Addis Ababa University
School of Graduate Studies
Faculty of Life Science

Study on the potential of some botanical Powders and Nimbecidine® for the management of Sesame seed bug (*Elasmolomus sordidus*, Fab.) (Hemiptera: Lygaeidae) in Humera, Northwest Ethiopia

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DEDICATION

To my beloved mother Letegebreal Yihdego and my step father Gebretsadkan Gebremikeal who had sacrificed much to bring me up to this level but passed away at a very early stage without seeing the final fruits of their effort.

To the late my grandfather Yihdego Legesse for his long-lasting advises and blessings

Certificate of Approval by Examiners

As member of the Board of Examiners of the M.Sc Thesis Open Defense Examination, we certify that we have read, evaluated the Thesis prepared by Selemun Hagos and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Science Program Unit (Insect science).

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Abstract

Sesamum indicum is one of the oldest oil seed crop grown for its high oil content in many countries. *Elasmolomus sordidus* is the major pest of sesame seeds both in field and storage condition. This experiment was done to evaluate the efficacy of Pyrethrum (*Chrysanthemum cinaraefolium*), neem (*Azadirachta indica*), birbira (*Milletia ferruginea*) and nimbecidine oil for the management of the series sesame seed pest, *E. sordidus* as alternative management options of synthetic pesticides. The bug was reared in the field on sesame seeds as a feed and the other test in the laboratory at 32±2^{0}C and 50 to 60% RH. Powder of pyrethrum, neem, birbira, and nimbecidine oil were tested under laboratory condition for its ability to protect sesame seeds against *E. sordidus* with respect to adult and nymph mortality, egg inhibition and seed weight and oil loss. For comparison standard check malathoin and untreated sesame seeds were included. Moreover treated sesame seeds and bagging materials were provided to evaluate the efficacy of treated seeds against weight loss due to *E. sordidus*. In addition treated sesame seeds in open plastic buckets were also provided in highly infested area to evaluate the efficacy of the botanicals against uncontrolled visitors of sesame seed bug both in weight loss and mean mortality. Hundred percent mortality of adult and nymph of *E. sordidus* were obtained with Pyrethrum powder at all levels of concentrations after 24 hour exposure time. About 100% mortality was also obtained in all concentrations of neem and birbira after 48hrs after treatment application. Nimbecidine also achieves >90% nymph and >70% adult mortality 48 hrs after treatment application. Sesame seeds treated with the botanicals also achieved excellent egg inhibition up to >70% in pyrethrum. Sesame seeds treated with neem and nimbecidine showed low weight loss than Malathion treated seeds after 50th day storage in the shade area due to the *E. sordidus*. In the treated sacks neem and nimbecidine showed lower weight loss than the others but there was no difference from Malathion. In open bucket lowest weight loss, oil loss and highest mortality of uncontrolled visiting seed bug was recorded in pyrethrum than the other treatments with no recorded oil loss in the closed control. Accordingly, these results indicated that the use of powders of the tested plants and nimbecidine can give effective control of the most important pest of stored sesame seed *E. sordidus.*

Keywords: *Elasmolomus sordidus*, sack treatment, seed treatment, uncontrolled visitors, shade, plant powders, weight loss

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) has early origins in East Africa and in India (Bedigian, 1985; Nayar and Mehra, 1970). It is belongs to the Pedaliaceae plant family which has bell-shaped flowers and opposite leaves. It is an erect annual plant that can reach two metres in height. Sesame cultivars grown commercially require 90 to 110 days from planting to reach physiological maturity (Opling1990 and Weiss, 2000).

It is one of the world's oldest oil seed crops grown mainly for its seeds that contain approximately 52 to 57% oil and 25% protein (Smith *et al.,* 2000; Khan 2009 and Umar *et al.,* 2010). Sesame has early origins in East Africa and in India (Bedigian, 1985; Nayar and Mehra, 1970). It has been grown in the near east and Africa for over 5,000 years for cooking and medicinal needs. The oil was used in barter since it would preserve and store in the desert for years (Smith *et al.,* 2000).

The oil seeds sector is one of Ethiopia's fastest growing and important sectors, both in terms of its foreign exchange earnings and as a main source of income for over three million Ethiopians. It is the second largest source of foreign exchange earnings after coffee. Study reports indicate that Ethiopia is among the top five producers of sesame seed, linseed and Niger seed (Wijnands *et al.,* 2007).

Sesame is rich in natural antioxidants or lignans, which are both oil and water-soluble. These antoxidative compounds provide very long shelf life and stable characteristics of sesame seed and oil (Ermias *et al.,* 2009 and Smith *et al.,* 2000). Furthermore, they are biologically active and provide a variety of healthy benefits upon ingestion. These compounds are being researched as potential industrial antioxidants and nutraceutical and pharmaceutical ingredients (Smith *et al.,* 2000). Despite its importance, the production and productivity of sesame is greatly affected by biotic and abiotic factors. Insect pests are one of the most important factors affecting the production of sesame both in quality and quantity (Ahirwar *et al.,* 2010, Egonyu *et al.,* 2005). Several pests attack sesame, with potential to limit economic production around the world. Some of these pests causes moderate to severe yield losses (Smith *et al.,* 2000). In Ethiopia however, only the sesame webworm *(Antigastra catalaunalis),* sesame seed bug (*Elasmolomus sordidus*), gallmidge (*Asphondilia sesami*), green vegetable bug *(Nezara viridula)* grasshoppers, African Bollworm, (*Helicoverpa armiger*), and crickets have been recorded.

Several liquid and dust formulations of insecticides have been recommended for the control of pests of sesame in different countries (Egonyu *et al.,* 2005). The use of more biodegradable pest control materials with greater selectivity might help to avoid the disadvantage caused by the use of synthetic pesticides (Raguraman and Singh, 1999). Therefore, in order to increase sesame seed export from Ethiopia minimizing the use of synthetic insecticides directly on sesame seed has to be promoted. Thus, finding safe alternative method to synthetic insecticides use is imperative. In line with this the following research work was carried out having the objectives listed below.

1.1 Objectives

1.1.1 General objective

- To find alternative and safe methods of sesame seed bug (*Elasmolomus sordidus,* Fab.) control to promote the export market of sesame seed from Ethiopia.

1.1.2 Specific objectives:

1. To evaluate the effect of Neem and Birbira seed powders, Pyrethrum flower powder and Nimbecidine® on the infestation of and damage to sesame by the Sesame seed bug, *E. sordid s*under storage condition by treating the Hessian sacks and the seeds.
2. To investigate the effect Neem and Birbira powders, Pyrethrum flower powder and Nimbecidine® on survival of nymphs and adults of Sesame seed bug (*E. sordidus)* under laboratory conditions.
3. To evaluate potential of these botanicals and Nimbecidine® in egg inhibition
4. To evaluate the potential of the botanicals and Nimbecidine® to prevent sesame seed weight loss in open plastic buckets (feeding response).

2. LITERATURE REVIEW

2.1 Sesame

Sesame (*S. indicum*) is a broadleaf summer crop similar to cotton, sunflower, soybeans, black-eyed peas, mung beans, or guar. When planted early and under high moisture and fertility conditions, sesame can reach 5-6 feet in height. In dry land conditions, it is generally 3-5 feet, depending on rainfall (Wiess, 2000).

Flowering starts about 35-45 days and stops after 75-85. The seed is produced in capsules with about 70 seeds per capsule. The first capsule is 1-2 ft from the ground. Physiological maturity (PM), is when 75% of the capsules on the main stem have mature seed, normally occurs 95-110 days after planting (Wiess, 2000). The plant is very leafy, but will self-defoliate at maturity. Sesame normally dries down in 120-150 days (Langham *et al.,* 2009). Sesame seed was processed not only for cooking oil and a cake, but also used for different cosmetics and medicinal purposes. The crop helps farmers to earn a reasonable and reliable income from the sale of sesame seed (Dawit Alemu and Meijerink, 2010).

2.1.1 Sesame production

Sesame is produced in around 75 countries of the world. All the major producers of the seed produce a total of around 30 million tons annually. China produces is the largest producer approximately 25% sharing in the total world's production (Dawit Alemu & Meijerink, 2010). The top ten sesame producing countries in descending order are China, India, Myanmar, Sudan, Uganda, Nigeria, Pakistan, Ethiopia, Bangladesh and Central African Republic (Dawit Alemu and Meijerink, 2010).

The major sesame growing areas are located in the Northwest; in Humera area in Tigray near the border with Sudan and Eritrea; in Metema in North Gondar and in Wollo area of Amhara region, Chanka area in Wellega of Oromiya, and in Pawi area in Benshangul Gumuz region. (Figure 2.1). In Humera, sesame productivity ranges between 4.28 quintals/ha (Sorsa Debela, 2009).

Figure 2.1: Main sesame growing areas in Ethiopia (Dawit Alemu & Meijerink, 2010).

2.1.2 Insects and mite pests of Sesame

A wide range of pests attack sesame around the world. In Ethiopia, the main sesame pests including the green peach aphid (*Myzus persicae* Sluzer), Sesame seed bug (*E. sordidus* Fabicius), African bollworm (*Helicoverpa armigera* Hubner), Sesame webworm (*Antigastra catalaunalis* Hubner), Flea beetle (*Padogracia spp* Jacoby), Cluster bug (*Agonoscelis pubescens* Thunberg), Sesame jassid (*Empoasca spp* Jacobi), Yellow tea mite (*Polyphagotarsonemus latus* Banks), green yellow tea mite (*Hemitrsonemus latus*), devil's grasshoppers (*Diabolocatantops axillaries*), Green stink bug (*Nezara viridula* L), simsim gall midge (*Asphondylia sesami*), Ants, termites, Aphids and White flies constitute as the major pest species of sesame (Bedigian, 2006; Bissdorf, 2007; Ermias *et al.*, 2009 and Murali Baskaran, 1998). These pests become more serious as crop acreage expands and mono cropping is practiced largely. Among insect pests attacking sesame, nowadays only the sesame seed bug, webworm, and gallmidge are causing serious problems. In the past, only seed bug was causing economic problems, while webworm and gallmidge were minor pests (Mandefro *et al.*, 2009).

Among the insect and mite pests recorded on sesame termites are reported as important pest in Wollega, Hararghe, Gamo Goffa and the Middle Awash. While, Sesame seed bug (*E. sordidus*) is a serious pest in the North West. In storages, webworm and different species of beetles were reported to be important on both crops. Sesame seed bug was reported to attack the seeds of sesame, and groundnuts, but has also been recorded feeding on grasses, sedges, cotton and bananas in Nigeria (Mandefro *et al.*, 2009).

2.2 Sesame seed bug (*E. sordidus* Fab.)

Sesame seed bug (SSB) is a Hemipteran species which belongs to the order hetroptera and family lygaeidea (Schmeutterer, 1969). The egg of the bug is sausage shaped, it is about 1.2 mm long, and changing its colour from pale yellow to pink and red during incubation period. The anterior end of the egg with spines arranged in a circle (Schumutterer, 1969). The nymph at the last instar is about 5-8 mm long, dorsal side patterned is red and brown. Wing pads are brown, usually extending over the third abdominal segment (Schumutterer, 1969). The adult sesame seed bug is about 7-10 mm long and about 2-3 mm long wide. Head and eyes are dark brown to black, and antennae four jointed. Anterior part of the pronotum is red brown to dark brown and posterior half ochraceous. Scutellum ochraceous with dark brown base and brown punctures. The underside of the body of the insect is dark brown to blackish (Schumutterer, 1969 and Dick, 1987).

The sesame seed bug (*E. sordidus*) is a serious pest causing extensive damage to sesame. It was reported as a post harvest pest of sesame occurring in large numbers on the harvested sesame plants which were heaped for curing in the threshing floor. It was also observed that bugs in all stages of development were feeding on the green pods of sesame in the field (Mohanasundaram *et a l.*, 1980; Mohanasundaram and Sandra Babu, 1987 and Kalaiyarasan and Palanisamy, 2002)

2.2.1 Biology and life cycle of Sesame seed bug (*E. sordidus*)

Sesame seed bug (SSB) reproduces sexually and undergoes in complete metamorphosis. The adult bugs are attracted by large dark objects like sesame stacks in the field. In the heat of the day, they move down towards the base of the stacks. As stacks dry out or threshade, migration of the pests is observed from one stack to another. The female lays the eggs either on the sesame stalks or in the soil near their base (Schmeutterer, 1969 and Dick, 1987). The newly laid egg of sesame seed bug is white in color and then changed to pale yellow, pink and finally to full red during incubation period. The red color is an indication for maturity of the embryo (Schmeutterer, 1969). The first instar nymphs have a bright red abdomen; later instars become progressively darker. The nymphs hatch in a few days and all stages feed on kernels, perforating the pod with their rostrum. After passing through six nymphal instars the adult stage is reached (Schmeutterer, 1969 and Dick, 1987).

The life cycle of SSB is varied with in different parameters such as temperature, season and diet. Due to such differences the life cycle of SSB varied. According to Osman *et al.*, (2009), in laboratory egg incubation period of SSB is 4.5 ± 0.17 days, while the respective nymphal duration from the 1^{st}, to the 6^{th} instar is 1.85 ± 0.13, 6.3 ± 0.20, 4.95 ± 0.16, 5.0 ± 0.27, 5.3 ± 0.28 and 4.2 ± 0.15 days, respectively. The developmental period from egg to adult stage is 32.1 ± 0.52 days. The lifespan of adult female and male is 19.2 ± 0.38 and 9.85 ± 0.39 days, respectively. The lifespan from egg to adult death is 51.2 and 41.9 days for female and male, respectively. The male to female sex ratio is 1:1.2. Oviposition period is 4.9 ± 0.07days and the peak laying period is on the second day. In Nigeria, the whole development period from the egg to the adult was found to last about 1 ½ months under laboratory conditions (Schmeutterer, 1969). Murali Baskaran *et al.,* (1998), also noted that the rainy season is more conducive for rapid multiplication of this pest than the dry season.

2.2.2 Effects of climate on sesame seed bug (*E. sordidus*)

A sesame seed bug (*E. sordidus*) is a predominant pest on sesame during rainy season. The rainy season is more conducive for rapid multiplication of SSB. It is very active during night hours and always invades the crop in hundreds. The population build up of this pest is very high at the time of sesame harvest. In general the activity of SSB during summer seasons is low (Murali Baskaran *et al.*, 1998).

3.2.3 Distribution of sesame seed bug (*E. sordidus*)

The distribution of SSB is recorded in major sesame growing countries of Africa and Asia, which includes West Pakistan, India, China, Senegal, Nigeria, Malawi, Somalia, Sudan and Uganda (Schmeutterer, 1969 and Dick, 1987). In Sudan, Kordofan Province, it is a serious local pest when it appears in large numbers at harvest time (Schmutterer, 1969; Dick, 1987 and Mandefro *et al.*, 2009). In 1977, it is reported as a major pest of sesame in North West Ethiopia. The bug is reported long ago however, its prevalence and damage was restricted to North Western part of the country and it is so important only in years of outbreaks (Mandefro *et al.*, 2009)

1.2.4 Host ranges of sesame seed bug (*E. Sordidus*)

The sesame seed bug breeds on a very large number of host plants. It mainly attacks seeds of Sesame, but has also been recorded feeding on groundnuts, grasses, sedges and banana in Nigeria (Schmuitterer, 1969). Sesame seed bug is a pest on Groundnut (Slater, 1972) and Sesame (Sharma *et al.,* 1990, Schmuitterer, 1969; Egonyu *et al.,* 2005). This bug is also reported to attack Wheat, (Mukhopadhyay and Saha, 1992), Millets and Bajra (Sinh and Rai, 1967), Peepal (Mukho-padhyay, 1989) and a weed plant *Cleome viscose* (Sanjayan and Ananthakrishnan, 1987).

2.2.5 Host preference of sesame seed bug (*E. Sordidus*)

Sesame seed bug is a polyphagous insect attacking a wide range of crop. (Palanisamy and Kalaiyarasan, 2006). Host preferences, including artificial diet, by SSB have been studied in a laboratory setting. Ground nut was found to be the most "suitable," followed by an artificial diet, sesame, sorghum and Bajra Palanisamy and Kalaiyarasan (2002). Sesame seed bug prefers particular host plants and appears to follow a hierarchy in food choice when a preferred host is unavailable. Under laboratory condition fecundity of the bug was higher on sesame 99.5 % eggs/female and ground nut 81.0 % and the adult longevity of male and female bugs is lower in sesame and ground nut than sorghum and bajra. This proveds that sesame and ground nut acted as suitable breeding host while bajra and sorghum acted only as feeding host (Palanisamy and Kalaiyarasan, 2002).

Mukhopadhyay and Saha (1995) observed that, final instar nymphs and adults showed that highest consumption of food and weight gain were on the seeds of sesame followed by ground nut, wheat and peepal.

1.2.6 Economic importance and type of injury due to sesame seed bug (*E. sordidus*)

There are a number of pests that attack sesame. From those the most common pest in Humera is the sesame seed bug locally known as **'Stayto'** which means drinks sesame oil limitless**.** No quantitative data was reported on the extent loss, although it is known to be high yield loss in the area. This has been causing high yield loss in the area. This pest is currently the predominant insect pest species attacking sesame in Ethiopia, particularly in western Tigray especially Humera.

Sesame is attacked in the field when pods are open, after the plants have been cut and put together in stacks for drying and in warehouses. Sesame seed bug mainly attacks the seeds of sesame ('simsim') and ground nuts ('Ful sudani'). In Ground nuts, the bugs are able to attack the kernels within the shells when the plants are stacked to dry at harvest. Stored and shelled groundnuts may also be heavily infested. The nymphs and adults suck the oil from the seeds, which becomes shrivel, bitter and worthless (Mandefro *et al.*, 2009). This causes the kernels to increases the free fatty acid content of the oil, producing a rancid flavour (Dick, 1987). Infested seeds are poor in germination and loose vigour (Mandefro *et al.,* 2009). The pest incurs both physical damage (weight loss, color change, and shape) and quality loss (oil yield, odour, and change of protein content) (Mandefro *et al.*, 2009).

Various damage of sesame seed due to major pests of sesame were reported. According to Murali Baskran *et al.,* (1998), the yield loss caused by major insects are of high magnitude ranging from 27- 40 % during rainy season. Weiss (2000) also reported that, insects reduce about 25% of the potential yield of sesame in the world. According to Osman *et al.*, (2009), Sesame seed bug caused losses in seed weight from 2 to 36%, reduction in oil content from 4 to 43%, increase in free fatty acids from 0.44 to 1.51% and increase in the shriveled seeds to 40% in comparison with the control.

2.7 Control of sesame seed bug (*E. sordidus*) species

For many years, sesame producing farmers in Humera have been spraying insecticides against Sesame seed bug. However, the efficacy of this practice remains questionable when considering the high level of re infestation within few days during the harvest and storage. Moreover excessive use of pesticides causes environmental pollution and eliminates non target organisms. There is no registered insecticide for the control of sesame seed bug in Ethiopia. However, farmers at Humera and Metema area spray Malathion 50% EC and Ethiosulfan 35% EC one to three times at the base of sesame stalks in stack. Dusting the base of stack and the soil around them with Ethiolathion 5% Dust, and Carbaryl 85% WP is well practiced (Mandefro *et al.,* 2009). In addition endosulfan is the major insecticide used for the control of sesame-seed bug in almost all commercial farms in Ethiopia now a days.

2.3 Botanical control of insect pests on stored seeds

2.3.1 Neem, *Azadirachta indica* and its uses in insect pests control

Neem contains several active ingredients; such as Azadirachtin, salanin, meliantriol, and nimbin, which are the most known and significant components. They act in different ways under different circumstances (Saxena, 1983; Ventura *et al.*, 2000 and Damaria, *et al.*, 2004). Extracts of neem are effective mosquito larvicides and inhibit metamorphosis (Saxena, 1983). Azadiracthin have been found to be effective against insects in Diptera, Isoptera, hetroptera , Homoptera, Coleoptera (beetles and their larvae), Lepidoptera (caterpillars = larvae of butterflies and moths), Orthoptera (nymphs and adults of grasshoppers and locusts) **(**Schmutterer *et al.,* 1995). Results against some bugs, leafhoppers and whiteflies have also been good (Dreyer & Staff, 1984).

2.3.2 Birbira (*Milletia ferruginea*) and its uses in insect pests control

M. ferruginea has been observed to be very effective in controlling insect pests (Bekele, 2002). Birbira seeds extract has been observed to be effective in controlling storage insect pests such as adzuki bean beetle, *Callasobruchus chinensis,* (Bayeh Mulatu and Tadesse Gebremedhin, 2000), maize weevil, *Sitophilus zeamais* (Bekele Jembere, 2002) and bean bruchid, *Zabrotes subfaciatus,* (Bekele *et al.,* 2007).

2.3.3 Pyrethrum, *Chrysanthemum cinaraefolium* (Treviranus): its uses in insect pests control

Pyrethrum is a broad-spectrum insecticide used to control true bugs, caterpillars, beetles, aphids, flies, mites, whiteflies, thrips and leafhoppers (Casida, 1973). Within these groups, pests may have a greater or lesser susceptibility to pyrethrum products. Specific pest species controlled by pyrethrum as noted in the different literatures including potato leafhopper, beet leafhopper, cabbage looper, celery leaf tier, Say's stink bug, twelve-spotted cucumber beetle, six-spotted leafhopper, lygaeidae bugs on peaches, grape thrips, flower thrips, grape leafhopper, and cranberry fruit worm(Casida, 1973).

Pyrethrum activates hidden insects, driving them from cover and into contact with the main insecticide. This "flushing" action has been most successful in the control of such hard to hit pests as the cotton bollworm and the gypsy moth (Casida and Quistad, 1995). Pyrethrum is also highly effective for the management of bruchids especially *C. chinensis* L. (Bayeh and Tadesse, 2000).

2.3.4 Nimbecidine and its use for pest control

Nimbecidine, the neem oil based pesticide contains Azadirachtin (0.03% EC) as an active ingredient. It also contains many other active compounds like Meliantriol, Salanin, Nimbin, and the like, of which Azadirachtin is the most effective insect growth regulator molecule. Azadirachtin seems to be non-mutagenic, readily degradable, with low toxicity to non target and beneficial organisms, and causes minimal disruption to the ecosystem (Sundaram, 1996 and Krishnaiah, *et. al*., 1999). It is totally safe to the environment, spray operators, fish, honeybees, birds and livestock. It is more effective when compared to water based formulation with higher azadirachtin.

Neem oil and nimbecidine were moderately effective against *L. orbonalis* **(**Murugesa1 and Murugesh**,** 2009). Several earlier workers have also demonstrated the effectiveness of neem oil (Udaiyan and Ramarathinam, 1994 and Shanmugaraj, 1995), nimbecidine against *L. orbonalis* (Udaiyan and Ramarathinam, 1994) and nimbecidine against Hadda beetle (*Henosepilachna vigintioo ctopunctata***)** (Murugesan and Murugesh, 2008).

3. MATERIALS AND METHODS

3.1 Description of the study area

The studies were conducted in Humera, North West Ethiopia. It is located in the Western Zone of Tigray Region at latitudes 14°18°N and 36°37°E and a longitude 14.3° N and 36.617° E near the borders of Sudan and Eritrea.

3.2 Rearing of sesame seed bug (E. sordidus Fab.) stock culture for warehouse/shade experiment

Adults of Sesame seed bug (SSB) were collected from the stalks of sesame locally called "jewjaw" from sesame fields around Humera Agricultural Research Center (HuARC). They were brought to the rearing site in big plastic buckets and placed in the laboratory. They were reared outside the laboratory in the natural environmental setting by providing them shade to avoid exposure to direct sun light and to preserve the shade of the environment. To rear the insect effectively 10 lt of water was applied within every 3 days by sprinkling over the stacks of sesame, which was found to provide sufficient moisture content in the rearing site.

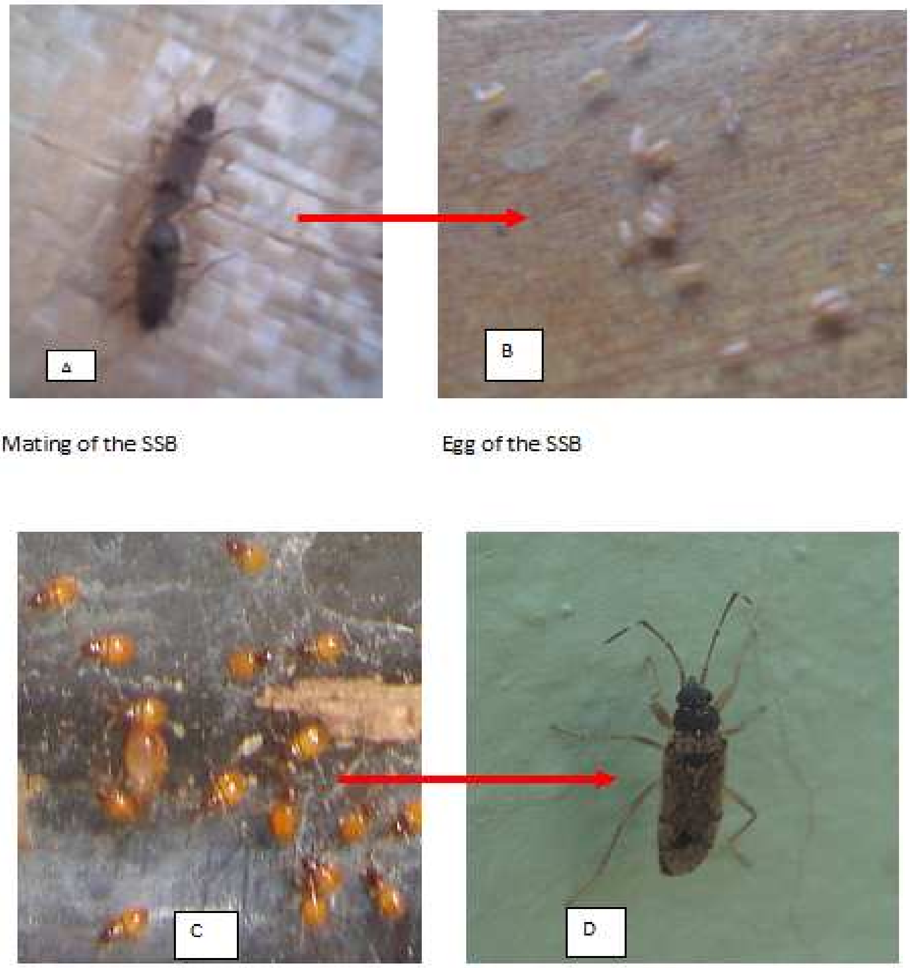
Plate 3.1.: Rearing site of adults of sesame seed bug in the shade area

The Sesame seed bugs were used to evaluate the efficacy of the botanicals in terms of adult and nymph mortality study on egg oviposition in laboratory experiments. Moreover, the bugs were used for sack treatment, seed treatment in the shade, and weight and oil loss assessment.

3.3 Rearing Sesame seed bug for laboratory experiment

Adult sesame seed bug were collected from the stacks of sesame (jewjaw) in the outdoor rearing site. It is possible to mass multiply the insect in 50 - 60% RH and 32 ± 2°C by feeding them on sesame seed. To simulate the natural situation the adults were introduced in to the plastic buckets which contain moist soil, sesame stalks, some amount of sesame seed, leaf of alternate host (*X. abysinicum*) and fine cotton. Unsexed above100 adults were then introduced into the prepared rearing buckets and 30 ml of water was sprayed over the covering mesh 3 times per day (morning, afternoon and evening) using hand sprayers to create appropriate moisture. The bugs started laying eggs after 1-4 days the egg containing cotton was removed and put into other small bucket which contains 100g of sesame seed and leaf of the wild and alternate host plants until hatching takes place (Plate 3.2.). The eggs were hatched 4 to 5 days after the laying of egg (Osman *et al.,*, 2009) and that is what has happened. Finally, 2 to 3 days old (2nd instars) (Plate 3.3C) nymphs were used for assaying the mortality effect of the botanicals.

Plate 3.2: Egg oviposition in the laboratory.



Mating of the SSB

Egg of the SSB

Nymphs of the SSB

Adult sesame seed bug

Plate 3.3 Life cycle of sesame seed bug, *E. sordidus*

3.4 Preparation of sesame seeds (*S. indicum* L.) used for the experiment and stock culture of sesame seed bug

Clean and well-sieved sesame seed of the Hirhir variety was obtained from HuARC and bought from local sources in Humera. Sesame seeds were disinfested by keeping them in a deep freezer at a temperature of -1°C for 48 h (Mulungu *et al.*, 2011).

3.5 Collection, processing and preparation of botanical test materials

Ripe neem fruits were collected from Dire Dawa; cleaned and depulped, in the laboratory (HuARC). The neem seeds were spread out and dried under shade on cloth to dry for 2 weeks. Dried seeds were manually ground with home-made pestle and mortar to obtain neem seed powder. The powders of neem, birbira and pyrethrum were filtered using spray sieves in order to remove larger particles and to obtain fine powder.

The ground fresh neem and birbira seed kernel powder were introduced separately into the buckets prepared for soaking of the powder, and diluted at the rate of 10g per 100ml of water to make a stock solution of 10 % (w/v). The mixture was then stirred using a wooden stirrer repeatedly and then kept for 24 h. Twenty-four hours after soaking of the powders of the different plant parts; the mixture was filtered through double-layered cheese cloth (Bekele 2002 and Singha *et al.,* 2007). The same concentration levels of water extracts of neem and Birbira were prepared and applied for the subsquent experiments. Part of the fine seed powder was also kept aside for seed powder treatment (Bekele, 2002).

A commercially available liquid formulation of Nimbecidine containing 0.03 % azadirachtin as active ingredient was used in the experiment. This product was obtained from Selit Hulling and Kaleb Farmers' Service House P. L .C. Serial dilutions were prepared at 0.5,1, 1.5, 2 and 2.5 ml/100ml distilled water for each experiment.

The standard check 5% Malathion dust, was bought from local shop in Humera and applied at the manufacturers' rate. Whereas Birbira powder and pyrethrum dust were obtained from Holeta Agricultural Research Center (HARC). Unlike the other treatments Malathion and pyrethrum were applied in dust forms. The same concentration levels of water extracts of birbira and neem seed powder were prepared and applied as treatments in storage, shade house and laboratory experiments.

3.6 Experimental layout

The laboratory treatments were arranged in a Complete Randomized Design (CRD) and each of them replicated five times whereas the warehouse experiments (sack treatment, seed treatment and weight loss in sample of infested area on open buckets) were arranged in a completely randomized block design (RCBD) and replicated five times outdoor in a shade.

The treatments were similar both for the laboratory and outdoor experiments and include: untreated control, 0.5% Malathion Dust applied at a rate of 0.1 g per 100 g of sesame seeds (standard check); Pyrethrum (*C. cinerariaefolium)* applied at 0.1g, 0.5g, 1g, 1.5g and 2g per 100g, Neem (*A. indica*) and Birbira (*M. ferruginea*) powders applied at the rates of 5g, 7.5g, 10g, 12.5g, and15g per 100g. Nimbecidine applied at 0.5 ml, 1 ml, 1.5 ml, 2 ml and2.5 ml were diluted with water and applied at the rate of 4ml per 100 g of sesame seed. The sesame seeds and each of the treatments at the rates specified were mixed in different plastic buckets separately and tumbled thoroughly for 5 min. Finally, 20 adults, nymphs and eggs of sesame seed bug were introduced into each buckets, bottles and petri dishes that were then covered with perforated cloth mesh, which does not allow even the younger nymphs to escape.

3.7 Efficacy some botanical powders and nimbecidine treatments applied on seeds against sesame seed bugs under laboratory conditions

The egg experiment was carried using petri dishes; the nymph bioassay was conducted using glass jars whereas the bioassay on adults was done using plastic buckets. The treatments were neem oil, neem seed powder extract, birbira seed powder extract, Malathion 5% powder, pyrethrum flower dust and control (water) were prepared as described earlier and applied.

3.7.1 Bioassay of some botanical powders and nimbecidine on egg inhibition

Neem, birbira, 5% Malathion dust, pyrethrum, nimbecidine and control were studied for their effect on egg inhibition. Application rate of 5g, 7.5g, 10g, 12.5g, and 15g of neem and birbira; 0.1g, 0.5g, 1g, 1.5g and 2g of pyrethrum; 0.10 g of 5% Malathion (manufacturers rate) and 0.5 ml, 1.0 ml, 1.5 ml, 2 ml and 2.5ml of nimbecidine /100ml of water were used per 100g of sesame seed. 4ml of diluted nimbecidine was sprayed per 100g of sesame seed. The sesame seed and the treatments were mixed and tumbled thoroughly for 5 min. Healthy disinfested 10 g of the 100g treated sesame seeds were placed in 100 mm Petri dish .The newly laid eggs (1-2) days of age in the fine cotton were collected by stretching the cotton over the Petri dish. Then 20 laid eggs were placed in to each petri dish containing 10g of seeds treated with neem, birbira , 5% Malathion, pyrethrum, nimbecidine and control. Finally each of the Petri dishes were covered with cloth mesh to prevent the escaping of the hatching nymphs (neonates) (Plate 3.5) and the setting was left for 8 days. Then all dead and live hatched nymphs were recorded.

Plate 3.4: Experiment on egg hatching

The data for effective ovicidal activity was corrected using Rajkumar and Jebanesan (2005) formula with some modifications.

$$\%EI = \frac{(NC - NT)}{Nc} X\,100$$

Where, EI (%) = percent effective hatching inhibitions NC = number of hatched eggs in control treatment and NT = number of hatched eggs in treatment

3.7.2 Bioassay of some botanical powders and nimbecidine on nymph mortality

Neem, birbira, 5% Malathion dust, pyrethrum, nimbecidine and control were studied for their effect on nymph mortality. Application rate of 5g, 7.5g, 10g, 12.5g, and 15g of neem and birbira; 0.1g, 0.5g, 1g, 1.5g and 2g of pyrethrum; 0.10 g of 5% Malathion (manufacturers rate) and 0.5 ml, 1.0 ml, 1.5 ml, 2 ml and 2.5ml of nimbecidine /100ml of water were used per 100g of sesame seed. 4ml of diluted nimbecidine was sprayed per 100g of sesame seed. The sesame seed and the treatments were mixed and tumbled thoroughly for 5 min. The eggs were reared in the fine cotton with sesame seed and leaf of *X. abbysinica* in the bucket prepared for egg hatching as shown in (Plate 3.6). The newly hatched nymphs (2-3) day's age were collected from the leaf of *X. abysinica* and transferd to 250 ml of glass jar and 100mm of Petri dish. Moreover, the leaf of *X. abysinica* served as food source and hiding site while transferred the nymphs to the prepared treatment.

Then 20 newly hatched nymphs (2-3) day's old were placed into each 1lt volume glass jar which contains healthy disinfested 100g of sesame seed treated with neem, birbira , 5% Malathion ,pyrethrum, nimbecidine and control (Plate 3.7).

The mouth of the jar was covered with cloth mesh and tightly held with rubber band to prevent the nymphs from escaping and to provide air. Mortality data were taken 30 min, 1 hr, 12 hr, 24 hr and 48hr after treatment.

Plate 3.5: Newly hatched nymphs

Plate 3.6: Nymphs in treated sesame seeds

3.7.3 Bioassay of some botanical powders and nimbecidine on adults mortality

Neem, birbira, 5% Malathion dust, pyrethrum, nimbecidine and control were studied for their effect on adult mortality. Application rate of 5g, 7.5g, 10g, 12.5g, and 15g of neem and birbira; 0.1g, 0.5g, 1g, 1.5g and 2g of pyrethrum; 0.10 g of 5% Malathion (manufacturers rate) and 0.5 ml, 1.0 ml, 1.5 ml, 2 ml and 2.5ml of nimbecidine /100ml of water were used per 100g of sesame seed. 4ml of diluted nimbecidine was sprayed per 100g of sesame seed. Untreated was added for comparison purpose. The sesame seed and the treatments were mixed and tumbled thoroughly for 5 min.

The adults of SSB were collected from the rearing site of the bug prepared outside under a shade (Plate 3.1) using plastic bucket. The plastic buckets were filled with stalks of sesame commonly called “jewjaw” before transferring of the bugs to the collecting material. The bugs were then transferred into the collecting material and then treated with water in the collection buckets before placing them in the treatments and allowed them to stay for 20-30 min covered with cloth mesh in order to settle them. The stalks (jewjaw) helped to pick and count the bugs while placed in the treatment buckets and to create their former habitation (Plate 3.8).

The treatments were prepared by placing 100g of sesame seed mixed with the treatments and stalks (jewjaw) of sesame in17 cm wide and16 cm height plastic buckets. The stalk of sesame (jewjaw) was helping the bugs to move freely and has simulated with the natural environment. The plastic buckets provided free movement of the insect and dark environment which is preferred by the insect. Then ten pairs of adults were placed in to each plastic bucket (17wide x16height) which contains healthy 100g of sesame seed treated with neem, birbira , 5% Malathion, pyrethrum, nimbecidine and control. Finally, it was covered with cloth mesh to protect the escaping of the adults, and to provide them air. In addition to covering of the buckets, the cloth mesh was dipped enough with water every morning, afternoon and evening after introduction of the SSB to the treatments to provide them enough moisture (plate 3.9). Then after, dead insects count was done 30 min, 1 hr, 12 hr, 24 hr and 48 hr after treatment and dead individuals were picked, while live ones were allowed to stay until the end of the experiment.

Plate 3.7: Preparation of treatments and transferring of bugs to the treatment

Plate 3.8: Adults sesame seed bug in treated sesame seeds

All the experimental buckets were randomly assigned to positions in a completely randomized design (CRD) and left undisturbed. Abbot (1925 cited in Ashouri and Shayesteh (2010)) formula was employed to correct percentage mortality of the adults and nymphs as:

$$Pt = \left(\frac{P0 - Pc}{100 - Pc}\right) X\ 100$$

Where, PT = corrected mortality (%),

Po = observed mortality (%),

Pc = control Mortality (%).

3.8 Weight loss assessment for storage experiment

3.8.1 Bioassay of some botanical powders and nimbecidine on storage sacks against sesame seed bugs under shade storage conditions (*sack dipping*)

New sacks were dipped in Neem oil (Nimbecidine), Neem seed water extract and Birbira water extract, in water and other sacks were dusted with Pyrethrum flower powder and 5% Malathion dust and the control dipped in pure tap water. Each sack was treated with 50 ml of the prepared neem and Birbira stock solution separately and hung in shade area to dry for 2 hrs. This amount of solution was used for sack dipping approach and all sacks were uniformly treated at equal time interval. Manufacturer's concentration of Nimbecidine solution was also applied at the rate of 50 ml per each sack and left for 2 hrs prior to filling of the seeds prepared for the experiment. For the dusting with Malathion and Pyrethrum each of the sacks was wetted in 50 ml water prior to application. Then 2g of Pyrethrum and Malathion dusts were weighed and uniformly spread/splashed over both sides of water dipped sacks and left for 25 min for Pyrethrum and 35 min for Malathion average time in a shade environment to dry prior to the filling of the seeds.

Then 3kg of clean seed were filled in all the treated sacks and replicated five times. Treated sacks were then placed in a raised wooden bench with a height of 50 cm above the floor (ground) and 50 cm interval between sacks in a Completely Randomized Block Design (RCBD). Data were collected and weighed every 10 days for 5 times. During the final data collection (50 days after treatment) 1000 seed samples of both sunken and healthy seeds were taken randomly from the lower, middle and upper parts of the sacks (plate 3.4).

Plate 3.9: Warehouse (shade) treatment of seeds and sacks

3.8.2 Bioassay of some botanical powders and nimbecidine applied directly on seeds against sesame seed bugs under warehouse conditions (*seed dressing)*

The treatments were applied as powder form except Nimbecidine applied as an aqueous solution. The seeds were treated at the rate of 20g neem and Birbira powder per kg of sesame seed separately (Asogwa *et al.*, 2010).

Pyrethrum dust and 5 % Malathion dust were applied after treating the seeds with 40 ml of water per 1kg of seed using hand sprayers. This made the moisture content of the required seed neither too wet nor too dry and increased the chance to attach the treatments with the seeds. Then 15g of pyrethrum and 1g of Malathion per 1kg of sesame seed were applied. The other treatments, Malathion and the control (Water) were replaced by other containers after being dressed in order to dry them further in shade area. Then the seeds were dried very well before putting them in clean sacks.

The prepared solution of Nimbecidene was also applied at the rate of 40ml per 1kg of the sesame seed. For the control 1 kg of seed were dressed at the rate of 40ml of water as a control. All the treatments were mixed using separate buckets and steel stirrer. Then 3kg of treated seed were filled in one clean sacks and replicated five times. The sacks were then placed in a raised wooden bench with a height of 50 cm above the floor (ground) and 50 cm interval between sacks in a Completely Randomized Block Design (RCBD). Data were taken and weighed with in every 10 days for 5 times to assess the total weight loss of sesame seed. At the fifth weighing time for weight loss, sampling of 1000 sample seeds of both sunken and healthy seeds were taken randomly from the lower, middle and upper parts of the sacks from the total seed weight per sack after the seeds were weighed for data on weight loss as in the previous.

Weight Loss Assessment of sesame seed in shade

The weight of the sesame seeds treated with those six treatments started before placing in the storage. Subsequent re-weighing every 10 days was done to determine the actual weight loss incurred by sesame seed bug, while in the shade storage. In this case the weight loss was calculated as follows

$$\%\text{ weight loss at time t} = \frac{\text{Wi} - \text{Wt}}{\text{Wi}} \times 100$$

Where % Total Weight Loss at time t = Loss obtained by 10 days interval weighing of the treated sacks and seeds Wi = initial weight of the treated treatments

Wt = weight of the treatments at a given weighing period.

Thousand sesame seed for percentage seed infestation

The 1000 randomly sampled sesame seeds were separated in to sunken and healthy seed. Then, percentage seed infestation was estimated using the following formula.

$$\%\text{ seed infestation} = \frac{\text{Number of sunken seed}}{\text{Number of healthy seed} + \text{Number of sunken seed}} \times 100$$

3.9 Weight and oil loss assessment in open plastic buckets

Treatments neem, birbira , 5% Malathion ,pyrethrum, nimbecidine and open control and closed control were applied at the rates of 5, 10 and 15 g of neem and birbira /100g of sesame separately; 2g, 1g, and 0.5g of pyrethrum per 100g of sesame seed; Malathion (manufacturers rate) 0.10 g/100g of sesame seed and 0.5 ml, 1.5 ml and 2.5ml /100ml of water diluted nimbecidine and applied at the rate of 4ml/ 100g of sesame seed. The sesame seed and the botanicals and nimbecidine were thoroughly mixed and tumbled thoroughly for 5 min. These experiments were replicated five times and arranged in RCBD experimental design.

The treatments were placed in the highly infested shade area outside (Plate 3.11). All the treatments left open in order to allow free visitation by the bugs from the surrounding (Plate 3.10). This simulated infestation may take place in harvested sesame before threshing and helps to estimate the seed losses that happen in the field. All the buckets containing about 200g of treated sesame seeds, untreated sesame seeds in an open bucket as open control and sesame seeds in closed bucket as closed control were also placed in the outdoor site. The buckets were then checked for the feeding response of the bugs each morning by counting the number of live and dead bug present per bucket. The buckets were kept for consecutive 5 days. All dead insects were sieved every day, while weighing the seeds. In the fifth day, the end of the experiment sample of 25 g of sesame seed were taken from each replication of the treatments for oil analysis. The oil analysis was also done in Holeta Agricultural Research Center (HARC) oil crops research laboratory.

Fig 3.10: Experiment on weight loss in highly infested area

The percent weight loss was calculated at the end of experiment by using the following formula

$$\%\text{weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{X } 100$$

Plate 3.11: Depicting high infestation of sesame seed bug

3.10 Data analysis

All the data obtained in the experiments were subjected to multiple and one way ANOVA using the JMP5 software. Transformation of the data was not required. Mean comparisons were conducted using Tukey Kramer honest significance test, and P value was set at 5% probability level.

4. RESULTS

4.1 Inhibition of egg hatching of Sesame seed bug (E. sordidus) in Seeds of sesame treated with botanicals and nimbecidine.

Mean percent egg hatching inhibition of the SSB is varied among the treatments (Table 1). Pyrethrum with all the rates used showed highest vicidal activity than any of the other treatments. Thus, at 0.1%, 0.5%, 1%, 1.5% and 2% (w/w) gave 51.8%, 56.4%, 61%, 65.8 % and 76.7% inhibitions, respectively.. The other treatments also significantly impaired egg hatchability that ranged from 12.8% to 48% at their highest rates compared to control. Moreover, all the botanicals except nimbecidine were better in ovicidal activities than the standard check, Malathion at a higher dose of application.

Table 1: Relative efficacy of different treatments against eggs of Sesame seed bug (*E. sordidus*) on treated Sesame seed.

Treatment Per 100g of seed	Mean±SE % Effective Inhibition						
	Rate 1	Rte 2	Rate 3	Rate 4	Rate 5	F value	P value
Birbira	1.9±5.3cD	25.2±9abC	25.3±11.2abC	28.4±11.1abB	48.6±9abA	3.11	0.03
Neem	5±15.8bD	8.2±10.8bCC	26.3±7.3abAB	28.4±11.2abB	39.3±9abA	1.66	0.19
Pyrethrum	46.7±10.9abC	56.4±10.6aC	61±8.3aC	65.8±8.3aB	76.7±3.5aA	1.4	0.26
Nimbecidine	51.2±9.5aA	19.4±16.3abB	15.3±10.2abB	14.4±15.4bC	12.8±17.1bD	1.38	0.27
Malathion	20.6±8.3abA	18.6±6.4abA	22.1±10.3abA	23.7±9.7abA	17.7±14.3abAB	0.31	0.86
Control	11.3±3.9abA	-5.8±7.2bB	-2.7±10.8bB	6.6±4.2bA	5±8.7bA	0.88	0.49
F (5,24)	4.73	3.91	4.51	3.47	5.77		
P value	P<.0038	P<.009	P>0.0048	P<.017	P<.0012		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

Birbira and Neem: rate 1 = 5g, rate 2 =7.5g, rate 3 = 10g rate 4= 12.5g, rate 5= 15g ; Pyrethrum: rate1 = 0.1g, rate 2 =0.5g, rate 3 = 1g rate 4= 1.5g, rate 5= 2g; Nimbecidine: rate 1 = 0.5ml, rate 2 =1ml, rate 3 = 1.5ml rate 4= 2ml, rate 5=2.5 ml and Malathion: rate =0.1g

4.2 Nymph Mortality in Seeds of sesame treated with botanicals and nimbecidine

Malathion and pyrethrum caused significantly ($p \leq 0.05$) higher mortality on the nymphs with in 30 min of the treatments whereas the other treatments caused significant mortality 12h after treatment application. Complete mortality (100%) was recorded in all treatments 48h treatment application except nimbecidine and neem that caused in 61 %and 95% mortality at the same time respectively (Table 2).

Table 2: Relative efficacy of different treatments against 2nd instar nymph of Sesame seed bug (*E. sordidus*) on sesame seeds treated at 1st application rate

Treatment Per 100g of seed	Mean±SE Nymph mortality %						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbira at 5 g	0.0±0.0cA	0.0±0.0cA	23±6.6bcB	47±7.8cC	100±0.0aD	82.44	0.0001
Neem at 5g	0.0±0.0cA	0.0±0.0cA	30±10.3bB	71±6.2bB	95±5aC	53.23	0.0001
Pyrethrum at0.1g	50±1.58bA	66±9.1bB	100±0.0aB	100±0.0aB	100±0.0aB	32.62	0.0001
Nimbecidine at 0.5ml	0.0±0.0cA	0.0±0.0cA	24±6.2bcB	43±2.5cB	61±3.3bB	64.04	0.0001
Malathion at 0.1g	97±2aA	99±1aB	100±0.0aC	100±0.0aC	100±0.0aC	1.70	0.189
Control	0.0±0.0cA	0.0±0.0cA	0.0±0.0cA	0.0±0.0dA	0.0±0.0cA	0.000	1.000
F value (5,24)	1533.69	136.6	58.2	83.14	269.66		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

Malathion caused higher nymphal mortality in 30 minutes and 1hr. after treatment application with 98% and 100% respectively. An extract of 0.5% pyrethrum powder was effective (58% and 81%mortality) at 30 minutes and 1hr after treatment which is significantly different from birbira, neem, nimbecidine and control (0% mortality) for the same time and rates. After 12 hr pyrethrum performed equally with the Standard check Malathion that caused 100% nymph mortality. After 48 hr to treatment application all the treatments performed 100% except nimbecidine with 69% mortality with no recorded mortality in the control (Table 3).

Table 3: Relative efficacy of different treatments against 2nd instar nymph of Sesame seed bug (*E. sordidus*) of sesame at 2nd application rate

Treatment Per 100g of seed	Mean±SE Nymph mortality **%**						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbira at7.5g	0.0±0.0cA	0.0±0.0cA	38±4.9dB	68±2.5cC	100±0.0aD	310.68	0.0001
Neem at7.5g	0.0±0.0cA	0.0±0.0cA	50±8.2bB	84±2.4bB	100±0.0aA	16.34	0.0001
Pyrethrumat 0.5g	58±2.5bA	81±6.2bB	100±0.0aC	100±0.0aC	100±0.0aC	38.35	0.0001
Nimbecidineat 1ml	0.0±0.0cA	0.0±0.0cA	46±1.9cB	56±1.9dC	69±1.8bD	495.80	0.0001
Malathion at 0.1g	98±1.2aA	100±0.0aB	100±0.0aB	100±0.0aB	100±0.0aB	2.66	0.062
Control	0.0±0.0cA	0.0±0.0cA	0.0±0.0eA	0.0±0.0eA	0.0±0.0cA	0.000	1.000
F value (5,24)	1336.8	346	79.17	530.4	2777.4		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

Neem, birbira and nimbecidine show no significance difference within 30 min. and 1 hr. time after treatment application whereas Malathion and Pyrethrum shows highly significant difference. Over 80%, 65% and 50% mortality was achieved for neem, birbira and nimbecidine at 24 hr after treatment. All the treatments achieved 100% mortality in 48 hr. after time of application except nimbecidine 69% (Table 4).

Table 4: Relative efficacy of different treatments against 2nd instar nymph of Sesame seed bug (*E. sordidus*) of sesame at 3rd application rate

Treatment Per 100g of seed	Mean±SE Nymph mortality %						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbira at10g	0.0±0.0cA	0.0±0.0cA	43±3.7cB	73±3.4cC	100±0.0aD	384.64	0.0001
Neem at10g	0.0±0.0cA	0.0±0.0cA	60±5.5bB	89±1.9bC	100±0.0aD	340.32	0.0001
Pyrethrum at1g	78±2.5bA	89±2.9bB	100±0.0aC	100±0.0aC	100±0.0aC	32.26	0.0001
Nimbecidine at1.5ml	0.0±0.0cA	0.0±0.0cA	50±3.5bcB	62±2.5dC	77±4.5bD	278.73	0.0001
Malathion at 0.1g	97±2aA	100±0.0aB	100±0.0aB	100±0.0aB	100±0.0aB	2.25	0.09
Control	0.0±0.0cA	0.0±0.0cA	0.0±0.0dA	0.0±0.0eA	0.0±0.0cA	0.000	1.000
F value (5,24)	1187.29	1689.52	152.5	398.02	2402.25		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

Table 5 shows the potent effect of pyrethrum over the synthetic standard check Malathion 30 min and 1 hr after treatment application at 1.5% rate of application. Neem at 12.5% shows (96.0%) nymph mortality followed 100 % mortality from both pyrethrum and Malathion at 24 hr after treatment application. Similarly all the treatments were performing 100% mortality in 48 hr except for nimbecidine that was 77% mortality at 48hr time after treatment application.

Table 5: Relative efficacy of different treatments against 2nd instar nymph of Sesame seed bug (*E. sordidus*) of sesame at 4th application rate

Treatment Per 100g of seed	Mean±SE Numph mortality %						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbira 12.5g	0.0±0.0bA	0.0±0.0bA	55±3.5cB	80.0±3.5bC	100±0.0aD	419.0	0.0001
Neem 12.5g	0.0±0.0bA	0.0±0.0bA	67±4.6bB	96.0±1.9aC	100±0.0aD	493.56	0.0001
Pyrethrum 1.5g	100±0.0aA	100±0.0aA	100±0.0aA	100±0.0aA	100±0.0aA	0.000	1.000
Nimbecidine 2ml	0.0±0.0bA	0.0±0.0bA	57±4.9bB	70.0±4.5cC	86±0.0bD	154.07	0.0001
Malathion 0.1g	96±2.9aA	99±1aB	100±0.0aC	100.±0.0aC	100±0.0aC	1.57	0.21
Control	0.0±0.0bA	0.0±0.0bA	0.0±0.0dA	0.0±0.0dA	0.0±0.0cA	0.000	1.000
F value (5,24)	1808.9	15841	141.16	245.44	1133.6		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

In table 6 excellent insecticidal activity (>90% mortality) of nimbecidine was observed at 48 hr after treatment. In addition neem 15% also achieved 100% mortality equally with pyrethrum and Malathion at 24 hr after treatment application. Similarly all the treatments were perform 100% mortality in 48 hr time of exposure after treatment application except for nimbecidine and control (Table 6).

Table 6: Relative efficacy of different treatments gainst 2nd instar nymph of Sesame seed bug (*E. sordidus*) of sesame at 5th application rate

Treatment Per 100g of seed	Mean±SE Numph mortality %						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbira at15g	0.0±0.0cA	0.0±0.0cA	60±3.2dB	88±3.4bC	100±0.0aD	525.76	0.0001
Neem at15g	0.0±0.0cA	0.0±0.0cA	75±2.7bB	100±0.0aC	100±0.0aC	1750.0	0.0001
Pyrethrumat2g	100±0.0aA	100±0.0aA	100±0.0aA	100±0.0aA	100±0.0aA	0.000	1.000
Nimbecidineat 2.5ml	0.0±0.0cA	0.0±0.0cA	71±3.7cB	77±4.6cC	94±2.9bD	232.56	0.0001
Malathion at0.1g	96±2.4bA	99±1bB	100±0.0aC	100±0.0aC	100±0.0aC	2.14	0.11
Control	0.0±0.0c	0.0±0.0c	0.0±0.0e	0.0±0.0d	0.0±0.0c	0.000	1.000
F value(5,24)	2562.67	15841	262.96	277.65	1152.5		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

4.3 Adult Mortality in the Seeds of sesame

No significant mortality was recorded on seeds treated with bibira, neem and nimbecidine at all rates 30 min and 1h after treatment application, on the other hand pyrethrum and Malathion caused significant mortality at the given time of exposure. All the treatments were effective in causing 100% mortality at the highest dosage with higher exposure time (48h) except nimbecidine that caused 75% mortality.

Highest mortality was observed in Pyrethrum (49%) followed by Malathion (38%) and 0% mortality of the other treatments after 30 minutes. Malathion showed (96%) followed by Pyrethrum (80%) and 0% mortality in the other treatments after 1hr. Pyrethrum and Malathion showed 100% mortality followed by neem (23%), birbira (14%), nimbecidine (4%) after 12 hours. After 24 hours, 100% mortality of adults was recorded in Malathion and Pyrethrum followed by 62% neem, 59% birbira, 20% nimbecidine After 48 hours all the treatments showed 100% mortality except nimbecidine 47%. This indicates the increment of the treatments as the increment of time (Table 7).

Table 7: Relative efficacy of different treatments against Adults of Sesame seed bug (*E. sordidus*) of sesame at 1st application rate

Treatment Per 100g of seed	Mean±SE Adult mortality%						
	Hours after treatment						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbira at5 g	0.0±0.0bA	0.0±0.0cA	14±3.6bcB	59±5.3bC	100±0.0aD	228.90	0.0001
Neem at5g	0.0±0.0bA	0.0±0.0cA	23±6.4bB	62±9.3bC	100±0.0aD	73.51	0.0001
Pyrethrumat0.1g	49±5.7aA	80±4.5bB	100±0.0aC	100±0.0aC	100±0.0aC	48.84	0.0001
Nimbecidine at0.5ml	0.0±0.0bA	0.0±0.0cA	4±2.4cdB	20±1.6cC	47±2bD	161.68	0.0001
Malathion at0.1g	38±1.48aA	96±2.4aB	100±0.0aC	100±0.0aC	100±0.0aC	9.44	0.0002
Control	0.0±0.0bA	0.0±0.0cA	0.0±0.0dA	0.0±0.0dA	0.0±0.0cA	0.000	1.000
F value(5,24)	12.4	482.46	217.59	85.22	68.23		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

Highest mortality was observed in Pyrethrum (70%) followed by Malathion (51%) and 0% in other treatments after 30 minutes. On the other hand, highest mortality was recorded in Malathion (98%) followed pyrethrum (90%) after 1 hour. Hundred percent mortality was observed both in 0.5g Pyrethrum and 0.1g Malathion followed by neem 7.5g (33%), birbira 7.5g (21%) and nimbecidine 1ml (13%) after 12 hours. Twenty-four hours after treatment 100% mortality of adults was showed in both Malathion and Pyrethrum and followed by neem (62%), birbira (59%), and nimbecidine (20%). After 48 hours all the treatments showed 100% mortality except nimbecidine (53%) (Table 8).

Table 8: Relative efficacy of different treatments against Adults of Sesame seed bug (*E. sordidus*) of sesame at 2nd application rate

Treatment Per 100g of seed	Mean±SE Adult mortality%						
	Hours after treatment						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbiraat 7.5g	0.0±0.0bA	0.0±0.0cA	21±4bcB	67±3.74bC	100±0.0aD	327.55	0.0001
Neem at 7.5g	0.0±0.0bA	0.0±0.0cA	33±8.6bB	72±8.2bC	100±0.0aD	70	0.0001
Pyrethrum at 0.5g	70±6.3aA	90±2.2bB	100±0.0aC	100±0.0aC	100±0.0aC	18.88	0.0001
Nimbecidine at 1ml	0.0±0.0bA	0.0±0.0cA	13±2.5cdB	26±2.9cC	53±2.6bD	114.02	0.0001
Malathion at 0.1g	51±13.5aA	98±2aA	100±0.0aB	100±0.0aB	100±0.0aB	7.17	0.0009
Control	0.0±0.0bA	0.0±0.0cA	0.0±0.0dA	0.0±0.0dA	0.0±0.0cA	0.000	1.000
F value (5,24)	27.47	1575.1	122.08	109.8	76.9		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

As in table 9, highest mortality was observed in Pyrethrum (81%) followed by Malathion (49%) after 30 min whereas, Malathion and Pyrethrum shows equal mortality (96%) after 1 hour After 48 hrs all the treatments showed 100% mortality except nimbecidine 62%

Table 9: Relative efficacy of different treatments against Adults of Sesame seed bug (*E. sordidus*) of sesame at 3rd application rate

Treatment Per 100g of seed	Mean±SE Adult mortality%						
	Hours after treatment						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbira at 10g	0.0±0.0cA	0.0±0.0bA	29±5.3bB	78±4.1bC	100±0.0aD	232.08	0.0001
Neem at10g	0.0±0.0cA	0.0±0.0bA	35±10.8bB	80±5bC	100±0.0aD	73.5	0.0001
Pyrethrum at 1g	81±6.6aA	96±2.4aB	100±0.0aC	100±0.0aC	100±0.0aC	6.84	0.0012
Nimbecidine at1.5ml	0.0±0.0cA	0.0±0.0bA	21±4bcB	34±4.3cC	62±7.6bD	73.45	0.0001
Malathion at 0.1g	49±12.9bA	96±1.9aB	100±0.0aC	100±0.0aC	100±0.0aC	7.42	0.0008
Control	0.0±0.0cA	0.0±0.0bA	0.0±0.0cA	0.0±0.0dA	0.0±0.0cA	0.000	1.000
F value (5,24)	35.2	1552.1	66.4	160.58	60.48		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

According the result displayed in table 10, highest mortality was observed in Pyrethrum 1.5g per 100g seed (87%) followed by Malathion 0.1g per 100g seed (37%) and 0% mortality of the other treatments after 30 minutes. Pyrethrum showed 100% mortality followed by Malathion 97%. within 1 hr time of application. Hundred percent mortality was observed both in 1.5g Pyrethrum and 0.1g Malathion followed by neem 12.5g (47%), birbira 12.5g (34%), nimbecidine 2ml (27%) after 12 hrs. After 48 hrs all the treatments showed 100% mortality except nimbecidine 67% and control 0% (Table 10)

Table 10: Relative efficacy of different treatments against Adults of Sesame seed bug (*E. sordidus*) of sesame at 4th application rate

Treatment Per 100g of seed	Mean±SE Adult mortality%						
	Hours after treatment						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbira at12.5g	0.0±0.0cA	0.0±0.0bA	34±5.8bcB	83±4bC	100±0.0aD	215.68	0.0001
Neem at12.5g	0.0±0.0cA	0.0±0.0bA	47±6.6bB	90±4.2abC	100±0.0aD	184.45	0.0001
Pyrethrum at 1.5g	87±5.1aA	100±0.0aB	100±0.0aB	100±0.0aB	100±0.0aB	6.37	0.0018
Nimbecidine at 2ml	0.0±0.0cA	0.0±0.0bA	27±3.7cB	38±4.6cC	67±2bD	100.54	0.0001
Malathion at 0.1g	37±14.5bA	97±2aB	100±0.0aC	100±0.0aC	100±0.0aC	10.82	0.0001
Control	0.0±0.0cA	0.0±0.0bA	0.0±0.0dA	0.0±0.0dA	0.0±0.0cA	0.000	1.000
F value (5,24)=	32.14	1689.52	108.6	179	74.4		
P valu	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

Highest mortality was observed in pyrethrum 2g per 100g seed (97%) followed by Malathion 0.1g per 100g seed (42%) and 0% mortality of the other treatments within 30 minutes. Hundred percent mortality was showed in pyrethrum, followed by Malathion (99%) within 1 hour after time of application. Twenty-four hours after treatment 100% mortality of adults was showed in Malathion and Pyrethrum and followed by 97% neem, 92% birbira, and 46% nimbecidine. After 48 hrs, all the treatments showed 100% mortality except nimbecidine 75% (Table 11)

Table 11: Relative efficacy of different treatments against Adults of Sesame seed bug (*E. sordidus*) of sesame at 5th application rate

Treatment Per 100g of seed	Mean±SE Adult mortality%						
	Hours after treatment						
	30 min	1 hr	12 hr	24 hr	48 hr	F value	P value
Birbira at 15g	0.0±0.0cA	0.0±0.0bA	43±5.4bcB	92±3.4aC	100±0.0aD	317.85	0.0001
Neem at 15g	0.0±0.0cA	0.0±0.0bA	56±6.2bB	97±2aC	100±0.0aD	0.000	1.000
Pyrethrum at 2g	97±2aA	100±0.0aB	100±0.0aC	100±0.0aC	100±0.0aC	2.25	0.099
Nimbecidineat 2.5ml	0.0±0.0cA	0.0±0.0bA	31±5.3cB	46±4.3bC	75±4.2bD	79.09	0.0001
Malathion at 0.1g	42±14.9bA	99±1aB	100±0.0aC	100±0.0aC	100±00aC	9.73	0.0002
Control	0.0±0.0cA	0.0±0.0bA	0.0±0.0dA	0.0±0.0cA	0.0±0.0cA	0.000	1.000
F value (5,24)	42.32	15841	97.3	298.28	78.5		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

4.4 weight loss assessment for storage experiment

4.4.1 Temporally recorded weight loss in sesame seeds treated with the different treatments and stored in clean sacks in a shade

The result in table 12 revealed that, a seed treated with Birbira powder was found not statistically significant different ($p \geq 0.05$) from the control in the percentage weight loss, at the first 10 days after treatment. On the other hand, seed treated with neem, nimbecidine, Malathion and pyrethrum showed statistically significant difference ($P \leq 0.05$) from the control in preventing seed weight loss. As time extended to 50 days after the treatment, neem and nimbecidine showed better protection relative to the other treatments.

Table 12: Weight loss caused by *E. sordidus* in Sesame seeds treated with different treatments in shade area

Treatment Per 100g of seed	Mean ±SE percent weight loss						
	10 days	20 days	30 day	40 days	50 days	F value	P value
Birbira at 2%	1.64±0.93aA	5±0.5bB	9.8±0.9cC	14.5±0.5aD	16.4±0.2aE	415.74	0.0001
Neem at 2%	1±0.3bA	2.3±0.2bA	6.4±0.8dB	9.6±0.2dC	10.4±0.1cD	262.98	0.0001
Nimbecidine at 4%	1.3±0.6bA	3.3±0.4bA	7.4±0.7dB	10.6±0.3dC	11.7±0.1dD	350.02	0.0001
Pyrethrum at 1%	1.2±0.5bA	5.1±0.9asB	10.3±0.7bC	13.3±0.2bD	14±0.1eD	22.85	0.0001
Malathion at 0.1%	1.2±0.5bA	4.7±0.7bB	9.2±0.6dC	12.9±0.5cD	14.7±0.1bE	420.57	0.0001
Control	1.8±1.1aA	6.1±0.9aB	11.6±0.6aC	15.1±0.3aD	16.0±0.1aD	255.7	0.0001
F value(5,24)	0.7	4.52	7.15	37.27	573.59		
P value	P<.6	P<.0048	P<.0003	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

4.4.2 Temporally recorded weight loss in sesame seed filled in sacks treated with the different treatments and stored in shade area

Results of sesame seed weight loss on dipped and dusted sacks with different treatments are given in Table 13. Weight loss was checked every 10 days and all the treatments were significant in reducing weight loss while compared with the control at every 10 days interval. The maximum weight loss was recorded in the Nimbecidine treated sacks (1.2%) on the first 10 days and pyrethrum dusted sack on the 50th day (13.2%). On the other hand, minimum weight loss was observed in Malathion (0.4%) and pyrethrum (0.8%) and Malathion (11.5%) and neem (11.7%) at the specified interval.

Table13: Weight loss caused by *E. sordidus* in sesame seeds kept in sacks treated with different treatments

Treatment Per 100g of seed	Mean ±SE percent weight loss						
	10 days	20 days	30 day	40 days	50 days	F value	P value
Birbira at 50ml/sack	1.1±0.22bA	3.9±0.45bB	6.9±0.2cC	9.8±0.6bD	12.1±0.1dE	620.63	0.0001
Neem at 2%	1.1±0.2bA	3.4±0.5bB	6.5±0.3cC	9.9±0.6bD	11.7±0.1eE	531.56	0.0001
Pyrethrum at 2g/ sack	0.8±0.2aA	4.2±0.8bB	8.6±0.3bC	11.5±0.5bD	13.2±0.1bE	353.86	0.0001
Nimbecidine at 0.5 ml /sack	1.4±0.4csA	4.2±0.4bB	7.1±0.3cC	10.4±0.5bD	12.4±0.1cE	592.83	0.0001
Malathion at 2 g/sack	0.4±0.1aA	3±0.8bB	6.9±0.2cC	9.8±0.5bD	11.5±0.0eE	367.94	0.0001
Controlat 50ml water/sack	1.4±0.3cA	7.6±0.9aB	13.1±0.3aC	16.5±0.6aD	18.9±0.1aE	352.47	0.0001
F value (5,24)	2.49	5.79	91.65	22.19	976.14		
P value	P<.059	P<.0012	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

4.4.3 Infested seeds of sesame seeds treated with the different treatments and put in shade

In treated sacks the mean percent of infestation was significantly different from the control. The lowest seed infestation was recorded in pyrethrum (15.8%) followed by Malathion (17.8%) and Nimbecidine (22.6%) (Table14) whereas in the treated seeds there was no significant difference among the treatments except in birbira where highest infestation was recorded (Table 14).

Table 14: Mean percent infested sesame seeds in treated sacks and treated seeds with the different botanical and kept in shade for 50 days

Treatment Per 1000g of seed	Mean±SE Percent infestation after 50 days	
	In treated sacks	In treated seeds
Birbira at 50ml/sack	25.3±2.6b	47.4±2.38a
Neem at 50ml/sack	26.3±3.6b	34.8±2.8c
Pyrethrum at 2g/ sack	15.8±2d	34.1±1.67c
Nimbecidine at 0.5 ml /sack	22.6±0.8c	35.1±2.45c
Malathion at 2g/sack	17.8±1.2d	31.3±0.9c
Control at 50ml water/sack	36±3.4a	37.6±2.24b
F value (5,24)	8.95	3.24
P value	P<.0002	P<.023

Means followed by the same letter within a column are not significantly different at P=0.05 (Tukey-Kramer HSD, JMP In 2003).

4.4.4 Weight loss and Adult mortality in open plastic buckets treated with the different treatments

Results of percentage weight loss of treated sesame seed in open buckets due to free visiting insects in highly infested area are given in Table 15-17 respectively. As the result indicated that maximum seed weight loss in birbira and the minimum loss in pyrethrum were recorded in the first two application rates in the fifth day. On the other hand, at application rate 3 maximum losses in nimbecidine and minimum loss in neem was observed in the fifth day (Table 15 to 20).

The results of the current study revealed that, there were statistically significant different ($p \leq 0.05$) in all treatments and all days of exposure in weight loss (table 15, 16 and 17). Similar trends were observed on the treatment effects on *E. sordidus* in number of dead visiting insects in all treatment rates and days of exposure (table18, 19 and 20).

In all the plastic buckets the percent of weight loss of sesame seed were lower in the 1st day and gradually increased in the following day after treatment (Tables 15, 16 and 17). The control check (open control) and birbira showed significantly higher weight loss than other treatments in the 1st day and following 2nd day. Moreover, in the closed control (none free insect visitation) there was no significant seed weight loss (Table 15 to 20).

Table 15 shows the mean separation of percentage weight loss in open plastic buckets for the treatments. The result showed that there was significant difference between the treatments and open and closed control as the time of after treatment application increased. In the 1st day after treatment application there was no significance weight loss difference between the treatments except in control and nimbecidine. As time of exposure increases there was a big weight loss difference between the treatments with lowest weight loss in pyrethrum (27%) and highest loss in open control (75%) at the 5th day. In all the exposure time pyrethrum, neem and Malathion performed better than the other treatments except in the non insect visitation closed control.

Table 15: Percent weight loss caused by *E. sordidus* in open plastic buckets treated with different treatments at application rate one

Treatment Per 100g of seed	Mean±SE seed weight loss in days after treatment						
	1st Day	2nd Day	3rd Day	4th Day	5th Day	F value	P value
Birbira at 5g	1.1±d0.4bA	16.3±5.2abB	42.7±9.4abC	60.8±11aD	72.1±10.9aE	12.45	0.0001
Neem at 5g	0.6±0.1bA	6.5±0.7bcB	17.5±1.6bcC	30.7±3.1bcD	43.5±3.3abE	64.44	0.0001
Pyrethrum at 0.1g	0.1±0.1bA	3.4±1.3bcB	9.3±2.6cC	19.5±4.9cD	27.8±6.9bcE	8.17	0.0004
Nimbecidine at 0.5ml	13.2±2.5aA	29.7±5.1aB	46.2±7.5aC	56.2±8.4abD	66±9.77aE	8.7	0.0003
Malathion at 0.1g	0.1±0.1bA	1.8±0.6cA	6.6±1.7cB	20.7±2.9cC	31.4±5.5bcD	21.24	0.0001
Closed control	0.1±0.1bA	0.4±0.1cA	0.4±0.1cA	0.6±0.1cA	0.8±0.1cA	13.55	0.0001
Open control	10.1±3aA	26.4±4.1aB	51.8±8.3aC	64.9±9.1aD	75.2±9.2aE	13.55	0.0001
F value(6,28)	14.0	14.19	13.72	13.46	13.55		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

As the result in table 16 shows, highest weight loss was observed in birbira and closed control (21.3 and 10.2%, respectively) after the 1st day after of treatment application. As time of exposure increased highest mortality was recorded in birbira and open control (76.9% and 75.2%, respectively) than any other of the treatments in the 5th day after treatment application. On the other hand, lowest weight loss was observed in pyrethrum (19.5%) followed by neem (30.3%) and Malathion (31.4%). But in the closed control since there was no insect visitation, there was no significance weight loss.

Table 16: Percent weight loss caused by *E. sordidus* on open plastic buckets treated with different treatments at application rate two

Treatment Per 100g of seed	Mean±SE seed weight loss in days after treatment						
	1st Day	2nd Day	3rd Day	4th Day	5th Day	F value	P value
Birbira at 10g	21.3±1.4aA	40.4±3.3a	54.5±4.3aB	69.3±5.5aC	76.9±3.9D	32.56	0.0001
Neem at10g	4.5±1.6bcA	13..3±2.3cdB	19.7±3.7cdC	15±12.2cD	30.3±6.3E	2.13	0.11
Pyrethrumat 1g	2.9±0.6cA	6.4±0.7deB	10.2±1.3dC	12.45±3.5cD	19.5±2.9E	8.79	0.0003
Nimbecidineat1.5ml	9.9±1.4bA	22.6±4.5bcB	31.9±6.1bcC	32.7±10.6bcC	53±8.9D	4.94	0.006
Malathion at 0.1g	0.1±0.1cA	1.8±0.6deA	6.6±1.7dB	20.7±2.9cC	31.4±5.5D	21.24	0.0001
Closed control	0.1±0.1cA	0.3±0.1eA	0.3±0.1abA	0.6±0.1cA	0.8±0.1A	9.89	0.0001
Open control	10.2±3bA	26.4±4.1bB	51.8±8.6abC	64.8±9abD	75.2±9.2E	13.55	0.0001
F value(6,27)	24.66	27.89	22.08	12.52	21.9		
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

The mean separation in table 17 indicates lowest weight loss in Malathion, closed control, neem and pyrethrum in the 1st day after treatment application. At 5th day the highest weight loss was recorded in the open control (75.2%) and nimbecidine (57%) while lowest weight loss was observed in the non insect visited closed control (0.8%) followed by pyrethrum (17.5%).

Table 17: Percent weight loss caused by *E. sordidus* on open plastic buckets treated with different treatments at application rate three

Treatment Per 100g of seed	Mean±SE seed weight loss in days after treatment						
	1st Day	2nd Day	3rd Day	4th Day	5th Day	F value	P value
Birbira at 15g	11.9±1.4aA	20.45±1.6aB	28.6±2.5bC	35.8±3bcD	41±3.5bcE	20.6	0.0001
Neem at 15g	4.6±0.5abA	7.9±1.2bcB	10.6±1.6cdC	10.5±3cD	13.6±1.8deE	3.31	0.030
Pyrethrum at 2g	5.2±1.6abA	6.5±2.3cA	9.4±2.6cdB	12.2±2.6cC	17.5±9.4deD	2.47	0.077
Nimbecidine at 2.5ml	11.2±4.6aA	18.5±4.6abB	36.3±6.7abC	46.9±7.8abD	57.4±9.4abE	7.83	0.0006
Malathion at 0.1g	0.1±0.1bA	1.8±0.5cB	6.6±1.7dC	20.7±2.9cdD	31.4±5.5cdE	21.24	0.0001
Closed control	0.1±0.1bA	0.3±0.1cA	0.3±0.1dA	0.6±0.1cA	0.8±0.1eA	9.89	0.0001
Open control	10.2±3abA	26.4±4.1aB	51.8±8.6bC	64.8±9.1aD	75.2±9.2aE	13.55	0.0001
F value(6,28)	4.89	14.6	18.02	20.52	20.92		
P value	P<.0016	P<.0001	P<.0001	P<.0001	P<.0001		

Means followed by the same upper case along rows and lower case letters within a column are not significantly different at the 5% level of probability ((Tukey-Kramer HSD, JMP 5).

The mean separations in tables 18-20 indicate the number of dead insects that remained in the buckets after successive data recording hours from those visiting insects. Thus, in all the tables (18, 19 and 20) pyrethrum was caused very high mortality as a result of high potential of knock down effect followed by Malathion and neem. From the result nimbecidine was not significantly different from the control.

Table 18: Mean percent visiting *E. sordidus* adults found dead in the open plastic buckets containing sesame seeds treated with different treatments.

Treatment Per 100g of seed	Mean ±SE Percent dead visitor adults on daily basis				
	1st Day	2nd Day	3rd Day	4th Day	5th Day
Birbira at 5g	19.1±12.4c	0.0±0.0c	0.0±0.0c	5.67±3.6c	6.66±6.66c
Neem at 5g	11.6±11.6c	19.2±7.9c	12.7±9.3	37.4±10.7b	22.8±11.7c
Pyrethrum at 0.1g	72.4±8.86a	71.8±7.4b	70.1±7.9a	77.5±6.6a	82.3±22.7a
Nimbecidine at 0.5ml	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c
Malathion at 0.1g	67.3±11.3b	74.8±4.4a	66.3±9.9b	78.3±7.4a	71.7±8.3b
Closed control	0.0±0.0c	0.0±0.0c	00±00c	0.0±0.0c	0.0±0.0c
Open control	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c
F value (6, 28)	14. 53	61.29	29.85	40.9	225.38
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001

Means followed by the same letter within a column are not significantly different at P=0.05 (Tukey-Kramer HSD, JMP In 2003).

Table 19: Mean percent visiting *E. sordidus* adults found dead in the open plastic buckets containing sesame seeds treated with different treatments.

Treatment Per 100g of seed	Mean±SE Percent dead visitor adults on daily basis				
	1st Day	2nd Day	3rd Day	4th Day	5th Day
Birbira at 10g	0.0±0.0c	13.5±9.9c	14.3±6.4c	0.0±0.0c	5.7±5.7c
Neem at 10g	0.0±0.0c	16.6±16.6c	20.6±8.9c	10±10c	3.1±3.1c
Pyrethrum at 1g	92.3±4.8a	87.9±3.8a	80.9±8.5a	84.1±4.1a	84.8±4.6a
Nimbecdine at 1.5ml	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c
Malathion at 0.1g	59.2±20.4b	74.8±9.9b	66.3±9.9b	78.3±7.3b	71.8±8.3b
Closed control	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c
Open control	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c
F value (6,27)	111.07	24.3	27.44	61.49	75.3
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001

Means followed by the same letter within a column are not significantly different at P=0.05 (Tukey-Kramer HSD, JMP In 2003).

Table 20: Mean percent visiting *E. sordidus* adults found dead in the open plastic buckets containing sesame seeds treated with different treatments.

Treatment Per 100g of seed	Mean±SE Percent dead visitor adults on daily basis				
	1st Day	2nd Day	3rd Day	4th Day	5th Day
Bibiraat15g	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c
Neem at 15g	4.6±4.6c	5±5c	6.7±6.7c	7.3±7.3c	8.6±5.3c
Pyrethrum at2g	88.1±5.6a	98.3±1.7a	95.9±2.5a	97.9±1.3a	98.2±1.1a
Nimbecidineat 2.5ml	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c
Malathion at0.1g	67.3±11.3b	74.8±4.4b	66.3±9.9b	78.3±7.4b	71.8±8.3b
Closed control	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c
Open control	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.0±0.0c
F value (6,27)	55.43	264.97	75.25	117.3	123.3
P value	P<.0001	P<.0001	P<.0001	P<.0001	P<.0001

Means followed by the same letter within a column are not significantly different at P=0.05 (Tukey-Kramer HSD, JMP In 2003).

4.4.5 Oil content of the sesame seeds in the shade experiment

The result in table 21 reveals that highest oil loss was recorded in the open untreated control and birbira at all rates of application (5%, 10% and 15%). Pyrethrum was possessed low oil losses comparable to the standard check Malathion and closed control. Nimbecidine also shows comparably low oil loss followed by neem. In this result there was significance difference oil loss between the treatments but there was no significance difference with in the treatments.

Table 21: Percent Oil loss due to *E. Sordidus* on sesame treated with botanicals and nimbecidine treated at different rates and kept in open buckets.

Mean±SE % oil loss by treatment								
Birbira	Neem	Pyrethrum	Nimbecidine	Malathion	Open Control	Closed control	F value (6, 16)	P value
at 5g	**at 5g**	**at 0.1g**	**at 0.5ml**	**at 0.1g**	**---**	**---**		
7±0.4a	3.3±0.92b	1.5±0.7b	2.1±0.56b	0.3 b	4.9a	0b	8.24	0.0004
at 10g	**at 10g**	**at 1g**	**at 1.5ml**	**at 0.1g**	**---**	**---**		
7.7±0.5a	3.37±0.8b	1.7±0.5b	1.8±0.4b	0.7b	3.06ab	0.1b	13.21	0.0001
at 15g	**at 15g**	**at 2g**	**at 2.5ml**	**at 0.1g**	**---**	**---**		
6.3±0.7a	3.37±0.8ab	1.4±0.6b	1.7±0.4b	0.38b	4.41ab	0.0000b	6.92	0.0009

Means followed by the same letter within a column are not significantly different at P=0.05 (Tukey-Kramer HSD, JMP5s).

5. Discussion

The current study was conducted to assess the ovicidal, nymphcidal, adulticidal, and weight loss and infestation protection of the sesame seeds with different treatments against the sesame seed bug. The result revealed that high ovicidal effects of pyrethrum seed powder extracts on eggs of Sesame seed bug under laboratory conditions. At the highest pyrethrum (2%) concentration 76.7% hatching inhibition were observed. Following pyrethrum, Nimbecidine at the manufacturers' rate of application also caused high egg inhibition with 53.3% mortality of eggs. Moderate ovicidal activity of birbira and neem were recorded at their highest rate of applications with 48.6% and 39.3% respectively.

Similar studies by (Umar *et al.*,, (2007), Sharma *et al.,* (2009), Chandrasekaran *et al.,* (2003) and Su and Mulla (1999)) reported that the ovicidal efficacy of different neem formulations against egg hatching. In addition Das *et al.,* (2006) also reported that Nimbicidine possessed ovicidal effect. The current study contrasts with the work of Pavela (2009) who reported that pyrethrum had no ovicidal effect on *E. sordidus*.

The plant materials tested gave a comparable control of sesame seed bug nymph and adult with that of the standard insecticide, Malathion. Among the powder plant materials, pyrethrum flower powder applied at all doses caused 100% mortality of sesame seed bug nymphs within 12 hours after treatment application. Pyrethrum flower powder at the lowest rate of application (equal amount with Malathion) was achieved 49% which is better than the standard checks Malathion 38% mortality of sesame seed bug within 30 min. after time of application. Whereas after 1 hr. time of application a comparable efficacy was possessed 80% but 96% adult sesame seed bug mortality. About 12 hrs after treatment application pyrethrum was equally effective with the standard check Malathion which achieves 100% mortality.

Insects react very quickly when dosed with pyrethrum, has quick knock-down effect Pyrethrum acts on a very wide spectrum of insect species – more so than with most individual synthetic insecticides (Pesticide Outlook, 2001). Pyrethrum is effective against wider range of insects in a wider range of application than any other pyrethroid (Wilson, 1973). Pyrethrin has highly unusual insecticidal activity, with the ability to control or repel numerous insect species, with little or no adverse environmental impact (Casida and Quistad, 1995).

Dried ground flowers of pyrethrum (*C. cinerariaefolium*) were shown to have different insecticidal activities against different storage insect pests. This is because of the effective knock down efficacy of its compounds. Silcox and Roth, (1995) stated that pyrethrum can be applied as quick Knock down spray on the day of harvest either to control insects or reduce their population which is in agreement with the present study.

All powder plant materials used in this experiment admixed with sesame seeds caused significant mortality of nymphs and adults of sesame seed bug. Seed of sesame treated with Birbira was causing 100% mortality of nymph and adults 48 hrs after treatment application in all doses. The study showed that the efficacy of birbira increases as dose and time of application increases. Similarly, Bekele (2002) evaluated the toxicity of Milletia seed against *Sitophillus zeamais* and reported higher mortality of the weevil within 48 hours after treatment. Furthermore, the toxicity of the plant can be attributed to rotenone which is one of the dominant compounds found in the seed and stem bark of birbira and is a well-known botanical insecticide through contact and stomach poisoning (Bekele, 2002; and Saxena, 1983).

Different dose of neem caused significant mortality of nymphs and adults of sesame seed bug. About 100 % mortality of nymphs and adults were recorded at all rates 48h after treatment application. Likewise, Tadesse and Basedow (2005) reported that NSP (neem seed powder) rates of 2 % caused equal amounts of adult weevil mortality as higher rates, following 5 days after infestation. Similarly, Pereira and Wohlgemuth (1982) evaluated NSP at rates ranging from 0.5 to 8 % against six species of stored grain pests on maize and found it to be toxic to the adults of *Sitophilus oryzae* followed by *Cryptolestes ferrugineus, Rhizopertha dominica* and *Sitophilus zeamais*. With *Sitophilus oryzae*, there was 99 % mortality at 4 % NSP treatment by the third day of exposure. Shaheen (2006) also reported the neem seed powder applied at the rate of 1% w/w caused 100% mortality against pulse beetle within four days.

Nimbecidine oil treatment on sesame seeds also caused a high mortality of nymphs and adults in all rates. About 61% to 94% mortality of nymph was recorded in all doses 48h after treatment application where as about 47% to 75% of adult mortality was recorded at the same rate of application and time of exposure. Similarly, El-Hawary *et al.*, (2008) found that the efficacy of Nimbecidine against *Aphis craccivora* Koch with the highest percentage reduction natal period and longevity. This was agreed with the El-Hawary *et al.*, (2008) work that is as the concentration increases mortality was also increased.

The shade storage studies with seeds and sacks treated with different treatments of the respective treatments showed that, the pest population increased through time and caused more seed loss in both the treated seeds and sacks. The highest damage in all the trials was also observed in the 40^{th} and 50^{th} days after storage.

In all the seed treatment trials, weight loss was increasing as storage time extends. The untreated check (control) had a significantly higher percent weight loss. However, neem and nimbecidine treated seeds had lower seed weight loss within 20 -50 days of storage. It could be justified as Maraddi (2002) who suggests that the insecticidal property present in the botanicals helps in making the seeds incompatible for insects during storage. The present finding also confirmed to Adugna (2006) who suggested an increase in weight loss as increase in storage time.

Similaly, weight loss of seeds kept in treated sacks showed an increasing trend with time of storage. However, seeds filled in Malathion and Neem treated sacks had significantly lower seed weight loss than the other treatments from 10^{th} days on ward of storage time. This is in agreement with the results of Anwar *et al.*, (2005) who indicated that neem oil has a strong insecticidal effect on stored grain beetles when used on packing bags.

On the other hand, nimbicidine both on treated sacks and seeds with treatments were superior in reducing weight loss as storage time increases compared to pyrethrum. This might be due to the fact that, these treatments have oily substance that keep the seeds and sacks intact and highly persistence. This is in agreement with the work of Aly and Sahar, (2010), the high efficacy of spearmint oil than powder against *C. maculates* is may be due to the high penetration ability of oil to insect body than powder.

Lowest seed infestation was recorded in treated sacks than treated seeds from all the treatments. However, pyrethrum was very effective in reducing seed infestation in treated sacks and it was next to Malathion in treated sesame seeds. This lower percent of seed infestation recorded in pyrethrum could be due to the treatment having different inhibiting factor against the sesame seed bug, such as high persistence, knock down effect and repellence of the treatment. The current study was also in line with the findings of Mulungu *et al.,* (2011) that is pyrethrum and *G. Kraussiana* powders could be used in protecting stored maize grians against maize storage pests through suppressing number of emerged adult insects, number of holes, damaged seeds, percentage damaged seeds and weight loss. Thus, botanicals because of their insecticidal property, reduces the insect attack and leads to better seed quality parameters as explained by (Merwade, 2000). Similarly, nimbecidine was effective in reducing seed infestation better than neem and birbira in treated sacks. Likewise, Channabasanagowda *et al.,* (2008), obtained that the seeds treated with organics namely sweet flag rhizome powder at 5g and10 g per kg seed, nimbicidine and neem oil also recorded lower seed infestation percentage on equivalence with deltamethrin (3.00%) indicating the possibility of use of these botanicals in controlling the insect infestation.

The experiment on open plastic buckets of seeds treated with different treatments showed that the respective treatments up to five days of storage period in a highly infested area and uncontrolled visitors of sesame seed bugs. This was due to the fact that the pest damage and weight loss is higher in the field while the sesame is cut and put together for drying in open field locally called “Hilla”. The trial in open buckets was carried out to represent the efficacy of the treatments in open fields. Highest sesame seed weight loss in open buckets due to free visitation of sesame seed bug were observed in birbira at 5% and 10% rate of application in the 5th day after treatment application where as lowest sesame seed weight loss was recorded in pyrethrum in the 0.1% and 1% and neem (15%) rate of application in the 5th day. It was also observed that the weight loss increased as the period of exposure extends.

Highest mortality of uncontrolled visitors of sesame seed bug was recorded in pyrethrum than the other treatments. Because pyrethrum has high knock down effect but the other botanicals have high repellence effect. However, mortality of the uncontrolled visiting insects in treated seeds with botanical treatments in open plastic buckets was not depending on the dose of application and days after the exposure time. This was also depends on the number of visiting insects and nature of the botanicals. Correspondingly Silcox and Roth (1995) suggested that pyrethrum products are used on major crops, although this is generally at lower, more economical application rates that are directed at pests that are particularly susceptible to payrethrins. In addition, Kalaiyarasan and Palanisamy (2002) reported that in the field condition neem seed kernel (NSK) (5%) and Neem oil (2%) are effective in the reduction of the incidence of *E. sordidus* and found that NSKE as superior to neem oil in the field condition. Moreover, a number of powder extract of plant materials was reported to have the potential of protecting cereals and pulses against attack by insects. Mekuria (1995), Bekele *et al.,* (1996), Bayeh and Tadess (200), Araya and Emana (2009), Dawit and Bekele (2010), Mulungu *et al.,* (2007) and Mulungu *et al.,* (2011) reported that botanical powders added to grains (i.e. cereals and pulses) gave effective protection against attack by insect pests.

6. Conclusion and Recommendations

6.1. Conclusion

This result suggests that the tested materials (neem and birbira seed powder, pyrethrum flower dust and nimbecidine) have the potential to provide seed protection and used for control of sesame seed bug in sesame storage in an environment-friendly way.

The protection of sesame seed against *E. sordidus* damage provided by plant powders varied in terms of plant materials, their application rates and exposure time. The study showed that longer exposures with higher rates provided significantly higher mortality of *E. sordidus.*

Application of the botanicals has reduced the seed weight loss and infestation by *E. sordidus.* This application of botanicals directly to the seeds and bugging sacks is effective technique for the management of *E. sordidus.*

6.2. Recommendations

- The present study on the efficacy of those local plant powders and nimbecidine illustrated their potential as seed protectants with verification under real storage conditions are needed.

- Further investigation is required for botanicals that caused highest mortality at the lowest dose used in the current study for the management of sesame seed bug in sesame seed storage.

- The efficacy of mixture of nimbecidine with other plant based products as sesame seed protectant against sesame seed bug should be evaluated in the future.

- Although the following recommendation is not an outcome of the present study it was witnessed that field sanitation such as burning of the stalks of sesame and ploughing of the land repeatedly will effectively reduce the adult population. In addition sanitation of the area around the storage area also provides reduction of the SSB population.

- Moreover, the stalks of sesame "Jewjaw" were found to contribute as concealing and breeding site. Since it stays in the field for long period of time and it is not needed by live stock as a source of feed due to its high lignin content, which requires devising away to reduce the lignin content.

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ANNEXES

Annex 1: Sample of the used materials

Nimbecidine


Cloth mesh

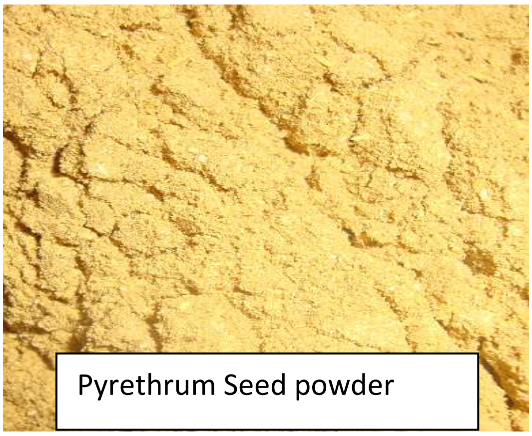

Glass jars and Petri dishes

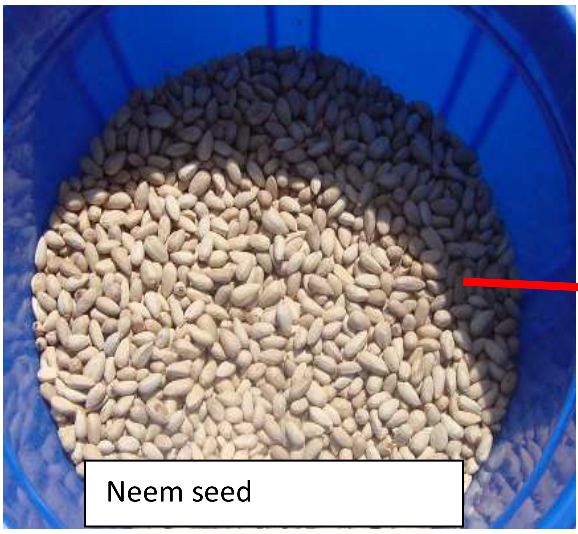

Hand sprayers

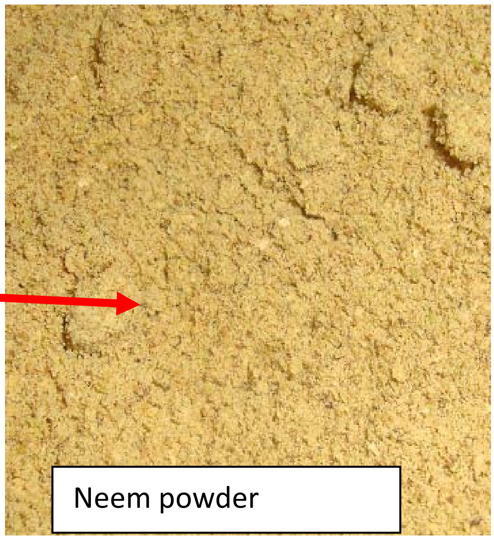
Plastic buckets


Sesame seed used for the experiment

Annex 2: Plant materials applied in the experiment







Annex 3: Sample of rearing of sesame seed bug and newly hatched nymphs

Annex 4: Filtration of neem and birbira water extracts through cloth mesh

Annex 5: Sunken and health sesame seed due to sesame seed bug

Annex 6: Some of the alternative hosts of sesame seed bug

Annex 7: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E.sordidus* nymphs due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds at 1st application rate

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	41537.500	8307.50	1533.692	<.0001
	With in groups	24	130.000	5.42		
	Total	29	41667.500			
Mortality after 1hr	Between Groups	5	48097.500	9619.50	136.6083	<.0001
	With in groups	24	1690.000	70.42		
	Total	29	49787.500			
Mortality after 12hrs	Between Groups	5	46084.167	9216.83	58.2116	<.0001
	With in groups	24	3800.000	158.33		
	Total	29	49884.167			
Mortality after 24hrs	Between Groups	5	36894.167	7378.83	83.1418	<.0001
	With in groups	24	2130.000	88.75		
	Total	29	39024.167			
Mortality after48 hrs	Between Groups	5	40450.000	8090.00	269.6667	<.0001
	With in groups	24	720.000	30.00		
	Total	29	41170.000			

Annex 8: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus* nymphs due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds 2nd application rate

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	44560.000	8912.00	1336.8	<.0001
	With in groups	24	160.000	6.67		
	Total	29	44720.000			
Mortality after 1hr	Between Groups	5	55504.167	11100.8	346.0000	<.0001
	With in groups	24	770.000	32.1		
	Total	29	56274.167			
Mortality after 12hrs	Between Groups	5	37336.667	7467.33	94.3242	<.0001
	With in groups	24	1900.000	79.17		
	Total	29	39236.667			
Mortality after 24hrs	Between Groups	5	35360.000	7072.00	530.4000	<.0001
	With in groups	24	320.000	13.33		
	Total	29	35680.000			
Mortality after48 hrs	Between Groups	5	40504.167	8100.83	2777.429	<.0001
	With in groups	24	70.000	2.92		
	Total	29	40574.167			

Annex 9: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus* nymphs due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds at 3rd application rate

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	51944.167	10388.8	1187.295	<.0001
	With in groups	24	210.000	8.8		
	Total	29	52154.167			
Mortality after 1hr	Between Groups	5	59837.500	11967.5	1689.529	<.0001
	With in groups	24	170.000	7.1		
	Total	29	60007.500			
Mortality after 12hrs	Between Groups	5	35904.167	7180.83	152.5133	<.0001
	With in groups	24	1130.000	47.08		
	Total	29	37034.167			
Mortality after 24hrs	Between Groups	5	35656.667	7131.33	398.0279	<.0001
	With in groups	24	430.000	17.92		
	Total	29	36086.667			
Mortality after48 hrs	Between Groups	5	40037.500	8007.50	2402.25	<.0001
	With in groups	24	80.000	3.33		
	Total	29	40117.500			

Annex 10: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus* nymphs due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds at 4th application rate

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	64066.667	12813.3	1808.941	<.0001
	With in groups	24	170.000	7.1		
	Total	29	64236.667			
Mortality after 1hr	Between Groups	5	66004.167	13200.8	15841	<.0001
	With in groups	24	20.000	0.8		
	Total	29	66024.167			
Mortality after 12hrs	Between Groups	5	34114.167	6822.83	141.1621	<.0001
	With in groups	24	1160.000	48.33		
	Total	29	35274.167			
Mortality after 24hrs	Between Groups	5	36816.667	7363.33	245.4444	<.0001
	With in groups	24	720.000	30.00		
	Total	29	37536.667			
Mortality after48 hrs	Between Groups	5	40150.000	8030.00	1133.647	<.0001
	With in groups	24	170.000	7.08		
	Total	29	40320.000			

Annex 11: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus* nymphs due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds at 5th application rate

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	64066.667	12813.3	2562.667	<.0001
	With in groups	24	120.000	5.0		
	Total	29	64186.667			
Mortality after 1hr	Between Groups	5	66004.167	13200.8	15841	<.0001
	With in groups	24	20.000	0.8		
	Total	29	66024.167			
Mortality after 12hrs	Between Groups	5	33966.667	6793.33	262.9677	<.0001
	With in groups	24	620.000	25.83		
	Total	29	34586.667			
Mortality after 24hrs	Between Groups	5	38177.500	7635.50	277.6545	<.0001
	With in groups	24	660.000	27.50		
	Total	29	38837.500			
Mortality after48 hrs	Between Groups	5	40816.667	8163.33	1152.471	<.0001
	With in groups	24	170.000	7.08		
	Total	29	40986.667			

Annex 12: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus adults* due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds at 1st application rate

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	12917.500	2583.50	12.4008	<.0001
	With in groups	24	5000.000	208.33		
	Total	29	17917.500			
Mortality after 1hr	Between Groups	5	52266.667	10453.3	482.4615	<.0001
	With in groups	24	520.000	21.7		
	Total	29	52786.667			
Mortality after 12hrs	Between Groups	5	55304.167	11060.8	217.5902	<.0001
	With in groups	24	1220.000	50.8		
	Total	29	56524.167			
Mortality after 24hrs	Between Groups	5	41724.167	8344.83	85.2238	<.0001
	With in groups	24	2350.000	97.92		
	Total	29	44074.167			
Mortality after48 hrs	Between Groups	5	42077.500	8415.50	68.2338	<.0001
	With in groups	24	2960.000	123.33		
	Total	29	45037.500			

Annex 13: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus* adults due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds at 2nd application rate

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	25304.167	5060.83	27.4796	<.0001
	With in groups	24	4420.000	184.17		
	Total	29	29724.167			
Mortality after 1hr	Between Groups	5	59066.667	11813.3	1575.111	<.0001
	With in groups	24	180.000	7.5		
	Total	29	59246.667			
Mortality after 12hrs	Between Groups	5	49087.500	9817.50	122.0829	<.0001
	With in groups	24	1930.000	80.42		
	Total	29	51017.500			
Mortality after 24hrs	Between Groups	5	40724.167	8144.83	109.8180	<.0001
	With in groups	24	1780.000	74.17		
	Total	29	42504.167			
Mortality after48 hrs	Between Groups	5	40846.667	8169.33	76.8878	<.0001
	With in groups	24	2550.000	106.25		
	Total	29	43396.667			

Annex 14: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus* adults due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds at 3rd application rate

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	30726.667	6145.33	35.2000	<.0001
	With in groups	24	4190.000	174.58		
	Total	29	34916.667			
Mortality after 1hr	Between Groups	5	61440.000	12288.0	1552.168	<.0001
	With in groups	24	190.000	7.9		
	Total	29	61630.000			
Mortality after 12hrs	Between Groups	5	44847.500	8969.50	66.4407	<.0001
	With in groups	24	3240.000	135.00		
	Total	29	48087.500			
Mortality after 24hrs	Between Groups	5	40146.667	8029.33	160.5867	<.0001
	With in groups	24	1200.000	50.00		
	Total	29	41346.667			
Mortality after48 hrs	Between Groups	5	39190.000	7838.00	60.4862	<.0001
	With in groups	24	3110.000	129.58		
	Total	29	42300.000			

Annex 15: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus* adults due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds at 4th application rate.

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	31876.667	6375.33	32.1445	<.0001
	With in groups	24	4760.000	198.33		
	Total	29	36636.667			
Mortality after 1hr	Between Groups	5	64704.167	12940.8	3882.25	<.0001
	With in groups	24	80.000	3.3		
	Total	29	64784.167			
Mortality after 12hrs	Between Groups	5	41416.667	8283.33	108.6339	<.0001
	With in groups	24	1830.000	76.25		
	Total	29	43246.667			
Mortality after 24hrs	Between Groups	5	41397.500	8279.50	179.0162	<.0001
	With in groups	24	1110.000	46.25		
	Total	29	42507.500			
Mortality after48 hrs	Between Groups	5	38770.000	7754.00	74.4384	<.0001
	With in groups	24	2500.000	104.17		
	Total	29	41270.000			

Annex 16: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus* adults due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds at 5th application rate

Source of error		df	Sum Squares	Mean squares	F value	P value
Mortality after 30 min	Between Groups	5	39764.167	7952.83	42.3211	<.0001
	With in groups	24	4510.000	187.92		
	Total	29	44274.167			
Mortality after 1hr	Between Groups	5	66004.167	13200.8	15841	<.0001
	With in groups	24	20.000	0.8		
	Total	29	66024.167			
Mortality after 12hrs	Between Groups	5	38980.000	7796.00	97.4500	<.0001
	With in groups	24	1920.000	80.00		
	Total	29	40900.000			
Mortality after 24hrs	Between Groups	5	42257.500	8451.50	298.2882	<.0001
	With in groups	24	680.000	28.33		
	Total	29	42937.500			
Mortality after48 hrs	Between Groups	5	38437.500	7687.50	78.5106	<.0001
	With in groups	24	2350.000	97.92		
	Total	29	40787.500			

Annex 17: Summary table for analysis of variance (ANOVA) for mean percent mortality of *E. sordidus* eggs due to different treatments of neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds.

Source of error		df	Sum Squares	Mean squares	F value	P value
Rate1	Between Groups	5	11332.587	2266.52	4.7387	0.0038
	With in groups	24	11479.123	478.30		
	Total	29	22811.710			
Rate2	Between Groups	5	10968.580	2193.72	3.9173	0.0097
	With in groups	24	13440.333	560.01		
	Total	29	24408.913			
Rate3	Between Groups	5	10859.474	2171.89	4.5158	0.0048
	With in groups	24	11542.884	480.95		
	Total	29	22402.358			
Rate4	Between Groups	5	10432.993	2086.60	3.4711	0.0168
	With in groups	24	14427.201	601.13		
	Total	29	24860.194			
Rate5	Between Groups	5	18044.810	3608.96	5.7778	0.0012
	With in groups	24	14991.098	624.63		
	Total	29	33035.908			

Annex 18: Summary table for analysis of variance (ANOVA) for mean percent Seed infestation per 1000 seeds from seeds treated with neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds.

Source of error	df	Sum Squares	Mean squares	F value	P value
Between Groups	5	936.2723	187.254	8.9536	0.0002
With in groups	19	397.3632	20.914		
Total	24	1333.6355			

Annex 19: Summary table for analysis of variance (ANOVA) for mean percent Seed infestation per 1000 seeds from sacks treated with neem, birbira, pyrethrum and nimbecidine over different rate on treated sesame seeds.

Source of error	df	Sum Squares	Mean squares	F value	P value
Between Groups	5	370.64807	74.1296	3.2424	0.0232
With in groups	23	525.83337	22.8623		
Total	28	896.48144			

Annex 20: The interaction table for the adult mortality

	Birbira	Neem	Pyrethrum	Nimbecidine	Malathion	Control
Whole model	<.0001	<.0001	<.0001	<.0001	<.0001	1.000
Intercept	1.000	1.000	<.0001	1.000	<.0001	1.000
Rate	1.000	1.000	<.0001	1.000	0.6553	1.000
Time	<.0001	<.0001	<.0001	<.0001	<.0001	1.000
Rate*Time	<.0001	0.0018	<.0001	<.0001	1.000	1.000

Annex 21: The interaction table for the nymph mortality

	Birbira	Neem	Pyrethrum	Nimbecidine	Malathion	Control
Whole model	<.0001	<.0001	<.0001	<.0001	0.0468	1.000
Intercept	1.000	1.000	<.0001	1.000	<.0001	1.000
Rate	1.000	1.000	<.0001	1.000	0.6295	1.000
Time	<.0001	<.0001	<.0001	<.0001	0.1871	1.000
Rate*Time	<.0001	<.0001	<.0001	<.0001	0.9999	1.000

Annex 22: The interaction table for the weight loss on open buckets

	Birbira	Neem	Pyrethrum	Nimbecidine	Malathion	c.control	O.control
Whole model	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Intercept	0.8511	0.8839	0.9737	1.000	0.0659	0.2449	0.1711
Rate	0.0439	0.7368	0.5016	1.000	0.9442	1.000	1.000
Time	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Rate*Time	0.0120	0.0023	0.1253	<.0001	0.9210	1.000	1.000

DECLARATION

I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged

Name of the candidate: Selemun Hagos

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DATE______________

CERTIFICATE OF APPROVAL

We hereby declare that this thesis is from the student's own work and effort, and all other sources of information used have been acknowledged. This thesis has been submitted with our approval

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