the growing season while the control had the highest. This is also in conformity with the findings of Maundu (1999), who observed that plants sprayed with Karate and neem oil EC had the lowest aphid scores, while the highest was in the control. Recent studies on the effect off neem on cabbage aphid parasitoids: *Diaeritiella rapae* and Alloxysta sp. survival in aphid mummies recorded no significant differences among the neem based pesticides.

1.4 Effect of neem formulations on natural enemies

From the results, it seems that the pesticide used had adverse effect on the population of parasitoids and predators of thrips and aphids. The plots sprayed with karate had the lowest population unlike the NSO and NKCP/ water extract plots, which had relatively higher populations. The foliar sprays of NSO and NKCP water extract seemed to have little effect on the predator and parasitoid numbers and the two were comparable. The foliar sprays were not statistically different from the control. The predators and parasitoid numbers in control plots were higher than NSO and NKCP water extract plots. This is in conformity with the findings of Srivastava and Parmar (1985), who observed that by applying 1%, 0.1% and 0.2% of emulsifiable concentrate of neem seed oil to sorghum, the larvae and adults of coccinellids and larvae of syrphids were not affected by any of these treatments. Schmutterer (1995) reported that the application of neem had no significant negative influence on field populations of bugs that are not only tomato pests but also predators of the sweet potato whitefly *Bemisia tabaci*. Moser (1994), also observed no obvious side effects of aqueous NSE (2.5% and 5%) among natural enemies of *A. gossypii* on okra field trials in the Domonican Republic.

Kaethner (1991) also found that 2 neem insecticide formulations, the first containing 1,000 ppm azadirachtin and the second containing 250 ppm azadirachtin and 3% neem oil, caused no detrimental effects on to the eggs, second instars, or adults of *Coccinella septempuctata* when they were exposed to dried residues on bean leaves. Lowery and Isman (1994) found no effect on the survival of larvae of *Coccinella undecimpuctata* L. topically treated with neem oil at concentrations of up to 1%. Studies on the ladybird beetle *Coccinella septempunctata* by Bigler (1988), reported that spraying NSKE (2%) and neem oil (3%) had no adverse effects on the fecundity and on he beetles fitness.

In the present study, neem was found to reduce the population of thrips and aphids substantially without affecting the population of natural enemies and therefore, it might be used as an alternative to synthetic chemicals that produce adverse effects on population of beneficial insects. There is a need to preserve the beneficial insects that are essential in regulating pest populations naturally in the field since utilising them helps in reducing the level of pesticides that would otherwise be required for the control of pests.

Biological control of western flower thrips has been studied extensively in the recent years and good results were obtained with the predatory mites *Amblyseius cucumeris* Oudemans (van Houten, 1991). Recently, several species of the anthocorid bug, *Orius* have been established throughout Europe in glasshouses on sweet peppers, cucumbers. They are mainly O. *niger* and *O. minutus (*Schreuder and Ramakers 1989); *O. majusculus* (Reuter) (Trottin-Caudal *et al*., 1991), *O.*

laevigatus (Fieber) (Villevieille and Millot, 1991). The bugs are polyphagous and feed on small arthropods including thrips, mites, aphids, whiteflies and lepidopterans, thus reducing their populations. Since *Orius* species is particularly abundant in flowers, their potential in reducing the larvae of thrips may be of economic importance in reducing pod damage and increasing the products of export quality. Correspondingly, less pesticide residues in the products would be expected and a low likelihood of pesticide resistance and pest resurgence. The use of neem for thrips management has the added benefit of weak or inconsequential side effects on pests' natural enemies and crop pollinators and other ecologically important non-target organisms, a factor today considered a prerequisite for successful integrated pest management (Schmutterer, 1995).

Overuse of pesticides may affect the control of pests due to their deleterious effects on the natural enemies. Thus, by switching from hazardous chemical insecticides to the relatively safer neem products, this may lead to reduction of chemical pesticides to a bare minimum thus, giving natural enemies a chance to increase in numbers and exert effective suppression on thrips and aphid population. The decline may no longer be a problem in future in French beans growing regions. Replacing the unilateral chemical approach with neem products seems the best option to break away from the current dependency on pesticides and the problems associated with it. The neem products used in the current study had no negative effects on natural enemies unlike Karate.

It was observed that the mean number of *Orius* species were relatively lower on plants treated with NKCP water extract than on those treated with NSO one day after spraying. However, the populations of parasitoids of thrips, *C. menes* were not affected by the neem products and the population remained relatively almost the same as that in non sprayed (control) plots. Schmutterer (1995) reported that parasitoids, which are mainly hymenopterous insects, are in general less sensitive to neem products than the predators. Sometimes the parasitoids may be favoured by neem application, when their hosts become more easily accessible for parasitization, due to reduction of the spinning ability (Saxena *et al.*, 1981). The special mode of action on the hormone system, feeding behaviour as well as generally low or even lack of contact effect of some neem products may have led to the fewer side effects on beneficial organisms in comparison with the synthetic pesticide Karate which has a strong contact and neurotoxic mode of action. From the low numbers obtained within the early stages of plant development, Furadan had some adverse effects on the population of *C. menes*.

5.5 Effect of neem formulations on leaf damage and flower drop

Generally, there was no significant difference in leaf damage between treatments. This could be attributed to the low numbers of defoliators. Thus, yield variation may not be related to leaf damage on the plants. Sprays of NSO resulted in lower leaf damage than NKCP water extract of 1.50 and 1.75, respectively and the sprays did not offer complete protection to French beans. Similar results were observed on common beans (*Phaseolus vulgaris*) by Karel (1989) who observed that at concentrations of 2.0 and 4.0% neem formulations of NSKE *Ootheca* *bennigseni* was deterred from feeding on bean leaves, thus resulting to lower leaf damage and less incidence of the pest than the other formulations. He also observed that none of the neem formulations used protected bean plots completely as the case reported here. Ramaprasad *et al.*(1987), observed the percentage of damaged leaves in tobacco compared amongst plots sprayed with neem seed kernel suspension and Fenvalevate, Cypermethrin or Methamodiphos. From this experiment, any variations in yield amongst treatments may not be attributed to leaf damage but it is possible the yield loss could be attributed to the level of thrips infestation.

In the present study, there was no statistical difference in flower drops among treatments within the early and late stages of reproductive development but at 43, 47 and 50 days after emergence, plots sprayed with Karate differed significantly from the other treatments. The plots sprayed with NSO and NKCP water extract had lower number of flower drop in comparison to the control although not significant. Conceivably, sprays of NSO and NKCP water extract reduced the number of thrips populations and their low numbers may have led to reduced number of flower drops and thus indirectly enhancing pod yields in French beans.

The foliar sprays of NSO may have caused deterrent effects against several important defoliating pests. Plots treated with NSO showed less leaf damage and a significantly lower incidence of pests than untreated plots. The mean rating scale in Karate treated plot was similar to that of NSO treated plots. Thus, NSO could be used as an alternative to the conventional pesticides. These findings indicate the potential of these safe extracts in the protection of *Phaseolus vulgaris*. Because of their effectiveness, safety for the environment, lower cost, availability, neem extracts have great potential in protecting beans against the pests.

5.6 Effect of neem formulations on pod yield

There was no significant difference in pod yield among the foliar sprays with NSO, NKCP/WE, Karate and the control. This finding is similar to those of Sinha (1993) on chickpea who observed no significant treatment effects in seed yield amongst plots which received neem emulsion (0.125%), neem kernel extract (5%), Flufenoxuron and Endosulfan. Plots sprayed with Karate, NSO and NKCP had higher mean yield than the control. This is in conformity with the findings of Emosaurue and Ubana (1998). In their findings, they observed that the cowpea yield from Karate treated plots were significantly higher than the control, although not statistically different from the yields of 5% and 10% of NSKE treated plots. The effect of foliar sprays with NKCP water extract and NSO, on yields compared with the synthetic pesticides Furadan, Gaucho, Karate and the control. Similar observations were reported on French beans that were grown at Thika in a green house (Maundu, 1999). The yields in plots receiving foliar sprays of NKCP water extract (25g/l water) and NSO EC 3% compared well with additional plots treated with the synthetic pesticides Gaucho and Karate. Saxena and Kidiavai (1997) observed that the cowpea grain yield in plots sprayed with 20% NSE was significantly higher than in control plots and was at par with that obtained with insecticide. From the results, it was observed that NSO and NKCP/WE sprays contributed to higher and better yields than the control and could be recommended as an alternative to chemical pesticides if we have to reduce pesticide usage in controlling pests.

5.7. Effect of neem formulations on pod quality

From the experiment, it was observed that NSO and NKCP water extract significantly reduced the level of pod damage by thrips. Sarode *et al.* (1995), also noted that two applications of 5% NSKE was effective in reducing pod and grain damage by *Helicoverpa armigera* on pigeon pea. Borkar *et al.* (1996), observed that NSKE at 5% resulted in minimum pod damage by *Melanogromyza obtusa* on pigeon pea. Similarly, Adhikary (1985) observed that after six applications at weekly intervals, crude methanolic NSKE proved to be very successful in reducing the percentage of damaged cabbage heads and infestation by larvae of *Plutella xylostella*. Also the average yield of undamaged heads was increased by 6-8t/ha, as compared with untreated plots.

The reduction in number of scars on sprayed pods with neem may be due to its antifeedant property, which prevented thrips from feeding as suggested by Siddappaji *et al*., (1986). They also suggested that, neem could be used as part of an Integrated Pest Management (IPM) programme since it is harmless to beneficial arthropods and cheaper than commercial insecticides. The scars on the pods appeared as a markedly white halo around the punctures. Kloft and Erhadt (1959) showed that the action of the saliva of thrips injected into plant cells was the real cause of damage because of its toxic effects on the plant tissues. The attack leads to cell dehydration and discoloration, resulting in superficial necrosis. This damage is extremely serious as it depleciates the pods' market value, especially when it is extensive. Pods harvested from plants treated with NSO, Karate and NKCP water extract were clean, whilst those of the control had a portion of the yield contaminated with sooty mould as a result of aphid infestation. This also greatly affected the quality and marketability of the produce. These pod quality variations seem primarily to a larger extent due to difference in thrip infestation. This is evidenced by presence of the silvery marks on the pods that are due to the thrips feeding on the pods.

CHAPTER VI

6.0. General discussion and recommendations

Neem extracts control insects by three strong modes of action: repellent, antifeedant and growth regulatory effects in addition to comparatively weaker insecticidal effect. Thus, after being sprayed with neem extracts, insects may remain alive for 24 hours but may not feed on the plant or cause damage because of the strong antifeedant effect.

The parameters used for evaluating the effects of neem formulations included aphid and thrips population, germination, flower drop, yield, pod quality and population of beneficial insects. They proved useful in the evaluation of use of various neem formulations in the control of French bean pests. Results in the field showed no significant difference in seed germination. There was high percentage germination in plots whose seeds were treated with NKCP/wannin. Thus, NKCP/wannin might be used as an alternative to Furadan, which is not recommended due to its persistence and high residue problem (Seif, 1995).

Three weeks after plant emergence, the plots whose seeds were treated with NKCP had already been infested with aphids and thrips when compared to Gaucho and Furadan treated plots. Thus indicating the effect of neem powder in seed treatment does not last more than two weeks. The failure of NKCP to offer protection to French beans against *A. Fabae* when applied as seed treatment could also be attributed to failure of the plant to absorb and translocate the bioactive neem components as reported by Maundu (1999). According to Schmutterer and Ascher (1984), plants vary in their ability to absorb and translocate bioactive components. This may have led to the failure of NKCP to protect French beans from aphids when used as soil amendment. Also, NKCP used as soil amendment can not be recommended due to the large amounts required by the farmers to apply in the farms and is uneconomical when compared to NKCP/wannin, which is used in small quantities in seed treatment. These conclusions are similar to those of Okoth (1998) and Maundu (1999). Although Furadan and Gaucho were effective at controlling pests during the vegetative stage, their residual effects seemed to have diminished during the reproductive stage resulting to high aphid and thrips infestation plus low pod quality. During the vegetative stage foliar application of NSO controlled thrips effectively. However, Karate had total control of thrips population. During the reproductive stage the number of thrips were generally high but the foliar sprays of NSO and NKCP water extract had significantly lower populations than the control, although they did not control the thrips populations completely.

Both predators and parasitoids of thrips and aphids were recorded in the field at different stages of plant development. Coccinellids were the main predators of aphids while the *Orius* spp and *Deraeocoris ostentants* species were the main predators of thrips. However, *Ceranisus menes* which are parasitoids of thrips larvae were observed within the flowers during the reproductive stage. There were more *Deraeocoris ostentants* St and *C. menes* during the first season. The coccinellids appeared late during the first season and could not be sampled. This could have been due to the low aphid infestation during the season. But during the second season, aphids infested the French beans by the second week and the coccinellids appeared in the plots by the fourth week after emergence. Their large numbers could have been due to high aphid infestation within the plots, an indication that coccinellids are density-dependent as suggested by Carl (1992). Unlike the other treatments, Karate sprays adversely affected the predator and parasitoid population. The predator and parasitoid populations were low throughout the growing period in plots sprayed with Karate unlike in the NSO and NKCP plots. From the results, NKCP water extract and NSO can be used as an alternative to Karate without adversely affecting the population of parasitoids and predators which are known to reduce the population of thrips and aphids naturally. Furadan had adverse effects on the parasitoids and predators when compared with the NKCP treated plots and the control. This suggests that neem products could be integrated with the natural enemies in controlling the pests of French beans, as it has no detrimental effects on the beneficial insects.

Although the results on yields showed no significant difference (P>0.05) amongst the treatments, there was significant difference in pod quality amongst the treatments. The extent of percentage pod damage was reduced in plots sprayed with NSO and NKCP water extract. The pods from plots sprayed with NSO and NKCP water extract had relatively fewer scars thus producing higher yield and better pod quality than the control. This was attributed to the lower number of thrips in the neem treated plots. From these observations, the use of NSO and NKCP water extract sprays could be encouraged during the reproductive stage in order to avoid pesticide residues on the products and at the same time, improve pod quality without affecting the population of beneficial insects. The highest proportion of unblemished pods response was observed in plots sprayed with karate, which differed significantly amongst the other treatments in the study. But the Karate sprays eliminated the beneficial insects thus, it is not suitable if the latter has to be used in integrated pest management and at the same time it may have some residues left on the produce which many consumers are trying to avoid.

The treated plants had significantly ($P<0.05$) lower number of flower drops and lower thrips infestation than the control and this could have contributed to higher yield within the former. Thus, NSO and NKCP water extract sprays might benefit the farmers in growing produce that enable them meet export market requirements of unblemished produce with no pesticide residues thus, increasing their export earnings with less rejection by European market.

Most synthetic insecticides used in controlling pests are expensive and incompatible with integrated pest management (IPM). Thus, there is a need to promote use of botanical pesticides world wide through the media and by using various Agricultural organisations. Botanical insecticides are locally available but not readily available as commercial products. They are selective, of low persistence, biodegradable, environmental friendly, non-pollutant, and are relatively cheaper than the conventional pesticides used. Because of their effectiveness, safety for the environment, lower cost, and easy preparation, neem extracts have great potential in protecting beans against pests. Neem might prove to be a good substitute of chemical pesticides.

There is need for more exploration on neem formulations to identify those with pesticidal activity in order to make available as pesticides. Neem is biodegradable, selective and can be locally produced especially for farmers who cannot afford expensive synthetic pesticides. From observations in the current study, neem fulfils the above qualifications and may reduce the residue levels and extent of pod damage thus, lowering the chances of French beans being rejected in the export market. Foliar sprays of NKCP and NSO may be used in place of the highly toxic synthetic insecticides because of safety to beneficial insects and the lower cost. There is need to disseminate more information on integrated pest management (IPM) and training, at the level of both farmers and extension officers bring about rational pesticide usage. There is need for adoption and implementation of legislation on pesticides in conformity with the international code of conduct on the distribution and use of pesticides. This may help in the reduction of pesticide use amongst the farmers in order for the export produce to be accepted in the international market. If vegetable production is to be sustained on an economical, environmentally safe and socially beneficial basis, the present trend of pesticide overuse, abuse and misuse must be reversed and integrated pest management systems developed and implemented by vegetable farmers. This approach of plant protection maximises the use of natural and cultural control techniques and selective use chemical pesticides selectively. Minimising the use of chemical pesticides reduces their deleterious effects on health, environment and on biological control agents. Even if the target species are brought under biological control, others may require additional control measures. This concurs with what Greathead (1991) suggested that in general, biological control must be integrated with other pest control techniques. This suggests that biological control should take a key position in pest control alongside the cultural methods. By using single or multiple introductions, we try to protect and augment the natural enemies of the pests by using less disturbing practices in order to enhance their effectiveness. The use of neem products is therefore, much more likely to be useful as biopesticide, especially against pests since they have no adverse effects on biological control agents. The natural enemies act as regulating factors on their host population and their presence helps in ecological balance. Harris (1990) suggested that the major reason for the acceptability of insects as control agents is that they tend to specialise on the most abundant hosts. Possibilities of improving efficacy of neem products by use of additives, the use of synergists, and improved methods of application needs to be explored.

6.1 Conclusions

In summation, it can be concluded that neem preparations would be suitable or even very suitable for the reduction of a wide range of pests in IPM systems, as they are usually not only slightly harmful to natural enemies, but there may be either desirable effects and thus, more investigations are needed to identify their exact role.

6.2 Important findings.

a) There was no significant difference in leaf damage and infestation by *Frankliniella* spp among the treatments.

b) Karate treatment gave the lowest infestation by both thrips (*Frankliniella* spp and *Megarulothrips sjostedti*) and aphids (*Aphis fabae*).

c) Karate adversely affected the population of parasitoids and predators compared to neem kernel cake powder (NKCP/WE) and neem seed oil (NSO).

d) High percentage of unblemished pods was obtained in plots sprayed with NSO, NKCP/WE and Karate.

e) Amount of NKCP used as soil amendment is not economical due to the large quantities required.

f) Seed treatment using NKCP could be used instead of conventional pesticides because it is cheap and little amount is required.

g) NSO and NKCP/WE could be used as alternatives for Karate because they reduced thrips population and had no adverse effects on the natural enemies.

6.3 Areas for further research.

More studies on various neem formulations are needed. There is also a need for further research on other ecological interventions in vegetable production systems in Kenya in order to reduce pesticide usage in vegetable production. Use of botanical mixtures, organic wastes and cultural methods needs to be investigated. Further research needs to be conducted on the effects of neem on egg hatchability, growth and development of predators and parasitoids.

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Annex 1: Mean percentage germination Season 1-1998

Treatment	Mean percentage germination± SE
NKCP/Wannin	89.02±1.89a
NKCP (SA)	77.98±2.82b
Gaucho	81.78±1.86ab
Furadan	82.99±1.91ab
Control	88.69±0.39a
Mean	83.91
CV%	4.38

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 2: Mean percentage germination Season 2-1999

Treatment	Mean percentage germination ±SE
NKCP/Wannin	77.57±3.88
NKCP (SA)	67.59±5.67
Gaucho	70.17±8.26
Furadan	72.33±5.41
Control	66.98±5.71
Mean	70.93
C.V%	16.70

Annex 3: Mean number of *Frankliniella* species obtained during the vegetative stage on different days Season 1-1998

Treatment	15 DAE	18 DAE	21 DAE	24 DAE	27 DAE	30 DAE
NKCP-Wannin	0.71	0.97± 0.15	1.19±0.33	3.56±0.33ab	5.00±0.65ab	5.22±1.00ab
NKCP(SA)	0.71	0.71	0.71	3.11±0.34ab	4.52±0.79ab	4.67±0.78ab
NSO	0.71	0.84±0.13	0.71	3.12±0.12ab	3.53±0.51b	3.22±0.74b
NKCP/WE	0.71	0.84±0.13	0.84±0.13	3.12±0.31ab	3.80±0.32b	4.73±0.23ab
Gaucho	0.71	0.84±0.13	0.84±0.13	2.18±0.71b	3.51±0.38b	4.06±0.58b
Furadan	0.71	0.84±0.13	0.84±0.13	3.59±0.33ab	4.15±0.41ab	4.25±0.26ab
Karate	0.71	0.84±0.13	0.71	0.71c	0.71c	0.71c
Control	0.71	0.93±0.22	1.19±0.33	4.18±60a	6.09±0.76a	6.64±0.25a
Mean	0.71	0.85	0.88	2.94	3.91	4.19
C.V%	0	30.53	42.45	21.13	25.63	25.28

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 4: Mean number of *Frankliniella* species obtained during the vegetative stage on different days Season 2-1999

Treatment	15 DAE	18 DAE	21 DAE	24 DAE	27 DAE	30 DAE
NKCP-Wannin	0.71	0.83± 0.13	1.19± 0.33b	3.05± 0.40b	4.52± 0.52ab	4.32± 0.43b
NKCP-SA	0.71	0.71	0.71b	2.62± 0.35bc	4.02± 0.78ab	3.19± 0.50b
NSO	0.71	0.71	0.71b	2.08± 0.39bc	3.09± 0.39b	3.19± 0.18b
NKCP/WE	0.71	0.83± 0.13	0.83± 0.13b	2.47± 0.46bc	3.37± 0.21ab	3.52± 0.34b
Gaucho	0.71	0.83± 0.13	0.83± 0.13b	1.60±0.56cd	3.03±0.31b	3.60±0.44b
Furadan	0.71	0.83± 0.13	0.83± 0.13b	2.91±0.13b	3.60±0.32ab	3.83±0.32b
Karate	0.71	0.71	0.71b	0.71d	0.71c	0.71c
Control	0.71	1.18±0.18	1.79± 0.13a	4.63±0.31a	5.18±0.68a	5.89±0.50a
Mean	0.71	0.83	0.95	2.51	3.44	3.63
C.V%	0	26.64	32.46	22.96	25.91	17.26

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 5: Mean number of adult thrips (*Megarulothrips sjostedti*) obtained from 20 flowers on different days Season 1-1998

Treatment	33 DAE Mean± SE	36 DAE Mean± SE	40 DAE Mean± SE	43 DAE Mean± SE	47 DAE Mean± SE	50 DAE Mean± SE	54 DAE Mean± SE
NKCP/WA	58.5±17.98a	26.0±3.51a	31.5±5.33a	50.5±3.75a	37.5±7.24a	51.25±5.01	102.5±11.46
NKCP(SA)	68.5±11.52a	29.25±3.09a	28.0±2.68a	55.0±11.0a	54.25±5.17a	66.25±4.01	118.5±23.32
NSO	36.5±15.12a	14.25±2.78a	25.5±5.56a	48.25±10.13a	35.5±9.04a	50.0±6.99	84.0±8.66
NKCP/WE	56.25±7.18a	18.0±1.87a	29.75±6.99a	44.75±4.11a	38.25±5.01a	59.25±14.46	86.75±19.46
Gaucho	40.5±4.48a	24.5±2.06a	31.0±5.28a	55.0±10.17a	62.75±6.56a	61.25±4.49	94.75±16.75
Furadan	48.0±4.33a	20.5±3.22a	29.0±1.58a	45.25±5.80a	53.0±10.46a	53.50±13.21	92.5±27.69
Karate	3.0±0.41b	0.25±0.25b	3.00±0.71b	3.25±1.03b	5.50±0.87b	38.25±1.31	70.75±11.11
Control	56.5±5.17a	20.0±5.61a	26.75±3.99a	54.5±5.95a	54.0±9.14a	56.75±6.21	85.5±19.05
Mean	3.52	2.91	3.03	3.52	3.53	3.95	4.45
CV%	11.48	12.83	11.44	10.67	10.43	6.54	6.32

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 6: Mean number of adult thrips (*Megarulothrips sjostedti*) obtained from 20 flowers on different days Season 2-1999

Treatment	33 DAE Mean± SE	36 DAE Mean± SE	40 DAE Mean± SE	43 DAE Mean± SE	47 DAE Mean± SE	50 DAE Mean± SE	54 DAE Mean± SE
NKCP/WA	15.75±4.57ab	17.5±1.94a	17.5±8.53a	16.25±3.97ab	20.25±3.71ab	30.75±4.57ab	21.5±3.01ab
NKCP(SA)	27.25±9.55ab	15.5±3.10a	14.25±2.87a	23.25±3.84ab	25.0±1.00ab	23.5±6.61ab	30.75±3.64ab
NSO	10.25±4.82bc	8.75±3.47a	7.5±2.40ab	10.75±3.33b	9.00±1.87c	20.00±4.62ab	21.75±3.84b
NKCP/WE	17.25±3.42ab	9.50±0.87a	6.75±2.46a	13.75±3.57ab	16.25±3.73bc	25.25±3.04ab	21.25±1.60b
Gaucho	17.5±3.57ab	16.25±8.74a	11.00±2.74a	15.75±4.64ab	20.50±7.09abc	28.25±6.38ab	26.75±6.80b
Furadan	25.25±3.28ab	15.75±2.93a	6.25±2.14a	14.75±1.49ab	23.00±4.91abc	17.00±3.58b	19.00±2.16b
Karate	2.50±0.86ab	0.25±0.25b	0.25±0.25c	1.00±0.41c	1.50±0.50d	3.00±0.91c	21.75±3.28b
Control	37.75±6.76a	26.75±3.32a	38.00±3.29a	36.25±1.75a	42.25±4.05a	49.75±1.65a	51.75±6.29a
Mean	2.58	2.46	2.21	2.52	2.73	2.93	3.20
CV%	25.04	24.81	35.53	21.51	15.45	15.41	9.71

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 7: Mean number of *Megarulothrips sjostedti* larvae obtained from 20 flowers on different days Season 1-1999

Treatment	33 DAE Mean± SE	36 DAE Mean± SE	40 DAE Mean± SE	43 DAE Mean± SE	47 DAE Mean± SE	50 DAE Mean± SE	54 DAE Mean± SE
NKCP/Wannin	2.89±0.43a	2.81±0.22ab	3.37±0.42a	3.44±0.41a	4.04±0.47a	4.07±0.27ab	5.07±0.18a
NKCP(SA)	3.04±.043a	2.46±0.18ab	3.32±0.51a	2.68±0.31a	3.43±0.31a	3.59±0.33a	4.47±0.25a
NSO	2.20±0.56a	1.65±0.42b	2.74±0.34a	2.84±0.20a	3.85±0.16a	3.67±0.26a	4.48±0.12a
NKCP/WE	2.58±0.34a	2.66±0.25ab	3.17±0.30a	2.70±0.69a	4.13±0.12a	4.48±0.49a	4.77±0.22a
Gaucho	1.85±0.19a	2.19±0.08a	2.79±0.24a	2.96±0.22a	3.78±0.29a	3.90±0.11a	4.91±0.14a
Furadan	2.86±0.17a	2.93±0.27ab	3.04±0.31a	2.58±0.29a	3.70±0.18a	3.64±0.16a	4.57±0.18a
Karate	0b	0 c	0.35±0.35b	0.35±0.35b	0.83±0.13b	1.68±0.12b	1.99±0.36b
Control	2.67±0.35a	3.30±0.20a	3.62±0.18a	3.39±0.24a	4.21±0.13a	4.16±0.13a	5.00±0.31a
Mean	2.41	2.48	2.96	2.76	3.58	3.65	4.41
CV%	28.68	18.49	22.72	22.23	13.74	15.22	8.45

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 8: Mean number of *Megarulothrips sjostedti* larvae obtained from 20 flowers on different days Season 2-1999

Treatment	33 DAE Mean± SE	36 DAE Mean± SE	40 DAE Mean± SE	43 DAE Mean± SE	47 DAE Mean± SE	50 DAE Mean± SE	54 DAE Mean± SE
NKCP/WA	3.33±0.40ab	2.98±0.43ab	2.82±0.19ab	3.24±0.33ab	2.70±0.43ab	2.69±0.36ab	4.51±0.10a
NKCP(SA)	3.49±0.47ab	2.85±0.59b	3.28±0.24ab	2.97±0.43a	3.22±0.45ab	3.65±0.45a	4.59±0.19a
NSO	2.14±0.47b	1.35±0.60bc	1.83±0.44bc	2.58±0.56ab	2.05±0.56ab	3.07±0.82a	4.54±0.10a
NKCP/WE	3.27±0.15ab	2.87±0.22ab	1.49±0.40bc	2.10±0.45ab	2.50±0.15ab	3.50±0.15a	4.40±0.24a
Gaucho	3.43±0.12ab	2.87±0.28ab	2.36±0.79bc	3.16±0.36ab	3.12±0.55ab	3.44±0.80a	3.81±0.55a
Furadan	3.58±0.18ab	2.92±0.38ab	3.08±0.39ab	3.24±0.37ab	2.19±0.90ab	3.15±0.28a	4.57±0.31a
Karate	0.40±0.40c	0.69±0.69c	0.69±0.0.69c	0b	0.78±0.47b	0.90±0.20b	1.27±0.38b
Control	4.04±0.05a	4.10±0.14a	3.76±0.16a	4.10±0.08a	4.19±0.09a	4.41±0.13a	5.14±0.03a
Mean	2.96	2.70	2.59	2.85	2.65	3.25	4.1
CV%	22.20	32.48	34.6	28.2	39.2	29.4	14.2

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 9: Aphid (*Aphis fabae*) population in French bean plant under different treatments and days Season 1-1998

TRT	26DAE	29 DAE	33 DAE	36 DAE	40 DAE	43 DAE	47 DAE	50 DAE	54 DAE
NKCPWA	1.00	1.25+0.25	1.00+0	1.25+0.25	1.50+0.29ab	1.50+0.29	1.25+0.25	1.25+0.25ab	1.50+0.29ab
NKCP-SA	1.00	1.25+0.25	1.25+0.25	1.75+0.25	1.75+0.25ab	1.50+0.29	1.75+0.25	2.00+0a	2.00+0a
NSO	1.00	1.00	1.00	1.25+0.25	1.50+0.29ab	1.25+0.25	1.75+0.25	2.00+0a	2.00+0a
NKCP/WE	1.00	1.00	1.50+0.29	1.25+0.25	1.50+0.29ab	1.50+0.29	1.50+0.29	1.50+0.29ab	1.50+0.29ab
Gaucho	1.00	1.00	1.000	1.00	1.00+0b	1.50+0.29	1.50+0.29	1.25+0.25ab	1.25+0.25ab
Furadan	1.00	1.00	1.00	1.00	1.00+0b	1.25+0.25	1.25+0.25	1.25+0.25ab	1.25+0.25ab
Karate	1.00	1.00	1.00	1.00	1.00+0b	1.00+0	1.00+0	1.00+0b	1.00+0b
Control	1.00	1.00	1.25+0.25	1.50+0.29	2.00+0a	1.50+0.29	1.75+0.25	2.00+0a	1.75+0.25ab
Mean		1.06	1.13	1.25	1.41	1.36	1.47	1.53	1.53
CV%		24.04	29.43	31.29	28.63	39.46	29.09	24.29	27.47

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 10: Aphid (*Aphis fabae*) population in French bean plant under different treatments and days Season 2-1999

Treatment	26DAE	29 DAE	33 DAE	36 DAE	40 DAE	43 DAE	47 DAE	50 DAE	54 DAE
NKCP/WA	1.00	1.25+0.25	1.00+0	1.25+0.25b	1.75+ 0.25ab	2.00+ 0ab	2.50+0.29a	2.75+ 0.25ab	3.25+0.25abc
NKCP-SA	1.00	1.25+0.25	1.50+0.29	2.00+ 0a	2.25+ 0.25a	2.50+0.29a	3.00+ 0a	3.50+0.29a	3.75+ 0.25ab
NSO	1.00	1.00	1.00	1.00+0b	1.25+0.25b	1.00+0b	1.25+0.25cd	1.50+0.29cd	2.00+ 0cd
NKCP/WE	1.00	1.00	1.00	1.00+0b	1.50+0.29ab	1.75+ 0.25ab	2.00+ 0abc	2.25+ 0.25bc	2.50+0.29bc
Gaucho	1.00	1.00	1.00	1.00+0b	1.00+0b	1.75+ 0.25ab	2.25+ 0.25ab	2.25+ 0.25bc	2.75+ 0.25bc
Furadan	1.00	1.00	1.00	1.00+0b	1.00+0b	1.00+0b	1.50+0.29bcd	2.25+ 0.25bc	2.25+ 0.25c
Karate	1.00	1.00	1.00	1.00+0b	1.00+0b	1.00+0b	1.00+0d	1.00+0d	1.00+0d
Control	1.00	1.00	1.50+0.29	1.75+0.25a	2.25+ 0.25a	2.25+ 0.25a	3.00+ 0a	3.50+0.29a	4.25+ 0.48a
Mean		1.06	1.13	1.25	1.5	1.66	2.06	2.38	2.72
CV%		24.04	26.11	20.27	26.81	30.06	21.68	21.18	21.04

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 11: The effect of neem on *Ceranisus menes* Season 1-1998

Treatment	36 DAE	40 DAE	43 DAE	47 DAE	50 DAE
NKCP-Wannin	1.98±0.16ab	2.23± 0.11ab	2.22±0.15ab	1.64±0.15a	1.91±0.19
NKCP-SA	1.83±0.21abc	2.29±0.06ab	2.06±0.06ab	1.76±0.24a	1.83±0.23
NSO	2.11±0.10ab	2.11±0.10b	1.99±0.07ab	2.11±0.10a	1.84±0.21
NKCP/WE	1.89±0.24abc	2.18±0.06b	1.98±01.6ab	1.98±0.16a	1.89±0.24
Gaucho	2.00±1.79ab	2.23±0.06ab	1.93±0.06ab	1.86±0.11a	1.87±0.40
Furadan	1.41±0.30bc	2.05±0.11b	1.70±0.19b	1.56±0.13a	1.46±034
Karate	0.97±0.15c	0.96±0.15c	0.96±0.15c	0.84±0.13c	1.06±0.21
Control	2.50±0.09a	2.60±0.05a	2.28±0.10a	2.30±0.28a	2.15±0.21
Mean	1.84	2.08	1.89	1.76	1.75
CV%	23.8	9.5	12.8	18.2	28.2

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 12: The effect of neem on *Ceranisus menes*. Season 2-1999

Treatment	36 DAE	40 DAE	43 DAE	47 DAE	50 DAE
NKCP-WA	0.84±0.12	0.71	0.71	0.71	0.71
NKCP-SA	0.05± 0.21	0.71	0.71	0.93± 0.22	0.71
NSO	0.97±0.15	0.71	0.71	0.71	0.84±0.13
NKCP/WE	0.96±0.15	0.71	0.71	0.71	0.71
Gaucho	0.71	0.71	0.71	0.71	1.10±0.13
Furadan	0.84±0.13	0.71	0.71	0.71	0.71
Karate	0.71	0.71	0.71	0.71	0.97±0.15
Control	0.93± 0.22	0.71	0.71	0.71	0.84±0.13
Mean	0.87	0.71	0.71	0.73	0.22
CV%	32.0	0	0	21.0	24.4

Annex 13: Mean yield Season 1-1998

Treatment	Total weight in KG
NKCP/Wannin	13.56±0.83ab
NKCP-SA	10.94±1.44b
NSO	12.75±1.73ab
NKCP/WE	12.99±2.19ab
Gaucho	13.10±1.16ab
Furadan	11.88±0.68ab
Karate	15.76±1.23a
Control	11.97±1.41ab
Mean	12.87
CV%	17.12

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 14: Mean yield Season 2-1999

Treatment	Mean weight in KG
NKCP-Wannin	5.0±0.78
NKCP-SA	4.98±1.107
NSO	5.75±1.11
NKCP/WE	5.59±1.059
Gaucho	5.69±0.94
Furadan	6.14±1.51
Karate	6.51±1.06
Control	5.52±1.40
Mean	5.66
CV%	25.17

Annex 15: The mean percentage pod damage obtained from different treatments Season 1 1998

Treatment	Unblemished pods	Slight damage	Moderate damage	Badly damaged
NKCP-Wannin	22.60± 2.49b	49.80±1.36a	20.30±1.27b	2.77±0.21c
NKCP-SA	14.20±2.65e	44.10±2.07ab	26.40±1.90a	3.9± 0.31b
NSO	33.90±1.10c	44.60±0.89ab	17.50±0.62b	2.11± 0.14cde
NKCP/WE	40.00±1.93b	45.50±0.62ab	12.60±1.58c	1.51±0.19ef
Gaucho	26.50±3.59d	48.90±2.27a	21.00±2.02b	2.00± 0.20de
Furadan	27.40±1.05d	47.90±1.64a	18.30±1.54b	2.60±0.23cd
Karate	49.40±2.04a	39.40±1.81b	10.40±0.59c	1.14±00f
Control	12.50±0.96e	42.40±1.66ab	25.10±0.50a	4.52±0.17a
Mean	28.31	45.32	18.95	2.57
CV%	14.52	7.33	13.99	14.89

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).

Annex 16: The mean percentage pod damage obtained from different treatments Season 2- 1999

Treatment	Unblemished pods	Slight damage	Moderate damage	Badly damaged
NKCP-Wannin	39.30±2.59cde	41.90±2.54a	16.00±0.97bc	1.79±0.19ab
NKCP-SA	34.500±1.11de	35.70±0.90a	26.20±0.53a	1.99±0.21ab
NSO	52.60± 2.13b	34.10±1.42a	12.30± 1.39c	1.21±0.11bc
NKCP/WE	48.40±2.73bc	37.80±0.53a	13.10±2.36c	1.03± 0.21bc
Gaucho	44.80±3.95bcd	41.60±2.29a	12.70±2.18c	1.11± 0.23bc
Furadan	40.30± 4.13cde	42.50±3.08a	14.80±1.66bc	1.68±0.15abc
Karate	80.50±2.23a	17.30±2.57b	2.10±0.57d	0.70±0.06c
Control	30.90±1.48e	43.50±1.37a	19.20±0.99b	2.54±0.38a
Mean	46.41	36.8	14.55	1.52
CV%	12.28	11.68	20.56	29.67

[a] Means within columns followed by the same letter are not significantly different at P=0.05% (REGWQ).