Semi-field Evaluation of the Systemic Activity of Neem Seed Powder against Immature Stages of Desert Locust \textit{[Schistocerca gregaria (Forskal)]} (Orthoptera: Acrididae)

By

Eman Slman Osman Abd El Rheem
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Supervisor

Dr. Azhari Omer Abddelbagi

Department of Crop Protection Faculty of Agriculture University of Khartoum

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Dedication

To My father, mother
To my sisters, brothers and my friends with Love
and respect
Acknowledgements

First of all, I render my gratitude and praise to “Allah”.

I wish to express my sincere gratitude to Dr. Azhari Omer Abdlbagi for his guidance, continuous encouragement, help and effort to solve all the problems in this research.

Thanks are due to ICIPE- Port Sudan, Sudan for offering egg pods tubes, thanks are extended to staff of the Department of Crop Protection, Faculty of Agriculture of the University of Khartoum specially Dr. Hamadttu Abd1Farag for tending the azadirachtin formulation (Celaflor® 4 ml/L).

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Abstract

The potential usage of neem seeds as an agent for control of the Desert Locust *Schistocerca gregaria* (Forskal) was investigated under semi-field conditions. Evaluation was based on the systemic growth regulatory, antifeedant and lethal actions of the neem seed.

The study showed that the neem seeds, which were tested using two different doses (0.25 and 0.50 g) have a considerable effect on the immature stage of desert locust when applied as seed dressing and dusting of soil inversely treated with the increase of the dose.

The study also showed that neem seeds have the potentiality to suppress feeding of the locusts (2nd, 3rd, 4th, and 5th Instar). The response was dose related and the effect surpassed that induced by the standard systemic insecticide Celaflor®.

The feeding of the nymphs (2nd, 3rd, 4th, and 5th Instar) on the treated leaves of the millet resulted in the delay of the nymphal development of the desert locust. The study indicated that dusting of millet seed with neem seed powder has a potential as an agent for control of the Desert Locust immature stages.
The results revealed that feeding of locust nymphs on leaves of millet treated systemically increase the mortality. The mortality was dose and time related.

The medium Lethal time (LT\textsubscript{50}) for the treatments (dusting of millet seeds and dusting of soil) at a dose of 0.25 g of neem seed powder was 552-588 hours, where as the LT\textsubscript{90} was 799-995 hours.

As required, the LD\textsubscript{50} for the two treatments (seed dusting and soil dusting) with the dose 0.05 g was 569-672 hours, whereas the LT\textsubscript{90} was 882-1069 hours.

Deformation was not noticed on the insects except for one insect fed on plants treated systemically with Celaflor®. No deformation was recorded on insects that fed on untreated millet plants.

The results showed that the insects exposed to the systemic neem seed powder died within 3-6 weeks.

The results reported here indicated the good potential of the neem tree as a promising friendly alternative to the problematic pesticides in the locust management programs. The widespread distribution of neem trees under different climatic conditions, The simplicity, easiness and cheapness of the preparation will favor our argument.
بسم الله الرحمن الرحيم

ملخص الأطروحة

تم اختيار إمكانية استخدام بذور نبات النيم كعنصر مكافحة ضد الجراد الصحراوي تحت ظروف شبه حقلية. اعتمد تقييم الفعالية الجهازية على قدرة هذه العوامل في منع تغذية أو إعاقة نمو أو قتل الحشرات المعاملة والتي تم تغذيتها على أوراق نبات الدخن المعاملة جهازيا.

أثبتت الدراسة أن بذور نبات النيم المختبرة بجرعتين مختلفتين (0.25 و 0.50 جرام) على صورة معاملتين مختلفتين (تغذير البذور ، تغذير التربة) لهما أثرًا كبيرًا على الحشرة المختبرة (الأطوار الغير بالغة) بزيادة تناسب مع الجربة. كذلك أثبتت الدراسة مقدرة بذرة النيم في تثبيت تغذية الأطوار المختبرة (حوريات الجراد الصحراوي ، الطور الثاني ، الثلاث ، الرابع ، الخامس) وكانت الاستجابة تناسب مع الجربة محدثة أثراً يفوق ذلك الذي أحدثه مبيد النسيم الجهازى (Celaflor ®).

أدت تغذية الحوريات (الأطوار الثاني ، الثالث ، الرابع ، الخامس) على أوراق نبات الدخن المعاملة جهازيا إلى التأخر في تطور الأطوار المختبرة وقد وجد أن تعفيز بذور الدخن بدرجة النيم له تأثيرًا كبيرًا في تطور الحوريات بدرجة استجابة تناسب مع زيادة الجربة.

أثبتت الدراسة على أن تغذية الحوريات على أوراق نبات الدخن المعاملة جهازيا تؤدي إلى زيادة نسبة الموت بزيادة تناسب مع الجربة والزمن.

كان الزمن النصفي المميت (LT50 ) (The medium Lethal time ) للمعاملات (تغذير البذور ، تغذير التربة) بجرعة وقدرها 0.25 جرام من بذرة بذور النيم يتراوح ما بين (552 - 588 ) ساعة ، بينما تراوح الزمن النصفي المميت لـ90% من الحشرات المعاملة (LT90 ) ما بين (799 - 995 ) ساعة. تراوح الزمن النصفي المميت (LT50 ) للمعاملات (تغذير البذور ، تغذير التربة) بجرعة وقدرها 0.50 جرام من بذرة بذور النيم يتراوح ما بين (569- 672 ) ساعة ، بينما تراوح الزمن النصفي المميت لـ90% من الحشرات المعاملة (LT90 ) ما بين (882 – 1069 ) ساعة.
لم تشاهد أي تشبهات على الحشرات التي غذيت على أوراق نبات الدخن المعاملة جهازياً عدا
(جهادة واحدة عولمت نباتاتها جهازياً بمبيد النم القياسي (Celaflor®) وكذلك لم تشاهد أي تشبهات على
الحشرات التي غذيت على أوراق نبات الدخن غير المعاملة.

أوضحت الدراسة أن ترتيب القدرة الإبادية الجهازية لبذور النم تتراوح ما بين 3 – 6
أسابيع وتتانتاب الاستجابة مع عامل الجرعة والزمن. أشارت الدراسة إلى الإمكانية الواعدة لنبات النم
كبدائل للمبيدات المصنعة في حملات إدارة الجراد الصحراوي.

الانتشار الواسع لشجرة النم في مناطق ذات ظروف مناخية مختلفة، إضافة إلى سهولة
تحضير وقلة التكلفة يقوى من الاستنتاج السابق ويوجه نحو دراسات مستقبلية هامة.
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CHAPTER ONE
INTRODUCTION

About 200 grasshoppers and locusts species with different food preferences and geographical distribution are known as agricultural pests in Africa (Anon, 1990). Out of these, only four locust species are of economic importance; namely the Desert locust, *Schistocerca gregaria*, the African migratory, *Locusta migratoria*, the red locust, *Nomadacris septemfasciata* and the brown locust, *Locustana pardalina*. Two species are rapidly gaining importance, in the past few years; the tree locust, *Anacridium* spp. and the Senegalese grasshopper, *Oedaleus senegalensis* (Elbashir, 1991). The desert locust (*Schistocerca gregaria* Forskal) is one of the most important pests known. It greatly reduces crop yields in the field and also destroys grasses and trees (Schmutterer and Ascher, 1986). Substantial losses caused by the desert locust attack may occur in different ways; the newly growing seedlings may be completely destroyed by nymphs or the crops may be gradually defoliated during the growing season.

The Desert locust, *S. gregaria* has a vast invasion zone of some 29 million km² affecting 57 countries, covering an area of about 20 % of land surface of the world (Fig.1) (Uvarov, 1977; Steedman, 1988).

In the past, traditional methods such as burning, beating and digging of trenches to bury hoppers were employed in the locust control. While currently locust control campaign is heavily dependent on the use of insecticides, which affect a wide range of non-target organisms including insects, livestock, birds and wildlife. Effects on human heath and the environment is of similar concern (Everts, 1990).

Dieldrin for a long time was the favorable insecticide because of its effectiveness at very low dosage and persistence (about 4 months) after application. The new concern about environment pollution which emerged in the recent years has led to banning of this compound and of the similar chlorinated products, and the less persistent locusticides such as fenitrothion and malathion were put in its place (Anon,
Considering the continuous threat caused by Desert locust, the high cost of control campaign and the possible crop losses as well as hazards associated with the use of synthetic chemical, it is necessary to find new alternative methods of control, preferably of wide margin of safety to human and environment. Alternatives to chemical pesticides were attempted against desert locusts, including biological control, insect growth regulators and natural pest control agents especially of plant origin with wide success. Various extracts of plant material have been used worldwide for insects control since ancient times. About 2000 species of plant were reported to possess pest control properties, out of which very little are being used for insect control purposes.

Botanicals based on extracts of the neem tree (*Azadirachta indica*) and *Melia volkensii* have repellent action, growth disruptive effects on many orthopteran species, and generally reduce fitness (Schmutterer *et al*., 1993; Wilps *et al*., 1993). These products have been tested against desert locust on a small scale in the field (Diop and Wilps, 1997). Results of field trials during the last five years although scarce, have demonstrated the great potential action of neem as pests control agent.

Compared to other insect species, *S. gregaria* (Forskal) seems to be extremely sensitive to azadirachtin (Nicol, 1991; Nasseh *et al*., 1993). Neem products, as well as injected azadirachtin, interfered with the hormonal regulation of flight metabolism and reproduction (Rembold *et al*., 1988, Dorn *et al*., 1988, Subrahmanyam *et al*., 1989), and led to reduced or completely inhibited flight ability and fertility (Schmutterer, 1990).

Langewald and Schmutterer (1995) found that topically applying neem oil or extracts of azadirachtin to nymphs and adults of *S. gregaria* tended to reverse their phase colour from gregarious to solatarious after 33 days (from black and yellow to pale yellow transciens then, to green solitary type). Treatment of *S. gregaria* with
Melia volkensii seed extracts induced solitary colour in the hoppers and an extra eye-stripe in the resultant adults, a solitary characteristic reflecting the number of moults (Nasseh et al., 1993).

The neem and sadom apple aqueous extracts had shown strong antifeedant actions against the various nymphal instars (2\textsuperscript{nd} – 5\textsuperscript{th} instars) of the desert locust (Mohammed, 1999). Elamin (2002) studies on the systemic action of neem products are very promising against various stages of Desert Locust immatures (2\textsuperscript{nd} – 5\textsuperscript{th} instars) on systemically treated potted pearl millet seedlings. The effects reported include: mortality, delayed development, deformation and antifeedant actions. Such encouraging results initiated our interest to confirm such findings in semi-field conditions, and to validate the possible method of application.

The specific objectives behind this study are to:

1. Evaluate systemic activity of neem Kernel powder on development of different nymphal instars of Desert locust under Semi-field condition.
2. Evaluate the anti-feedant activity of neem seed kernel powder on the different nymphal instars of Desert locust under Semi-field condition.
3. Evaluate the efficacy of different methods of treatments viz.; soil applied, seed treatment etc.
CHAPTER TWO

LITERATURE REVIEW

2.1 Desert Locust *Schistocerca gregaria* (Forskal): -

Locusts are polymorphic species, which belong to the family Acrididae and consist of a large group of short horned grasshoppers. They are capable of changing phase reversibly both in terms of behavior and physiology in response to the prevailing biotic and abiotic factors (Gillett, 1988). Desert Locust is found in the two extreme forms, gregarious and solitarious encompass several intermediate forms known as transients (Gunn and Hunter-Jones, 1952; Pener, 1991). There are two subspecies of the Desert Locust in Africa; first species is the well known Desert Locust *Schistocerca gregaria*, which has been known to invade northern Africa while the other subspecies is *Schistocerca gregaria flaviventris*. It is known as Southwest Africa species, which occurs in Namibia, South Africa, Botswana, Angola, and Ascension Island (Meinzingen, 1993).

2.2 Geographical distribution:

The desert locust occurs in recession and invasion areas; the invasion area that has been reached by locust swarms, covers some 29,000,000 km² or about 20 % of the world land surface (fig.1) (Uvarov, 1977; Steedman, 1990; Meinzingen, 1993). This area include the whole North Africa, Southern and Western part of Arabian Peninsula, Middle-East, North to Eastern Turkey, the Southern Republics of the former
USSR, Afghanistan, the Indian sub-continent south to latitude 10° north and east to the border of Burma. Desert Locust has also been recorded in the Caribbean in 1988 and northern part of South America, the British Isles, Italy, Yugoslavia, Greece, and the coasts of Red Sea, Gulf of Aden, the Arabian Sea, and Arabian Gulf (Meinzingen, 1993). During recession, the Desert Locust is restricted to arid and semi-arid central parts of these areas, a broad belt covering some 16,000,000 km² extending from the Atlantic Ocean to northwest India (Meinzingen, 1993). The main ecological factor responsible for its general pattern and seasonal occurrence is rainfall (80-400 mm).

2.3 Biology of desert locust: -

One life cycle of *S. gregaria* takes probably between 2.5 and 5 months (Steedman, 1990). The life cycle comprises three stages; egg, nymph (hopper) and adult. The time spent in each stage varies considerably depending on the weather conditions (Steedman, 1988).

2.3.1 Egg stage: -

Mature desert locust females oviposit in sandy soil. The yellow eggs are conspicuous. Full-grown egg is about 7mm long. Gregarious female lays 2-3 egg-pods, each with about 60-80 eggs, whereas the solitarius female lays 3-4 egg-pods, each with about 95-160 eggs (Injeyan and Tobe, 1981; Anon, 1982; Steedman, 1988). Egg pods are laid at intervals of about 7-10 days, placed in the soil and covered with frothy secretion (Steedman, 1988).

About 20 mm of rain in one or several falls over few days or its equivalent in run off from higher level provides sufficient moisture to allow eggs to complete its development. Egg pods, which have not absorbed enough moisture in few days can remain dormant and continue its development after further rainfall. Dormancy periods of up to 70 days have been recorded in the field. Even in adequate soil moisture, the rate of egg development also depends upon soil temperature (Steedman, 1988).

2.3.2 Hopper stages: -
The development of hoppers is less dependent on temperature as they can adjust their body temperature. The rate of development is similar in both the gregarious and solitarious phases. The hopper stage of the gregarious phase is divided into five instars. Solitarious phase has six instars with an extra 7-8 days. Hoppers generally spend a similar period in each of the first–fourth instars of 6-7 days, and longer period in the fifth instars before fledgling, 10 days (Steedman, 1988). Steedman (1988) has described the morphology of gregarious nymphs as follows:

2.3.2.1 First - Instar hopper:

The first instar is whitish in color when newly hatched but after one to two hours turns black. As it grows bigger and become ready for moulting a pale colour pattern becomes more obvious. Average body length is 7mm and average weight, is 30-40 mg.

2.3.2.2 Second - Instar hopper:

It is not always easy to distinguish the second instar from the first, but with experience, one can recognizes that the pale colour pattern is more obvious. Average body length is 15 mm and average weight, is 50-80 mg.

2.3.2.3 Third - Instar hopper:

This stage is easily recognized by the two pairs of wing pads, which can be seen projecting from underneath the pronotum on each side of the thorax. Average body length is 20 mm and average weight is 120-200 mg.

2.3.2.4 Fourth - Instar hopper:

The colour here is conspicuously black and yellow, more black under cold condition and less black under hot condition. The wings are large and more obvious but they are still shorter than the length of the pronotum measured along the middle line. Average body length is 33 mm and average weight, is 500-700 mg.
2.3.2.5 Fifth - instar hopper: -

The colour is bright yellow with black pattern, wing pads are longer than the pronotum, but still cannot be used for flight. Average body length is 50 mm and average weight, is 1000-1200 mg.

2.3.3 Adult stage: -

The duration of the immature adult stage is variable. When conditions is suitable adult may mature in three weeks after fledging. Under cold and /or dry conditions adult can remain immature for upto 8 months. Males usually mature before females. Ovipostion starts within two days after copulation.

2.3.3.1 Immature adult: -

Colour is pink, lighter or darker according to the weather condition. The bright pink colour may change to brownish red if the locust have spent more than two months in this immature stage.

2.3.3.2 Mature adult: -

Colour is yellow, with the males being brighter than the females. Females are usually larger than males. Average length for female and male is 7-9 cm and 6-7.5 cm respectively.

2.4 Incubation period and hatchability: -

The period of egg development, between laying and hatching, is called the incubation period .The rate at which eggs develop varies according to soil temperature. In the summer breeding areas of West Africa, the Red Sea Coast and low land of India, the incubation period takes 10-14days, but this extends to 25-30 days in the cooler spring breeding areas of Central Arabia, southern Iran and Pakistan while in North Africa it can take as long as 70 days in exceptionally cold weather.

Hatching takes place either shortly before or within three hours of sunrise and all hoppers from one egg-pod normally hatch in the same day. It usually takes three days for the complete hatching of a whole egg field but longer period have been recorded (Steedman, 1988).
2.5 Phase theory: -

The desert locusts exist in different phases, solitarious and gregarious. The solitarious phase occurs as scattered individuals in the recession area, whereas the gregarious phase occurs as swarms throughout the invasion area. When breeding conditions are suitable, this will lead to an increase in numbers, locust crowded together, and the insects change their color, behaviour, shape and physiology. Not all these changes occur at once; behaviour and colour change first (Steedman, 1988; Loher, 1990 and Pener, 1991). An adult in the solitarious phase is often pale-gray or pale when immature, with males becoming pale-yellow upon maturation and pale with brown patterns in mature females. Solitary nymphs are green or brown. In contrast, the gregarious adult is usually bright pink when immature and bright yellow when it is matured with nymphs showing distinctive black pattern on their bodies (Gunn and Hunter-Jones, 1952).

Behaviorally, solitary locusts live as harmless individuals far apart from another (Roessingh et al., 1993) and show strong repulsive reactions to confrontations with other hopper (Wiesel et al., 1996). The adult stages fly individually usually at night and occasionally during the day when disturbed (Steedman, 1988). In contrast, the gregarious phase hoppers actively aggregate; forming large crowded groups, termed bands. Hoppers in bands have a higher locomotive activity in the same direction (Uvarov, 1977). Likewise adults fly together in swarms during the day with a higher flight activity compared to solitarious ones (Michel, 1980). Solitary locusts generally appear larger than gregarious forms, but they can be differentiated using morphometric measurements which include ratio of adult forewing or Elytron (E) to hind femur length (F), (E/F), and hind femur length (F) to the greatest width of head capsule (C), (F/C). The F/C ratio is higher, whereas the E/F ratio is lower in solitary than in gregarious locust (Dirsh, 1951; 1953). Different authors have reported different values of E/F ratios ranges for the phases, e.g. 1.92 to 2.08 for
solitaria and 2.11 to 2.27 for gregaria (Drish, 1951; 1953; Meinzingen, 1993; Ochieng Odero et al., 1994). The different F/C values reported include for example a range of 3.77 to 4.10 in solitaria and 3.42 to 3.59 in gregaria (Jackson et al., 1978), greater than 3.75 in males and 3.85 in females of solitaria (Meinzingen, 1993 and Ochieng Odero et al., 1994). These ratios (E/F and F/C) have been found to vary with locust strain (Gunn and Hunter-Jones, 1952). Deng et al., 1996) suggested that morphometerics ratios are not good phase indicators since they change slowly over several generations.

2.6 Economic importance of desert locust: -

In the past, desert locust outbreaks occurred only every 10 or 20 years, and thus the economic damage over time might have been small, compared with more regular but less important grasshopper pests. The damage caused by the desert locust stems from the fact that it can consume food equivalent to its own weight, 1.5-3 g of vegetation daily (Meinzingen, 1993). However, damage varies with the locust stages. Meinzingen (1993) indicated that 8 % of the total damage by locusts is due to hoppers, 69 % to immature and 23 % to mature adults. The damage inflicted by hoppers is low because the breeding areas are mostly outside cropping areas. It is difficult to generalize on damage due to the highly migratory nature of the pest (Meinzingen, 1993). The gregarious phase of S. gregaria is a destructive agricultural insect pest (Walsh, 1988), the non-migrating solitary phase is of little economic importance. Apart from the damage they cause by eating leaves, flowers, seeds, and growing point. Sometimes they settle densely on some plantation and fruit trees, weigh down and break the branches of trees, like coffee, when they don’t eat (Meinzingen, 1993). Some of the main graminaesous crops damaged are barely, maize, rice, sorghum, sugar cane and wheat. The other important crops are banana, citrus, cotton, date palm, apple, cabbage, cucumber (Anon, 1982). For the period 1949-1957 FAO estimated the total values of crop losses in 12 countries out of 40 subject to invasion is £ 15 millions (Anon, 1982).
Examples of crop losses due to the desert locust (Steedman, 1988): -

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Crops destroyed by the desert locust</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>Libya</td>
<td>7,000,000 grapevines; 19 % of total vine cultivation.</td>
</tr>
<tr>
<td>1954</td>
<td>Sudan</td>
<td>55,000 tones of grain.</td>
</tr>
<tr>
<td>1957</td>
<td>Senegal</td>
<td>16,000 tones of millet, 2000 tones of other crops.</td>
</tr>
<tr>
<td>1957</td>
<td>Guinea</td>
<td>6000 tones of oranges.</td>
</tr>
<tr>
<td>1958</td>
<td>Ethiopia</td>
<td>167,000 tones of grain, which is enough to feed 1,000,000 people for a year.</td>
</tr>
<tr>
<td>1962</td>
<td>India</td>
<td>4000 hectare of cotton (value$300,000).</td>
</tr>
</tbody>
</table>

During outbreaks or plagues control measures are always undertaken, therefore, it can not be determined unequivocally whether damage has been prevented by these measures or if in fact it never would have occurred. Desert Locust control will always remain a political issue and decisions are made independently of purely economic calculations (Symmons, 1992).

2.7 Control of Desert Locust: -

Today efforts to control locust have already begun with the surveillance of recession areas and control at the solitary phase (Krall and Willps, 1994). Many measurements are used to control desert locust, these include the following: -

2.7.1 Traditional methods: -

Many traditional methods of locust control have been used in the past (Duranton et al., 1987). They include; herding, burning, trenching, harrowing and tilling.
2.7.2 Natural control: -

Weather is probably, the most important natural factors that limit locust populations. The Desert Locust is affected adversely by the conditions outlined below: -

2.7.2.1 Temperature: -

Locusts are resistant to low temperature, but adults buried in snow or exposed to prolonged frost may die. Near the upper limit of their temperature range, hoppers have been seen to die during the heat of the day if they are unable to find shade or get off the hot ground (Anon, 1966).

2.7.2.2 Rainfall: -

Too little rain in the soil don’t allow the eggs to develop successfully, or even if the eggs hatch the amount may not be enough to allow growth of suitable food plants for the young hoppers. Too much rain may kill eggs by exposing them on the surface of the soil, washing them out of the ground or causing them to rot. Floods can drown large numbers of young hoppers (Anon, 1966).

2.7.2.3 Wind: -

This can carry flying locusts out to sea where they may drown, or push swarms into ice high mountains where they may die by cold. Strong winds sometimes blow the soil away from the egg pods, cause them to dry out and die. Also on some occasions strong winds may drift sand to bury a live settled locust when they are too cold to move (Anon, 1966).

2.7.2.4 Natural Biological control: -

The Desert Locust has different natural enemies, which include pathogenic organisms, parasites and predator.

2.7.2.4.1 Pathogens: -

During the latest major desert locust outbreak in the late 1980s, million liters of pesticides in ultra low volume (ULV) formulation, emulsifiable formulations and baits were applied. The resulting concern about environmental and toxicological issues has stimulated studies on the development of alternative
control strategies. There are more than 1800 naturally occurring microorganisms and products that hold promise for the control of major insect pests. The most advanced strategy is a product based on the deuteromycete fungus *Metarhizium anisopliae var. acridum* (Bateman, 1997; Lomer *et al*., 1999). This can be applied using common ULV formulation (Bateman, 1997). The fungus has been studied extensively in the field against many orthopterans and desert locust in particular (Kooymann and Godonou, 1997; Langewald *et al*., 1997, 1999; Price *et al*., 1997). The pathogen-host interaction between *Metarhizium* and orthopterans is a key element to the efficacy of this novel product (Thomas *et al*., 1997; Blanford and Thomas, 1999). Once sprayed, the spores can remain viable for a long time and transfer infection to non-infected orthopterans (Langewald *et al*., 1999). The *Metarhizium* strain used is environmentally safe (Peveling *et al*., 1999) and has been registered in many countries. The closely related fungus *Beauveria bassiana* has also been tested against several orthopterans species (Johnson and Goettel, 1993; Delgado *et al*., 1999).

The use of baits containing pathogen such as the protozoan, *Nosema locustae*, with or without an admixture of an insecticide such as carbaryl had some success against range of grasshoppers in the United States and Argentina (Steedman, 1988).

### 2.7.2.4.2 Parasites and predators

#### 2.7.2.4.2.1 Egg parasites and predators:

They include several parasitic wasps of the genus *Scelio*, the dipterous flies *Stomorhina lunata* and the beetle *Trox proceus* (Greathead, 1963; Steedman, 1990).

#### 2.7.2.4.2.2 Parasites of hoppers and adults:

They include *Blasoxipha filipjevi*. The fly *Symmictus costatus* and Nematodes (Steedman, 1988).

#### 2.7.2.4.2.3 Predators of hoppers and adults:
They are including hoppers themselves through cannibalism, Ants, wasps, Ant lions, Reptiles and Mammals (Steedman, 1988). Some bird species commonly feeding on hoppers are described by Ashall and Ellis (1962), including, for example, the European white stork.

2.7.4 Chemical Control: -

Locust control became efficient only after the development of dieldrin (Courshee, 1983). The major advantage of this insecticide was its long persistence, which made it possible to introduce the barrier spraying technique, thus saving costs and time (Courshee, 1990). Dieldrin and lindane remained the major products used in locust control until the early 1980s. However, these compounds are no longer used because of growing concern over the environmental impact (Courshee, 1983). Most pesticides, which are recommended by the FAO Locust Pesticide Referee Group, have a very short persistence in the field in order to avoid accumulation of these compounds in the environment. Different insect growth regulators have been tested for acridid control (Dorow, 1996). These products cause low risk for non-target organisms, except aquatic arthropod. The use of pheromones in the integrated management of desert locust populations presents a real alternative to the exclusive application of synthetic insecticides. It is presently believed that pheromone influence or affect gregarisation, oviposition and the development of locust (Ferenz, 1990; Luber et al., 1993).

2.8 Application methods: -

The insecticides is actually applied or offered to the locusts in one of three forms: bait, dust or spray. All forms are used for killing by stomach action, and dusts and sprays are also used for killing by contact action (Steedman, 1990).

2.8.1 Baiting: -

Baits are usually prepared by the anti-locust organizations themselves. The insecticide, or insecticide and biological control agent, is mixed with a material, the carrier, which locusts eat readily. Carbamates such as bendiocarb are now
commonly used as baits. The effectiveness of bait will clearly depend upon the concentrations of the insecticide it contains. The concentration is usually 1 or 2 % active ingredient (Steedman, 1990).

2.8.2 Dusting: -

Commercial preparations of insecticidal dusts consist of an insecticide mixed with some inert material like powdered chalk or talc. The most suitable insecticidal dust for killing locusts and grasshoppers is bendiocarb (Steedman, 1990).

2.8.3 Spraying: -

In this method of locust control, liquid insecticide is broken up into fine drops and sprayed either onto the locusts or onto the vegetation, which they eat. Spraying can be done either from the ground or from aircraft. Spraying can be successfully carried out with many types of machines. Suspensions, emulsions or oil solutions of insecticides may be used. All sprayers produce drops in a range of sizes called the drop spectrum (Steedman, 1990).

ULV rotary disc spray equipments are mainly used in desert locust control. These equipment are available for hand application, application by vehicle or by aircraft (Matthews, 1992). This technology is the most efficient way of transferring an insecticide to its target (Bateman, 1993) and to allows volume application rates.

2.9 Early Warning Systems: -

The recession areas of *S. gregaria* are relatively well known; however, access is difficult and costly. A locust early warning control system aims at the early discovery of suitable breeding conditions for desert locust, mainly rainfall and subsequent vegetation types and patterns determined these. Several remote sensing tools are available to discover desert locust outbreaks more efficiently. Over large areas, rainfall patterns can be monitored from satellite images either by following vegetation growth (Voss and Dreiser, 1997) or more quickly by monitoring cloud-top temperatures (Burt *et al.*, 1995). These data are combined
with other weather data and historical data from previous desert locust outbreaks. The combined data are fed into geographic information systems such as SWARMS, developed by FAO (Cressman, 1997) or 'SGR biomodel' by PRIFAS (Launois, 1997). Vertical radar can be used as an additional tool to monitor migration of solitary adult locusts towards areas suitable for breeding and consequent outbreaks (Riley and Reynolds, 1997).

2.10 Field Monitoring and Control Strategies: -

Pest management strategies in locust control are still under discussion. The major debate concerns the efficiency of early intervention. A major desert locust plague develops following a local outbreak in recession areas, followed by an upsurge (several generations of successful breeding). The current strategy is the outbreak or upsurge prevention. Recession areas of *S. gregaria* are monitored carefully, making use of satellite imagery, weather reports, aerial surveys and ground surveys (VanHuis, 1997). This is a purely preventive control strategy. The main targets when using this strategy are hopper bands, which might be difficult to spot; large desert locust populations might fledge and escape such operations, especially if no persistent insecticides for barrier treatments are available. If an upsurge occurs, hopper bands and adult swarms become larger and the strategy aims to trace and control these populations under all circumstances. Should this effort not succeed, the strategy turns to plague elimination, an operation that costs hundreds of millions of US$ and is not possible without international financial aid and co-ordination. If a significant proportion of hopper bands is not found, the efficacy of attempting hopper band control is questionable. Also, natural mortality in hopper bands is very high (Ashall and Ellis, 1962) and controlling the adult survivors could be more cost efficient. Flying locust swarms are easily visible from an aeroplane and escape is less likely compared with hopper bands (Symmons, 1992). On the other hand,
ground treatments require less skilled personnel and only very few pilots are ready to fly into desert locust swarms (Symmonds, 1992).

2.2 Neem as a botanical material of Insecticidal potential: -

Historically, botanical pest control materials have been used frequently in many parts of the world. Many home gardeners in urban areas plant marigolds around their vegetable patches and find this to be an effective means of keeping their crop healthy from certain insects and nematodes. Dried neem (*Azadirachta indica*) leaves are known to be placed in sacks of grain by villagers in India and Pakistan to reduce damage to their harvest in storage. The nicotine is also applied to plants in the Middle East. An effective solution may be obtained by soaking tobacco leaves in water. A few plant derivatives, such as pyrethrum, nicotine and rotenone, are also used in modern agriculture. These materials have relatively low mammalian toxicity compared with many pesticides, short period of activity and a fairly broad spectrum of control.

These botanical materials showed selective action against a number of pests through variety of biological activities including, production of behavior-modifying chemicals (such as pheromone analogues, repellents, and attractants) (Patel *et al*., 1968) direct toxicants (Chiu, 1982) and insect growth regulators (juvenile and anti juvenile hormones) (Bowers *et al*., 1976). These selective agents are found in many plants as part of their natural defensive strategies. Ahmed and Grainge (1982) have compiled a list of approximately 2000 plants species.

2.2.1 Neem Tree *Azadirachta indica* A. Juss: -

2.2.1.1 Characteristic, description and distribution: -

Neem tree is an attractive broad–leaved evergreen tree that can grow up to 30 m tall and 2.5 in girths. Its spreading branch form rounded crowns as much as 10 m across. It retains it leaves except during extreme drought, when the leaves may fall off. The short, usually straight trunk has a moderately thick, strongly furrowed bark. The roots penetrate the soil deeply, at least where the
site permits. When injured, they produce suckers. The suckering is especially prolific in dry localities. Neem tree can easily withstands pollarding, also it freely coppies. Regrowth from both pollarding and coppies can be exceptionally fast because it is being served by a root system large enough to feed a full-grown tree (Ruskin, 1991). The small, white, bisexual flowers are borne in auxiliars clusters. They have a honey-like scent and attract many bees. Neem honey is popular, and reportedly contains no trace of azadirachtin. The fruit is a smooth, ellipsoidal drupe, upto almost 2cm long, when ripe; it is yellow or greenish yellow and comprises a sweet pulp enclosing the seed. The seed is composed of a shell and kernel (sometimes two or three kernels). It is the kernel that is used most in pest control.

The leaves also contain pesticide ingredients, but as a rule they are much less effective than those of the seed (Ruskin, 1991).

A neem tree normally begin bearing fruit after 3-5 years, becomes fully productive in 10 years where it can produce up to 50 kg of fruits annually. It may live for more than two centuries (Ruskin, 1991).

Neem is native to India and Burma. In India the tree is most widely used. It is grown from the southern tip of kerala to the Himalayan hills, in the tropical and to subtropical regions, in semi-arid to wet tropical regions, and from sea level to about 700 m elevation (Ruskin, 1991).

As already noted, neem was introduced to Africa earlier of the 20th century. It is now well established in at least 30 countries. Over the last century or so, the tree has also been established in Fiji, Mauritius, the Caribbean, and many countries of Central and South America. In some cases it was probably introduced by indentured laborers, who remembered its value from their days of living in Indian villages. In other cases foresters have introduced it.

In the continental United States, small plantings are prospering in southern Florida, and exploratory plots have been established in southern California and Arizona (Ruskin, 1991). Neem also seems to play a well-
established part of the scene in the Sudan. There, it is valued mainly as a street and amenity tree and is commonly seen in rail-way stations and beside mosques. The first trees were apparently planted at Shambat in 1916 (Ruskin, 1991; Siddig, 1991).

2.2.1.2 Chemical constituents of neem Tree: -

Neems have multitude of pesticidal ingredients. Its main chemical ingredients of 3 composed related compounds and others minor ones but nonetheless active on one way or another. These compounds belong to a general class of natural products called “Triterpenoid” or “Limonoids” (Ruskin, 1991). The main constituents include Azadirachtin, Salanin, Meliantriol, Nimbidin, salannol, salnnol acetate, 3-deacety-salnnin, epoxyazaradion, gedunin, mimbinen and deacetyl nimbin (Jones et al., 1989; Ruskin, 1991).

Azadirachtin: -

Azadirachtin is one of the first active ingredients isolated from neem, azadirachtin has proved to be the tree main agent for battling insects. It appears to cause some 90 percent of the effect on most pests. It doesn’t kill insects immediately. Instead it both repels and disrupts their growth and reproduction. It is the one of the most potent growth regulators and feeding deterrents ever assayed. It repels or reduces the feeding of many species of pest insect as well as some nematodes (Ruskin, 1991). On average, neem kernels contain between 2 to 4 mg of azadirachtin per gram of kernel (Ruskin, 1991) (Fig.2).

Salannin: -

It is another triterpenoid isolated from neem. This compound powerfully inhibits feeding, but does not influence insect molts. The migratory locust, California red scale, houseflies, Japanese beetle have been strongly deterred in both laboratory and field tests (Ruskin, 1991) (Fig.2).

Meliantriol: -

It is another feeding inhibitor, which is able, in extremely low concentration, to cause insects to cease eating. The demonstration of its ability
to prevent locusts chewing on crops was the first scientific proved for neems traditional use for insect control on Indian crops (Ruskin, 1991) (Fig.2).

**Nimbin and Nimbidin:**

Nimbin and nimbidin have been found to have antiviral activity. They affect virus x, vaccinia virus, and fowl poxvirus. They could perhaps open the way to control these and other viral diseases of crops and livestock. Nimbidin is the primary component of the bitter principles obtained when neem seeds are extracted with alcohol. It occurs in sizable quantities—about 2 percent of the kernel (Ruskin, 1991) (Fig.2).
2.2.1.3 Biological activities of neem products:

Neem tree has emerged as the single most important source of insecticides. All parts of the tree are biologically active. The maximum insecticidal activity is in seed kernel. The kernel extracts and pure compounds isolated from the seed have shown diverse biological effects against insects. These include the repellent, feeding and oviposition deterrent, growth regulatory and sterilant effects. In addition, neem is also reported to have direct toxicity and impairs egg hatchability.

2.2.1.3.1 Antifeedant activity:

The seed kernel of the neem tree contains principles having antifeedant (Pradhan and Rai, 1963; Pradhan and Jotwani, 1968; Gill, 1972) effects. In India, neem seed kernel suspensions are used to protect crops against locusts (Pradhan and Jotwani, 1968) and tobacco seedlings against *Spodoptera litura* (Joshi and Ramaprasad, 1975). Gill and Lewis (1971) found that different neem seed preparations applied to the soil protected a plant for up to 25 days against *S. gregaria*. They also found that bean seedlings grown from seeds soaked for 25 h in 0.01% and 1% solutions of azadiracthin (alcohol extract and water extract from neem seed) were protected against damage by *S. gregaria* adult for one week after germination. Mane (1968) screened neem seed kernel suspensions effective against four pest’s viz., *Euproctis lunta, Spodoptera litura, Utetheisa pulchella* and *Acrida exaltata*. *E. lutata* was found highly sensitive, perhaps the most sensitive among the lepidopterous larvae tested so far with neem seed kernel suspension (NSKs). NSKs were reported as an effective antifeedant against all the five larval instars of *Spodoptera litura*. The effect of the treatment decreased and the feeding increased with advancing larval instars (Joshi and Ramaparasd, 1975). Singh (1987) extracted neem seed kernel, seed coat and fallen leaves with water and ethanol. Ethanolic extract was re extracted successively with hexane, chloroform and methanol. Five extracts of each part thus obtained were quantified and tested for their antifeedant efficacy against the
desert locust, *S. gregaria*. Neem seed kernel was most active, followed by seed coat and leaves. Water extract deterred feeding nearly as effectively as ethanol indicating that water can be used as an effective solvent for extracting seed kernel, seed coat which constitutes about 60% of seed weight exhibited high antifeedant property. Chloroform extract obtained as a result of successive extraction of ethanolic extract inhibited feeding at a very low concentration of 0.007%. Water and ethanolic extracts of seed kernel were evaluated against chafer beetle, *Apogonia blancharadi* and found to inhibit the feeding of the beetle at 2.5 and 1% respectively (Doharey and Singh, 1989). Attri (1975) tested neem oil extract and water extract of seed kernel against desert locust. The oil extract was found 40 times less active than water extract of seed kernel. Absolute feeding inhibition by water and oil extract was at 0.05 and 2% concentration respectively. Different fractions of neem oil when tested against desert locust revealed that one of the fractions at (0.25%) gave 92.9% protection of cabbage leaves against the pest (Narayan *et al.*, 1980). Upto 2% of the oil failed to give any significant protection to castor leaves against the hairy caterpillar, *Amsacta albistriga*. However, it protected castor leaves to the extent of 70.7 and 91.4% at 3 and 4% respectively. Neem guard and Repelin (Commercial products) at the concentrations of 1-4% offered protection of 82.2 to 99.5% and 18.9 to 96.0% respectively (Mani *et al.*, 1990). JhansiRani (1984) compared the antifeedant property of ethanolic and aqueous extracts of deoiled neem seed kernel against the desert locust; the ethanolic extract completely inhibited feeding of locust on cabbage leaves at 0.003% while the aqueous extract gave the same degree of effect at 0.006%. According to Siddig (1991), neem seed powder mixed with wheat protected the cereal under storage condition against damage by *Trogoderma granarium* Everts.

Mohamed (1999) studied the effect of neem suspension and extract sprayed on alfalfa leaves and given to the nymph instars (2-5th) of the desert locust *S. gregaria*. He found that all extracts suppressed food intake and effects
were dose related. From the foregoing, it is clear that the antifeedant activity of neem to various species varies greatly. Desert locust, *S. gregaria* is the most sensitive insect followed by the *Heliothis armigera* (*Helicoverpa armigera*) is the least, in antifeedant effect of neem.

Elamin (2002) reported that all the tested neem seeds products (NSWE, NSOE and NSP at 1, 5, 10, 20 %) under laboratory conditions were able to induce significant systemic antifeedant activity against immatures tested (2-5th nymphal instars) of Desert Locust reared in treated millet seedlings and also caused significant dose-related delay in the develop of nymphal instars of desert locust.

### 2.2.1.3.2 Repellent activity:

Pruthi (1937) reported the first scientific data on the repellent action of neem leaves against storage pest. The diverse biological effects of the neem kernel extracts include phagodeterrent and repellent (Pradhan and Rai, 1963; Jacobson *et al.*, 1978). Pradhan *et al.*, 1962 reported that sprayed ground neem kernel in water suspension over different crops caused antifeedant effect against the desert locust for 3 weeks after treatment. (Heyde *et al.*, 1984) demonstrated that on ultra low volume spray of 3% neem oil allow only few adults of brown rice hopper *Nilaparavata lugens* to light on treated rice plants. Coudriet *et al.*, (1985) reported that the sweet potato white fly *B. tabaci* was repelled and fewer adults lighted on cotton treated with neem seed extract than untreated cotton. They further reported that the application of 1.4 % emulsitiable neem oil effectively repelled the asiatic citrus psyllid *Diaphorina citri*, a vector of the yellow shoot disease of citrus. Nasseh *et al.*, 1993 reported repellent effect of neem oil on adults of *S. gregaria* at dose 10 L/ha.

In Sudan, Siddig (1987) reported that neem seed and leaves water extracts at 1 kg/40 L water repelled foliage pests of potato, including the *Bemisia tabaci*, *Jacobiasca lybecia* and *Aphis gossypii* and increased yield by 0.5 tones /ha. The same author reported that, spraying potato tuber after harvesting, then sacking
them in jute sacks reduced post harvest losses by repelling the tuber moth, *Phthoremea opercellella*. According to Balandrin et al., 1988 the repellent action of neem could result from the presence of volatile sulphur containing compounds.

2.2.1.3.3 Insect growth regulatory effect: -

McMillan *et al.* (1969) were the first to report the growth disrupting effect of chloroform extract of the leaves of *Melia azadarach*, against *Spodoptera frugiperda* and *Heliothis zea*. Later Gill and Lewis (1971) reported that *Pieris brassicae* larvae fed on foliage treated with neem kernel extract failed to develop to maturity and most died while moulting. Malformation and prolongation of pupal period were also reported. Ruscoe (1972) reported that the growth disrupting effect of azadirachtin on the last instars larvae of the diamond back moth, *Plutella xylostella* L and the last instars of the cotton stainer bug, *Dysderus fasciatus* Sig. The treated insects developed at slower rates. He found that at high concentrations insects died without further ecdysis and at low concentrations either no adult were produced or pupae were small and deformed. The insect-growth-disrupting effect of azadirachtin has been attributed to ecdysis inhibition or failure to shed exuvia during the moulting process (Kubo and Klocke, 1982). Neem oil at 200 Mg/pupa caused 100 % mortality of *Spodoptera litura* pupae and produced pupal–adult intermediates at 100 Mg (Gujar and Mehrotra, 1984). Azadirachtin- at 1-8 Mg/g body weight caused dose-dependent reduction in body weight of final instars nymph of the desert locust, *S. gregaria* but even the highest dose did not caused absolute feeding inhibition (Rao and Subrahmanyam, 1986). Nicol and Schmutterer (1991) reported that sprayed nymph instars of *S. gregaria* with 2.5 to 10 L/ha showed high mortality that often occurred during moults, prolonged nymph development and disturbance of metamorphosis.
Mohamed (1999) reported deformation and failure moulting in desert locust nymphs fed with alfalfa leaves treated with neem extracts and even those instars that succeeded to molt died as overaged larvae.

2.2.1.3.4 Effect on reproduction and fecundity: -

_Epilachna varivestis_ fed azadirachtin-treated leaves suffered decreased longevity and reduced reproduction, while administration of azadirachtin injections sterilized the migratory locust, _Locusta migratoria migratoroides_ (Steets and Schmutterer, 1975; Rembold and Sieber, 1981). Gujar and Meheotra (1984) reported that topical application of 10 Mg azadirachtin caused a significant reduced adult longevity, fecundity and reproduction in _S. litura_. Pathak and Krishna (1985) observed a significant reduction in reproduction potential in terms of egg yield, egg viability, etc., of rice moth _Coreyra cehalonica_ when the pest was exposed to vapors emanating from 160 ML of neem oil. Neem oil vapors- at the above concentration under identical conditions reduced egg laying by _Earias fabia_. The hatchability of eggs deposited was also adversely affected (Pathak and Krishna, 1986). Singh and Singh (1987) reported that _S. gregaria_ laid significantly less number of eggs in the sand treated with 0.1,0.5% and 1% of neem seed kernel suspension.

The testis removed from the 5th instar of _S. gregaria_ injected with azadirachtin showed significant reduction in the width, length, and volumes. Cytological examination of testis exhibit azadirachtin poisoning i.e. showed arrested spermatogenic meiosis at metaphase (Linton _et al._, 1997).

2.2.1.3.5 Effect on natural enemies and beneficial insects: -

Neem derivatives evaluated so far have generally been found to conserve parasites and predators of insect pests and also other insects. Joshi _et al_ (1982) demonstrated that application of 2 % neem seed kernel suspension to the eggs of _S. litura_ parasitised by _Telenomus remus_ did not adversely affect the emergence of parasites and did not repel the oviposition by female. Neem seed kernel
suspension was also observed to be safe to *Chrysopa scelestes*. Field trials conducted using neem emulsifiable concentrate for control of sorghum aphid *Melanaphis sacchari* did not show any adverse effect on syrphids larvae and adults of coccinellids, which prey on aphids (Srivastava and Parmar, 1985). Ruskin (1991) proved that neem products have to be remarkably benign to spiders and bees that pollinate crops and trees, ladybug beetles that consume aphids and also wasps which act as parasites on various crop pests. Neem products have to be ingested to be effective.

### 2.2.1.3.6 Insecticidal activity: -

Many workers have reported that neem products possess an insecticidal activity against different insect species. Fagoone and Lauge (1981) investigated the effect of methanolic extract of neem leaves against cabbage webworm, *Crocidolomia binotalis* zell. The extract has shown to be very toxic as evidenced by high larval mortality and poor emergence. Hellap (1984) found that 5 ppm of a methanolic neem seed kernel extract caused mortality in 4 and 10 day old larvae of the fall army worm, *Spodoptera frugiperda* (Smith).

Saxena and Khan (1985) reported that neem seed oil was highly effective in reducing the survival of a plant hopper, *Nilaparvate lugens* (Stall). Similarly *N. lugens* females died when topically treated with neem seed bitters (NSB) (Saxena and Co-workes, 1987). Extracts from seed and leaves of the neem tree (*Azadirachta indica* A. Juss) are known to contain several insecticidal, nematicidal, and acaricidal principles (Gill, 1972; Jacobson *et al.*, 1978; Warthen, 1979).

### 2.2.1.3.7 Neem as fertilizer: -

Bains *et al.*, 1971 were the first to show, under field conditions, that treatment of urea with dried and crushed neem kernels increase the rice yield by 22 % and saving of 100 kg N/ha was reported to be obtained. Kethar (1974) found that application of urea with neem cake increased rice yield with about
400 kg/ha. Sharma and Prasad (1980), observed that neem cake mixed with urea increased recovery of urea nitrogen by the rice crop from 28% to 47.4%.

It was mentioned by Hoddy (1986), that the neem cake, which comprises between 70% and 90% of the crushed seed, is widely used in many parts of India as fertilizer to grow tomatoes, cabbages, cauliflowers, potatoes and grapes. Ruskin (1991) reported that neem has considerable potential uses as fertilizer mainly the neem cake and leaves.

**2.2.1.3.8 Medical uses of neem: -**

Ruskin (1991) extensively reviewed the Medical uses of neem. The neem preparations are reported effective against a variety of skin diseases, septic sores, and infected burns. The leaves, applied in the form of poulties or decoction, are also recommended for boils, ulcers, and eczema, the oil is used for skin diseases such as scrofula, indolent ulcers, and rig worm.

Neem has proved effective against certain fungi that infect the human body such as, *Trichophyton, Epidermaphtont, Microsporoma, Geotrichum* and *candido*. In trials, neem oil has suppressed several species of pathogenic bacteria, including *Staphylococcus aureus* and *Salmonella typhosa*. Recent pharmacological studies have supported the belief that neem leaves possess some anti-viral activity. In the United States, aqueous neem leaf extracts have shown to moderate inhibition of the viral DNA polymerase of hepatitis B virus. In Germany, an ethanolic neem kernel extract has proved effective against herpes virus (Ruskin, 1991).
CHAPTER THREE

Materials and Methods

3.1 Rearing of the test insects:

Eighty-one plastic cups containing egg pods were brought from the International Center of Insect Physiology and Ecology (ICIPE) field station, PortSudan, Sudan on 20-1-2004. The plastic cups measured 10 (deep) × 7(diameter) cm, and kept in the laboratory at the Faculty of Agriculture University of Khartoum. Each cup contains about 6 egg pods on average.

Every five days, water was added to the cups to maintain suitable moisture for the egg-pods. The average temperature during rearing of the desert locust nymphs was 37° C and the average relative humidity was 33 %. Eggs started hatching on 21-1-2004. Three different types of cages were used in the study. Hatched nymphs were transferred to the first type a small cages made of cloth and metal (rearing cages) which measured 75×45×45cm (Plate 1). A small plastic tube was used for the transfer of nymphs. The first hatched instars were fed millet seedlings grown in pots (7cm diameter and 10 cm deep) and wheat bran. Every day the cages were cleaned from the insect’s feces by a small brush.

Mature adults (both sexes) were transferred to the egg-laying cage measured 120×100×100 cm (Plate 3), for mating and egg-laying. Females and males started mating on 22-3-2004, egg-laying started on 1-5-2004, and continued until 14-6-2004 (Plates 4, 5).
Plate (1): Desert Locust Rearing Cage

Plate (2): Experimental Cage

Plate (3): Desert Locust Egg-Laying Cage
Plate (4): Mature Female of Desert Locust S. gregaria during testing of soil

Plate (5): Adults Male and female of Desert Locust S. gregaria during mating
The cups containing egg-pods were removed and replaced by new empty ones for further egg-laying.

Nymphs hatched from these egg-pods were transferred to rearing cages until they reached the second instars and were then taken to the third type of cages (Experimental cage) in the field for the treatment (Plate 2).

3.2 cages used in testing the experiment: -

The cages were made of wood and wire mesh and measured 150x100x100 cm. The bottom or floor side of the cage was not covered by wire mesh, but inserted in the ground (Plate 2).

3.3. Preparation of neem Seed Powder: -

Mature seeds of the neem tree, *Azadirachta indica* A. Juss were brought from the National Research Center at Khartoum. The collected seeds were immersed in water to aid in skining the outer layer of the fruits. The seeds were then spreaded on filter papers to dry-out under shade at laboratory temperature 25° C for three days. The dried seeds were first crushed to remove the shell without damaging the kernels. An electric grinder was used for milling of kernels into fine powder. The powder was kept in clean glass jars tightly closed and wrapped with the aluminum foil and store at room temperature for extraction or bioassay (Plates 6, 7).

3.4 Semi - field cage experiment: -

Millet seedlings were sown in the experimental cages on flat on 25-5-2004. Irrigation was done manually (using bucket and tin) every
Plate (6): Collected neem fruits

Plate (7): Crushed neem seeds
three days. Every cage was thinned to 50 old seedlings, which were left for eight days to grow and develop to reach stage of good leaf growth, to allow easy uptake of active ingredient of the products.

3.5 Effect of treatments on development:

Test neem powders were studied through two types of applications (Seed dressing, Soil application). The following sets of treatments were investigated: -

T₀: Untreated caged millet plants (Control).

T₁: Caged millet plants treated with Celaflor® at 4 m/L (recommended dose) as standard neem treatment (pre-plant soil application).

T₂: Caged millet plants treated with Neem Seed Powder (NSP) as pre-plant seed dressing at 0.25 g/hole.

T₃: Caged millet plants treated with Neem Seed Powder (NSP) as pre-plant seed dressing at 0.50 g/hole.

T₄: Caged millet plants treated with Neem Seed Powder (NSP) as pre-plant soil application at 0.25 g/hole.

T₅: Caged millet plants treated with Neem Seed Powder (NSP) as pre-plant soil application at 0.50 g/hole.

In the seed dressing treatments and soil application treatments 0.25 and 0.50 g of neem seed powder were mixed with 0.50 g of millet seed.

Ten desert locust nymphs (2nd Instars) were starved for (24 hrs) and released into the cages containing the treated seedlings and were daily observed during the whole period of the experiment.

Each treatment was replicated three times, and units were arranged in Randomized Complete Block Design (RCBD). The daily observations included mortality, deformation, and duration of developmental period. Necessary correction, were done according to Abott's formula (1925).
Corrected mortality % = Test mortality % - Control mortality % 

\[ \frac{100 - \text{Control percentage}}{100} \]

Corrected mortality was subject to probit analysis according to Busvine (1972). Mortality data was also subject to time-probit analysis and analysis of \( \log t \).

The measurements of the antifeedant action on nymphal instars (2\(^{nd}\), 3\(^{rd}\), 4\(^{th}\), 5\(^{th}\)) of desert locust were recorded every three days by measuring the consumed area in 10 randomly selected leaves. Care was taken to exclude the attacked leaves and to adjust for previously measured consumption by marking the previously consumed areas.

3.6 Statistical analysis: -

All data was Statistically analyzed by ANOVA and means were separated by Duncan Multiple Range Test (DMRT) at 1% & 5%.
CHAPTER FOUR
RESULTS

4.1 The systemic action of neem seed products on the development of desert locust nymphs.

4.1.1 Effects on nymphal duration:

The effect of various neem products on developmental period was summarized in [Table (1) Fig (3) and Appendix (1)]. It is clear from the results that the various treatments with neem product significantly increased the developmental period of various nymphal instars. The results also indicated that increasing the concentration of neem seed powder in nymphal food resulted in progressive increase in nymphal period. The increase in the duration was highly significant from the control during both the 2nd and 5th instars, whereas the non-significant increases was noticed in the duration of the 3rd and 4th instars.

Neem seed powder caused delays in development surpass that caused by the based insecticide Celafor®. Both methods of application (soil application and seed dressing) gave comparable effects. Although seed dressing prevented further development after the 2nd or 3rd instars depending on the dose and therefore seemed to be more effective than soil application. Respective increases in the duration were summarized below.

The duration of the 2nd nymphal instar reared on millet seedlings treated with different dosages of soil applied neem seed powders (NSPs.a) were summarized in table (1). The respective increases in duration of this instar were 57.1 and 38% for the doses 0.50 and 0.25 g respectively. Higher dosage resulted in longer duration. The increase in duration of the 3rd nymphal instar was 15.7 and 5.3% while the increase in nymphal duration of the 4th nymphal instars was 20.7 and 13.4% for the doses 0.50 and 0.25 g respectively. The 5th nymphal instars duration was increased by 54.3 and 52.2% following the same order.
Whereas the total developmental period (2\textsuperscript{nd}-5\textsuperscript{th}) instar was increased by 36.7 and 27.8\% for the two respective doses. All treatments was highly significantly different at (p \geq 0.01) from the control especially for the 2\textsuperscript{nd} and 5\textsuperscript{th} instars.

Soil applied Celafor\textsuperscript{®} (4 m/L) gave 25.4, 60.5,19.6 and 51.1\% increase in the duration of the 2\textsuperscript{nd} 3\textsuperscript{rd},4\textsuperscript{th} and 5\textsuperscript{th} nymphal instars respectively [Table (1) Fig (3) and Appendix (1)].The increase in the total developmental period 2\textsuperscript{nd}–5\textsuperscript{th} is 39.9\%. The duration of the nymphal instars 2\textsuperscript{nd} reared on millet seedlings treated with different dosage of seed dressed with neem seed powders (NSPs.d) were summarized in Table (1) Fig (3) and Appendix (1). Increases in the duration of the 2\textsuperscript{nd} instars were 57.1 and 49\% for the doses 0.50 and 0.25 g respectively. The corresponding increase in nymphal duration of the 3\textsuperscript{rd} nymphal instars was 54\% for the dose doses 0.50 g. No further mouling occurred to the 3\textsuperscript{rd} instars similarly, the low dose .25 g prevented further mouling and nymphs died as overaged. All treatments were significantly different from the control Table (1) Fig (3) and Appendix (1).

4.1.2 The effect of the systemic action on the mortality of the nymphs: -

The following mortality cases among various nymphal instars of desert locust were delayed observed for upto 51 days after exposed to various treatments. Results were displayed in [Table (2) Fig (4) and Appendix (2)].

Most of the treatments were significantly different from the control. The mortality rate is dose-related and increases progressively as time advanced. The results show non- significant differences within the period 12-18 days in all treatments, however in the period 21-30 days the mortality rate was significantly different (p<0.01) from the control in all treatments except Celaflor treatment (T\textsubscript{1}). However, differences between the various dosage levels were sometimes non-significant. Between 33-51 days the mortality rate became highly significant (p<0.01) from the control in all treatments also except with Celafor treatment.
(T₁). Most of mortality cases occurred after molting. After 51 days the mortality rate became non-significant compared to the control in all treatments.

4.1.3 Deformation:

One case of deformation was noticed on desert locust nymphs fed on pearl millet seedlings treated with Celaflor applied in the soil and therefore data was not subjected to statistical analysis. No deformation was noticed in the control or other treatments.
Table I: The effect of systemic action of neem seed powder on the nympha duration of Desert locust.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>2nd instar duration (days)</th>
<th>3rd instar duration (days)</th>
<th>4th instar duration (days)</th>
<th>5th instar duration (days)</th>
<th>Total duration (2nd to 5th)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_1 ) (Standard)</td>
<td>7.9ab (25.4)</td>
<td>12.2a (60.5)</td>
<td>9.8a (19.6)</td>
<td>13.9a (51.1)</td>
<td>43.8 (39.9)</td>
</tr>
<tr>
<td>( T_2 ) (s.d 0.25 g/hole)</td>
<td>9.4a (49.2)</td>
<td>- (-)</td>
<td>- (-)</td>
<td>- (-)</td>
<td>- (-)</td>
</tr>
<tr>
<td>( T_3 ) (s.d 0.50 g/hole)</td>
<td>9.9a (57.1)</td>
<td>11.7a (54)</td>
<td>- (-)</td>
<td>- (-)</td>
<td>- (-)</td>
</tr>
<tr>
<td>( T_4 ) (s.a 0.25 g/hole)</td>
<td>8.7a (38)</td>
<td>8.0a (5.3)</td>
<td>9.3a (13.4)</td>
<td>14.0a (52.3)</td>
<td>40 (27.8)</td>
</tr>
<tr>
<td>( T_5 ) (s.a 0.50 g/hole)</td>
<td>9.9a (57.1)</td>
<td>8.8a (15.7)</td>
<td>9.9a (20.7)</td>
<td>14.2a (54.3)</td>
<td>42.8 (36.7)</td>
</tr>
<tr>
<td>( T_6 ) (Control)</td>
<td>6.3b (0.0)</td>
<td>7.6a (0.0)</td>
<td>8.2a (0.0)</td>
<td>9.2b (0.0)</td>
<td>31.3 (0.0)</td>
</tr>
<tr>
<td>LSD</td>
<td>2.22**</td>
<td>3.89</td>
<td>3.73</td>
<td>2.64**</td>
<td></td>
</tr>
<tr>
<td>CV%</td>
<td>9.87</td>
<td>21.39</td>
<td>21.29</td>
<td>6.83</td>
<td></td>
</tr>
</tbody>
</table>

- Mean values having the same letter in each column are not differing significantly \((p<0.05)\).
- Values having ** are highly differing significantly \((p<0.01)\).
- Values between brackets represents the percentage increase in nympha duration.
- Least Significant difference (L.S.D).
- Coefficient of variations (C.V).
- No duration (-)
Table 2: Mortalities Percentage among desert locust 2nd instar fed on millet seedlings treated systemically with eem seed powder

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Period of Experiment (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td>T1</td>
<td>(6.5a)</td>
</tr>
<tr>
<td></td>
<td>{14.78}</td>
</tr>
<tr>
<td>T2</td>
<td>(0.0a)</td>
</tr>
<tr>
<td></td>
<td>{0.57}</td>
</tr>
<tr>
<td>T3</td>
<td>(0.0a)</td>
</tr>
<tr>
<td></td>
<td>{0.57}</td>
</tr>
<tr>
<td>T4</td>
<td>(5.0a)</td>
</tr>
<tr>
<td></td>
<td>{12.79}</td>
</tr>
<tr>
<td>T5</td>
<td>(0.0a)</td>
</tr>
<tr>
<td></td>
<td>{0.57}</td>
</tr>
<tr>
<td>T0</td>
<td>(1.5a)</td>
</tr>
<tr>
<td></td>
<td>{6.87}</td>
</tr>
<tr>
<td>SE+</td>
<td>5.92NS</td>
</tr>
<tr>
<td>CV%</td>
<td>149.16</td>
</tr>
</tbody>
</table>

- Values between ( ) represent the percentage mortality.
- Values between {    } is transformed data by arcsine Transformation.
- Values having different letters in each column differ significantly (p<0.05) and highly significant (p<0.01) according to Duncan Multi Range Test (DMRT).
Fig (3): Percentage increase in the duration of various nymphal instars of desert locust reared on systemically treated millet seedlings.
Fig (4): % Mortality of desert locust nymphs (2nd-5th) fed on millet seedlings systemically treated with Neem seed powder.
4.2 probit analysis of relative toxicities of neem seed powder to the 2nd - 5th Nymphal Instar of Desert Locust:

The time mortality response of the effect of the different doses of neem seeds powder (0.25 and 0.50 g) used as seed dressing and soil application on the nymphs of the desert locust were subjected to probit analysis.

4.2.1 Time response at 0.25 g:

Table (3), Fig (5) show the comparative time related toxicities data of the dose 0.25 g of neem seed powder used as seed dressing (NSP<sub>s,d</sub>) and soil application (NSP<sub>s,a</sub>).

The results indicated that, the test population slope was fairly homogenous as indicated by the values of the slope of LT-P line (slope range 5.6-8) and narrow LT<sub>90</sub>/LT<sub>50</sub> ratios (1.4-1.6). The LT<sub>50</sub> values ranges between 552 and 588 hours, whereas LT<sub>90</sub> values ranged between 799 and 995 hours.

4.2.2 Time response at 0.50 g:

Table (3), Fig (6) show the comparative time related toxicities data of the dose 0.50 g of neem seed powder used as seed dressing (NSP<sub>s,d</sub>) and soil application (NSP<sub>s,a</sub>).

The results indicated that, the slope of mortality regression line LT-p were steep and positive (slopes range between (6.35-8) with LT<sub>50</sub> values ranged between 569 and 672 hours and LT<sub>90</sub>/LT<sub>50</sub> ratios (1.4-1.5). The LT<sub>90</sub> values ranged between 822 and 1069 hours.

The results indicated that, the seed dressing treatment is more effective than soil application treatment.
Table (3): Time response (mortality) data of the nymphal instars of desert locust fed on millet seedlings treated with neem seed powder applied as seed dressing and in the soil at doses of 0.25 and 0.50 g respectively.

<table>
<thead>
<tr>
<th>Doses</th>
<th>Days</th>
<th>$LT_{50}$</th>
<th>$LT_{90}$</th>
<th>$LT_{90}/LT_{50}$ ratio</th>
<th>Slope</th>
<th>Chi-square</th>
<th>D.F</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSPs.d at 0.25</td>
<td>23.33</td>
<td>252</td>
<td>799</td>
<td>1.4</td>
<td>8</td>
<td>0.3</td>
<td>13</td>
</tr>
<tr>
<td>NSPs.d at 0.05</td>
<td>23.34</td>
<td>569</td>
<td>822</td>
<td>1.4</td>
<td>8</td>
<td>0.3</td>
<td>13</td>
</tr>
<tr>
<td>NSPs.a at 0.25</td>
<td>24.41</td>
<td>588</td>
<td>995</td>
<td>1.6</td>
<td>5.6</td>
<td>0.3</td>
<td>14</td>
</tr>
<tr>
<td>NSPs.a at 0.05</td>
<td>24.44</td>
<td>672</td>
<td>1069</td>
<td>1.5</td>
<td>6.4</td>
<td>0.5</td>
<td>13</td>
</tr>
</tbody>
</table>
4.3 Effect of Feeding by Various Nymphal Instars of Desert Locust on Millet Treated with Different Dosages of Neem Seed Powder Extract (NSPE).

4.3.1 Food Intake: -

The results summarized in Table (4), Fig (7) and Appendix (3) show that the amount of food ingested by the different nymphal
instars of Desert Locust (2\textsuperscript{nd}, 3rd, 4\textsuperscript{th}, 5\textsuperscript{th}) from various types of treated food (pear millet seedlings systemically treated plants). The results revealed that the amount of ingested food is negatively related to the dose. Increasing the dose of neem results in progressive decrease in the amount of food ingested. This observation is true for the various instars studied (2\textsuperscript{nd} – 5\textsuperscript{th}). The overall percentage reduction in food intake by all nymphal instars ranges from 21.75-47.14\% for the different methods of application. All treatments significantly suppressed the feeding rate of test insects compared to the control. Azadirachtin as Celaflor at the recommended dose 4 m/L reduced the feeding by 7.70 \% which was not a significant reduction compared to the control.
Table (4): Amount of ingested food area (cm²) and % reduction in food intake of various desert Locust instars (2nd -5th) fed on millet seedlings treated Systemically with neem powder.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Means</th>
<th>% Reduction in food intake by various desert locust nymphs instars</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁ (standard)</td>
<td>40.53a</td>
<td>7.70</td>
</tr>
<tr>
<td>T₂ (s.d 0.25 g/hole)</td>
<td>34.36b</td>
<td>21.75</td>
</tr>
<tr>
<td>T₃ (s.d.50 g/hole)</td>
<td>24.11c</td>
<td>45.09</td>
</tr>
<tr>
<td>T₄ (s.a 0.25 g/hole)</td>
<td>33.11b</td>
<td>24.60</td>
</tr>
<tr>
<td>T₅ ( s.a 0.50 g/hole)</td>
<td>23.21c</td>
<td>47.14</td>
</tr>
<tr>
<td>T₀ (Control)</td>
<td>43.91a</td>
<td>0.0</td>
</tr>
<tr>
<td>L.S.D</td>
<td>4.53**</td>
<td></td>
</tr>
<tr>
<td>SE⁺</td>
<td>1.44</td>
<td></td>
</tr>
<tr>
<td>C.V %</td>
<td>7.51</td>
<td></td>
</tr>
</tbody>
</table>

-Mean values having same letters are not significantly different (P≤0.05)

According to DMRT.

- Least Significant difference (L.S.D).

- Coefficient of variations (C.V).

- Standard error (SE +).
Chapter Five

Discussion

One of the promising sources of natural products is neem tree. Large body of information on properties of pesticides from the Neem tree (*Azadirachta indica* A. Juss) is currently available (Schmutterer, *et al.*, 1980; Menn, 1983; Anon, 1992).


In the current study, various aspects of systemic activity of different concentrations of neem seed powder and a commercial neem preparation (NSP and azadirachtin as Celaflor®, 4 m/L) were tested against various instars of desert locust. Aspects covered included evaluation of effects on development of immature, deformation, mortality and food intake. The products were evaluated in a semi-field experiment in caged millet seedlings with objectives of predetermining validation of Elamin (2002) findings.

According to Elamin (2002) individuals who are able to consume lager amount of food, reach the critical body weight for moulting faster, and therefore develop, and were able to proceed to the next moult. Once the feeding rate decrease they remain as immature without further moulting, whether this argument is true or not, further investigation is needed. It was planned to investigate this argument in the current study but for shortage of time, it was not done. Further research should look at this area.

The results of the current study showed a dose dependent antifeedant effect of neem seed powder applied by various methods as indicated by the significant
reduction in food intake. All modes of application gave superior suppression of food intake compared to celaflor® 4 m/L.

Elamin (2002) examined the systemic activity of various neem products in potted millet plants, and reported strong systemic activity of various neem products tested and (growth regulatory, antifeedant and mortality) against Desert Locust immatures.

Previously mentioned authors reported the antifeedant effect of neem. Neem exert its antifeedant action through gustation at physiological site associated with chemoreceptors (Fagoone, 1981; pradhan et al., 1962; Gill and lewis, 1971; Goyal et al., 1971).

Neem seed product posses systemic activity, which was first proved by Gill (1972) who reported a systemic antifeedant action of three-neem compounds compared to the control and gave similar results compared to neem seed powder treatments. McMillian et al., (1969) found that extracts from leaves of the chinaberry tree, Melia azadirach L. deterred feeding, retarded development, and caused mortality in the larval stage of the corn army worm, Heliothis zea (Baddie) and the fall army worm, Spodoptera frugiperda (H. E. Smith) when incorporated into a meridic diet or applied to corn seedlings. Gill and Lewis (1971) found that different neem seed preparations applied to soil protected bean plants for upto 25 days against S. gregaria, they also found that bean seedlings grown from seed soaked for 25 hours in 0.01% ansSd 1% solutions of azadirachtin (alcholol extract and water extract of neem seed) were protected against damage by S. gregaria adult for one week after germination. In field trials in Togo spraying of crude of methanolic extract of neem seeds at weekly intervals protected okra plants from Podagrlica spp and Sylapta derogata F. damage (Adhikary, 1984). Results indicated that plants can be protected from pest attack for long period (more than 45 days) (Saxena et al., 1984 and Schoonhoven, 1984).

Results reported have indicated that neem seed powder applied by seed dressing and /or soil application finally induced significant mortalities among test nymphs. The
line slopes for the doses 0.25 and 0.50g were steep and positive indicating a homogenous test population. The homogeneity of response is also evident from the narrow LT_{50} / LT_{90} ratios and low chi-square values. Complete mortalities of test nymphs subject to various treatments occurred within 3-6 weeks. One of test instar was deformed prior to death. The malformations occurred far less frequently than it has been observed in laboratory trials with *S. gregaria* (Nicol and Schmutterer, 1991).

Completely prevented further moulting after the 2^{nd} or 3^{rd} instar is depending upon the dose applied. Results indicated that, various neem seed products are capable of delaying the development of all tested instars of Desert Locust. The delay in development, is dose–related in most cases, with a significant delay in 2^{nd} and 5^{th} instar, while a noticeable delay occurred in the development of the 3^{rd} and 4^{th} instars but effect were statistically not significant. NSP caused delay in development surpasses that caused by the neem based formulation (Celaflor®). The two modes of application give comparable results.

In the later, most of tested 2^{nd} instar individuals either never moult to the third instar or moulted without further development and died as overaged 3^{rd} instar nymphs. Prolongation (delay) of development by neem seed products is well documented and current results agree with the findings of previous authors (Sharma, 1983; Kubo and Klock, 1982; Remblod *et al*., 1984; Elamin, 2002). The later author (Elamin, 2002) conducted a thorough testing of efficiency of systemic activity of various neem products against Desert Locust immatures in potted plants. His findings reported similar trend of delay with reported values being relatively higher than the current findings. The discrepancy from his results can be explained by the difference in the experimental conditions (potted vs. filed exp.) as well as differences in methods of application and doses tested.

Active principle of neem could mostly kill test insects through feeding suppress and/or growth regulatory effects on immature stages. As reported by Ruscoe (1972) and Ruskin (1991) azadirachtin, the active principle of neem, the
structurally similar to ecdysone which are ecdsyteriod hormones controlling metamorphosis in insects. Azadirachtin affect the corpus allatum, which secrete vital hormones in insects. Azadirachtin blocks the secretion and release of ecdysone and this may delay the moulting process and therefore prolong the duration of the immature stages and causes the associated deformations and mortality before or during moulting process (Rembold et al., 1984 and Schumttterer, 1991). Reduction in food intake might also lead to the prolongation of the nymphal period and deformation of test immature, which they must reach a critical body weigh for moulting (Ruskin, 1991; Elamin, 2002). Azadirachtin seem to prolong the time needed by the immatures to gain the critical body weigh through its suppression of feeding rate (Ruscoe, 1972; Joshi and RamaPrasad, 1975; Jacobson et al., 1978 and Mohamed, 1999). The fact that many of test nymphs either died within the 2nd nymphal stage or succeeded to molt to the third stage with or without further moulting may support this argument (Elamin, 2002).

The observed mortalities may results from the growth regulatory effects, delay in develop and deformations, the drastic reduction in food intake observed and /or direct toxic action. These modes were previously reported as possible modes of neem action (Jacobson, et al., 1978; Fagoone and Lauge, 1981; Hellpap, 1984 and Saxena and Khan, 1985). Steets (1976) reported that application of 2-5, 5 and 10% solutions of neem leaf extract to bean leaves inhibited the growth of 1st instar larvae of the Mexican bean beetle, Epilachna varivestis Muls and caused 100% larval mortality. He also reported that 4th instar larvae of diamond back moth, Plutella xylosella L., treated with 2.5 and 5% methanol: water (1:1) solutions of neem leaf extract, could not pupate. Mariappan and Saxena (1984) reported that application of neem oil, custard oil and their mixtures to rice seedling significantly reduced the survival of the green leafhopper, Nepholetix viresens (Distant) and its transmission of the rice tungro virus. Saxena, et al., 1981 found that the pests feeding behavior, growth,
longevity, fecundity and ovisposition in neem oil treated rice were adversely affected and the incidence of the hopper transmitted ragged stunt virus disease was significantly reduced in neem oil-sprayed field. The current study may be further improved by refining extraction and application procedures. Field evaluations of systemic action of various natural products against immature stages of desert locust through continuous treatment of vegetation in breeding site deserve further studies. Stability of natural product tested under field conditions of equal significance and must be considered in further line of research.
Conclusion and Recommendations

1. The semi-field evaluation of systemic action of neem powder gave encouraging results confirming the previous findings of Elamin (2002) in potted plants.

2. Neem powder tested by various methods of application showed significant systemic activity against test insects.

3. The Systemic action on locust immatures was manifested as suppression in moulting, delay in development, deformation, mortality and suppression of feeding activity. These effects could be attributed to the growth regulatory, antifeedant and insectcidal activities of various neem products.

4. The effects were dependent on dose.

5. Soil treatments (systemic action) could have additional merits such as protection against photo-degradation, decrease in frequency of application as well as high safety margin for human and natural enemies.

6. Seed dressing treatments gave better results compared to soil application and therefore needed further investigation.

7. Complete mortality of desert locust nymphs under semi-field condition was noticed after 3-6 weeks from treatments with neem seed powder.

8. Field evaluation of efficiency of neem powder in small scale experiment against Desert Locust and their stability
under field condition should be investigated in future lines of research.

9. Systemically applied neem powder provide a promising agents to be used in early stages of Desert Locust development before outbreak and may not be a suitable for intervention of plague and outbreak situation because of slow action.

10. The efficiency of neem powder usage in breeding sites for long term management of Desert Locust under field conditions deserve further confirmatory semi-field and field experiments to validate these findings.

11. Further improvement of application method of neem powder needs further studies.

12. Efficiency of neem powder on plants endogenous to the natural breeding sites of Desert Locust must be investigated as well.

13. The products of neem and other natural flora must be evaluated also under improved extraction and fine application procedure.
REFERENCES


Menn, J.J. (1983). Present Insecticides and Approaches to Discovery of Environmentally Acceptable Chemicals for Pest Management; P-5-25, in: Natural Products for Innovative Pest Management (D.L.


Appendixes
**Appendix (1): Nymphal duration (days) of desert locust nymphs reared on millet seedlings systemically treated with NSP**

| Treatments | 2nd Instar | | | | 3rd Instar | | | | | 4th Instar | | | | | 5th Instar | | | |
|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|            | R1         | R2         | R3         | Average    | R1         | R2         | R3         | Average    | R1         | R2         | R3         | Average    | R1         | R2         | R3         | Average    | R1         | R2         | R3         | Average    |
| T₁ (standard) | 6.6        | 8.4        | 8.8        | 7.9        | 15         | 12.2       | 9.3        | 12.2       | 9          | 11.4       | 9          | 9.8        | 13.6       | 13.6       | 14.5       | 13.9       |
| T₂ (S.d 0.25 g/hole) | 10         | 9.6        | 8.6        | 9.4        | -          | -          | -          | -          | -          | -          | -          | -          | -          | -          | -          | -          |
| T₃ (S.d 0.50 g/hole) | 10         | 10         | 9.6        | 9.9        | 13         | 14.1       | 8          | 11.7       | -          | -          | -          | -          | -          | -          | -          | -          |
| T₄ (S.a 0.25 g/hole) | 8.6        | 8.8        | 8.8        | 8.7        | 7          | 9          | 8          | 8.0        | 8          | 11         | 9          | 9.3        | 14         | 14.8       | 13         | 14.0       |
| T₅ (S.a 0.50 g/hole) | 8          | 11         | 10.8       | 9.9        | 9.6        | 7          | 9.8        | 8.8        | 12.5       | 7          | 10.2       | 9.9        | 13         | 14         | 15.5       | 14.2       |
| T₀ (Control) | 5.5        | 6.8        | 6.6        | 6.3        | 7.5        | 7.8        | 7.4        | 7.6        | 8.5        | 8          | 8          | 8.2        | 8.5        | 9          | 10         | 9.2        |

**Treatments were:**
- T₁ = Celafor (recommended dose 4 m/L).
- T₂ = Seed dressing (NSPs.d at 0.25 g/hole).
- T₃ = Seed dressing (NSPs.d at 0.50 g/hole).
- T₄ = Soil application (NSPs.a at 0.25 g/hole).
- T₅ = Soil application (NSPs.a at 0.50 g/hole).
- T₀ = Control
Appendix (1-a): Mean square of duration (days) of 2\textsuperscript{nd} instar nymphal of desert locust reared on systemically treated millet seedlings by neem seed powder.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t) 5%</th>
<th>Pr &gt; F (t) 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
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<td>3.1677</td>
<td>1.5839</td>
<td>2.15NS</td>
<td>4.10</td>
<td>7.56</td>
</tr>
<tr>
<td>Treatments</td>
<td>5</td>
<td>29.1627</td>
<td>5.8325</td>
<td>7.93**</td>
<td>3.33</td>
<td>5.64</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>7.3590</td>
<td>0.7359</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>39.6894</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix (1-b): Mean square of duration (days) of 3\textsuperscript{rd} in star nymphal of desert locust reared on systemically treated millet seedlings by neem seed powder.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t) 5%</th>
<th>Pr &gt; F (t) 1%</th>
</tr>
</thead>
<tbody>
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<td>Block</td>
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<td>10.2613</td>
<td>5.1307</td>
<td>1.20NS</td>
<td>4.46</td>
<td>8.65</td>
</tr>
<tr>
<td>Treatment</td>
<td>4</td>
<td>54.9640</td>
<td>13.7410</td>
<td>3.22NS</td>
<td>3.84</td>
<td>7.01</td>
</tr>
<tr>
<td>Error</td>
<td>8</td>
<td>34.0920</td>
<td>4.2615</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>99.3173</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix (1-c): Mean square of duration (days) of 4\textsuperscript{th} in star nymphal of desert locust reared on systemically treated millet seedlings by neem seed powder.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t) 5%</th>
<th>Pr &gt; F (t) 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>0.4200</td>
<td>0.2100</td>
<td>0.05NS</td>
<td>5.14</td>
<td>10.92</td>
</tr>
<tr>
<td>Treatment</td>
<td>3</td>
<td>5.6867</td>
<td>1.8956</td>
<td>0.48NS</td>
<td>4.76</td>
<td>9.78</td>
</tr>
</tbody>
</table>
Appendix (1-d): Mean square of duration (days) of 5th in star nymphal of desert locust reared on systemically treated millet seedlings by neem powder.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>Block</td>
<td>2</td>
<td>1.9217</td>
<td>0.9609</td>
<td>1.26NS</td>
<td>5.14</td>
</tr>
<tr>
<td>Treatment</td>
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<td>52.6892</td>
<td>17.5631</td>
<td>23.02**</td>
<td>4.76</td>
</tr>
<tr>
<td>Error</td>
<td>6</td>
<td>4.5783</td>
<td>0.7931</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>59.1892</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Were: -
- Degree of Freedom (D.F).
- Sum Square of treatments (SS).
- Mean Square of treatments (MS).
- F Calculated Value (c).
- F Tabulated Value (t).
- Non Significant (NS).
- Highly significant (**).
Appendix (2-a): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 12 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t) 5%</th>
<th>Pr &gt; F (t) 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>802.9983</td>
<td>401.4992</td>
<td>3.82 NS</td>
<td>4.10</td>
<td>7.56</td>
</tr>
<tr>
<td>Treatments</td>
<td>5</td>
<td>960.7502</td>
<td>192.1500</td>
<td>1.83 NS</td>
<td>3.33</td>
<td>5.64</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>1050.0727</td>
<td>1050.0073</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>281308122</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SE= ± 5.92 CV= 49.16%.

Appendix (2-b): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 15 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t) 5%</th>
<th>Pr &gt; F (t) 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>297.3862</td>
<td>148.6931</td>
<td>0.46 NS</td>
<td>4.10</td>
<td>7.56</td>
</tr>
<tr>
<td>Treatments</td>
<td>5</td>
<td>451.3864</td>
<td>90.2773</td>
<td>0.28 NS</td>
<td>3.33</td>
<td>5.64</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>3245.8849</td>
<td>324.5885</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>3994.6575</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

SE= ± 3.40 CV = 90.53%.

Appendix (2-c): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 18 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t) 5%</th>
<th>Pr &gt; F (t) 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>36.4570</td>
<td>18.2285</td>
<td>0.12 NS</td>
<td>4.10</td>
<td>7.56</td>
</tr>
<tr>
<td>Treatments</td>
<td>5</td>
<td>1133.7061</td>
<td>226.7412</td>
<td>1.49 NS</td>
<td>3.33</td>
<td>5.64</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>1552.7573</td>
<td>155.2757</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>2722.9204</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SE= ±7.19 CV = 46.20%.
Appendix (2-d): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 21 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t) 5%</th>
<th>Pr &gt; F (t) 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>615.7401</td>
<td>307.8701</td>
<td>4.84*</td>
<td>4.10</td>
<td>7.56</td>
</tr>
<tr>
<td>Treatments</td>
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<td>996.3918</td>
<td>199.2784</td>
<td>3.14*</td>
<td>3.33</td>
<td>5.64</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>635.5403</td>
<td>63.5540</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>2247.6722</td>
<td></td>
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</tr>
</tbody>
</table>

SE= ±4.460 CV= 24.76%.

Appendix (2-e): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 24 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t) 5%</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
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<td>491.7195</td>
<td>245.8598</td>
<td>3.36NS</td>
<td>4.10</td>
<td>7.56</td>
</tr>
<tr>
<td>Treatments</td>
<td>5</td>
<td>1063.6656</td>
<td>212.7331</td>
<td>3.14*</td>
<td>3.33</td>
<td>5.46</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>678.0809</td>
<td>67.8080</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>2233.4655</td>
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</tr>
</tbody>
</table>

SE= ±4.75 CV= 24.86%.

Appendix (2-f): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 27 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t) 5%</th>
<th>Pr &gt; F (t) 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
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<td>93.2501</td>
<td>46.6251</td>
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</tr>
<tr>
<td>Treatments</td>
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<td>3849.9813</td>
<td>769.9963</td>
<td>3.46*</td>
<td>3.33</td>
<td>5.64</td>
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<tr>
<td>Error</td>
<td>10</td>
<td>2223.3348</td>
<td>222.3335</td>
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<td></td>
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<td>6166.5662</td>
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</tr>
</tbody>
</table>

SE= ±8.61 CV=36.31%.
Appendix (2-g): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 30 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
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<td>94.8393</td>
<td>0.35NS</td>
<td>4.10 7.56</td>
</tr>
<tr>
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<td>5330.6099</td>
<td>1060.1220</td>
<td>3.97*</td>
<td>3.33 5.64</td>
</tr>
<tr>
<td>Error</td>
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<td>2688.5731</td>
<td>268.8573</td>
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<td></td>
</tr>
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<td>8208.8616</td>
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</tbody>
</table>

SE= ±9.47 CV= 36.41%.

Appendix (2-h): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 33 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
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<th>MS</th>
<th>F value (c)</th>
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</thead>
<tbody>
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<td>1356.0057</td>
<td>5.65**</td>
<td>3.33 5.64</td>
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<tr>
<td>Error</td>
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<td>2398.3690</td>
<td>239.8369</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>9461.0356</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

SE= ±8.94 CV= 30.31%.

Appendix (2-i): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 36 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>282.6383</td>
<td>141.3192</td>
<td>0.59NS</td>
<td>4.10 7.56</td>
</tr>
<tr>
<td>Treatments</td>
<td>5</td>
<td>6780.0283</td>
<td>1356.0057</td>
<td>5.56**</td>
<td>3.33 5.64</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>2398.3690</td>
<td>239.8369</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>9461.0356</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

SE= ±8.94 CV= 30.31%.
Appendix (2-j): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 39 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t)</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>Block</td>
<td>2</td>
<td>515.75257</td>
<td>257.8629</td>
<td>1.15 NS</td>
<td>4.10 7.56</td>
</tr>
<tr>
<td>Treatments</td>
<td>5</td>
<td>8208.6911</td>
<td>1641.7383</td>
<td>7.32 **</td>
<td>3.33 5.64</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>2242.0302</td>
<td>224.2030</td>
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</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>10966.4470</td>
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</tr>
</tbody>
</table>

SE= ±8.64 CV= 22.55%

Appendix (2-k): Mortalities cases among desert locust nymphs (2nd instar) fed on Millet seedlings treated with NSPs.a after 42 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t)</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>Block</td>
<td>2</td>
<td>584.7185</td>
<td>292.3593</td>
<td>1.80 NS</td>
<td>4.10 7.56</td>
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<tr>
<td>Treatments</td>
<td>5</td>
<td>7347.0766</td>
<td>1469.4153</td>
<td>9.05 **</td>
<td>3.33 5.64</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>1622.7827</td>
<td>162.2783</td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>9554.5778</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SE= ±7.35 CV= 18.79%

Appendix (2-l): Mortalities cases among desert locust nymphs (2nd instar) fed on millet seedlings treated with NSPs.a after 45 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t)</th>
</tr>
</thead>
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<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>2</td>
<td>273.2722</td>
<td>136.6361</td>
<td>0.73 NS</td>
<td>4.10 7.56</td>
</tr>
<tr>
<td>Treatments</td>
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<td>5710.7168</td>
<td>1142.1434</td>
<td>6.07 **</td>
<td>3.33 5.64</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>1882.5797</td>
<td>188.2580</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>7866.5687</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

SE=±7.92 CV=19.70%
Appendix (2-m): Mortalities cases among desert locust nymphs (2nd instar) fed on millet seedlings treated with NSPs after 48 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(c)</td>
<td>5%</td>
</tr>
<tr>
<td>Block</td>
<td>2</td>
<td>480.6225</td>
<td>240.3112</td>
<td>1.94NS</td>
<td>4.10</td>
</tr>
<tr>
<td>Treatments</td>
<td>5</td>
<td>4776.4722</td>
<td>955.2944</td>
<td>7.71**</td>
<td>3.33</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>1238.7367</td>
<td>123.8737</td>
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</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>6495.8314</td>
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</tr>
</tbody>
</table>

SE= +28.80 CV= 15.22%.

Appendix (2-n): Mortalities cases among desert locust nymphs (2nd instar) fed on millet seedlings treated with NSPs after 51 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(c)</td>
<td>5%</td>
</tr>
<tr>
<td>Block</td>
<td>2</td>
<td>419.0625</td>
<td>209.5313</td>
<td>1.50 NS</td>
<td>4.10</td>
</tr>
<tr>
<td>Treatments</td>
<td>5</td>
<td>4106.8545</td>
<td>821.3709</td>
<td>5.90**</td>
<td>3.33</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>1392.7827</td>
<td>139.2783</td>
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</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>5918.6997</td>
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</tr>
</tbody>
</table>

SE= +6.81 CV= 15.28%.

Appendix (2-s): Mortalities cases among desert locust nymphs (2nd instar) fed on millet seedlings treated with NSPs after 54 days.

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D. F</th>
<th>SS</th>
<th>MS</th>
<th>F value (c)</th>
<th>Pr &gt; F (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(c)</td>
<td>5%</td>
</tr>
<tr>
<td>Block</td>
<td>2</td>
<td>1076.8189</td>
<td>538.4095</td>
<td>2.98NS</td>
<td>4.10</td>
</tr>
<tr>
<td>Treatments</td>
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<td>2407.9994</td>
<td>481.5999</td>
<td>2.66NS</td>
<td>3.33</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>1809.1437</td>
<td>180.9144</td>
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</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>5293.9620</td>
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</tr>
</tbody>
</table>

SE= +7.77 CV= 16.93%
Appendix (3): Mean Square of ingested food by various instars of desert locust fed on millet seedlings systemically treated by neem seed powder (N.S.Ps.a and N.S.Ps.d).

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>D.F</th>
<th>SS</th>
<th>MS</th>
<th>F value (C)</th>
<th>Pr &gt; F(0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>Block</td>
<td>2</td>
<td>31.3465</td>
<td>15.6733</td>
<td>2.52</td>
<td>4.10</td>
</tr>
<tr>
<td>Treatments</td>
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<td>1056.2768</td>
<td>211.2554</td>
<td>34.01**</td>
<td>3.33</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>62.1187</td>
<td>6.2119</td>
<td></td>
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<tr>
<td>Total</td>
<td>17</td>
<td>1149.7420</td>
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</tr>
</tbody>
</table>

CV = 7.51 % SE = ±1.44