Research Article
Malays. j. med. biol. res.

i-PROCLAIM .my

Studies on the Biology and Eco Physiology of Sesame Seed Bug, *Elasmolomus Sordidus* Fabricius, at Kafta - Humera Sesame Fields

Muez Berhe[1*], Berhanu Abraha Tsegay[2], Geremew Terefe[3]

[1]Ethiopian Institute of Agricultural Research: Humera Agricultural Research Center, **ETHIOPIA**
[2]Bahir Dar University, Department of Biology, Bahir Dar, **ETHIOPIA**
[3]Ethiopian Institute of Agricultural Research, Addis Ababa, **ETHIOPIA**

[*]Email for Correspondence: muez.sbn@gmail.com

ABSTRACT

The experiment was conducted in the plant protection laboratory of the Humera Agricultural Research Center to study the biology of sesame seed bug, *Elasmolomus sordidus* (Fabricius**),** Hemiptera: Lygaeidae. *E.sordidus* is considered as the most important harvest and post-harvest insect pest of sesame in North western Ethiopia. The rearing and other tests were conducted in the laboratory at 28-330C and 50 to 65% RH. The result of this laboratory investigation indicated that the mean egg incubation period was 5.4± 0.05 days while the total mean nymphal duration took 18.44±0.10. A mean adult lifespan of 20.24±0.19 days was recorded. The mean lifespan from egg to adult death was 44.08 days, which range from 32-54 days. The reproductive period was 7.08 ± 0.26 days and the peak laying period was on the first and second day of its reproductive days. Even though E.sordidus was present the whole year high outbreak was recorded at harvest (October) and continued up to January, which afterward declined until the next harvest time.

Key words: Elasmolomus Sordidus, Biology, Ecophysiology

Manuscript Received: 16 November 2019 - Revised: 02 January 2020 - Accepted: 16 January 2020

INTRODUCTION

Sesame, locally called '**Selit**', is one of the major economically important traditional oil crops in Ethiopia It is considered as one of the priority crops being intensively worked with under both the previous and present phases of the Agricultural Growth Program (AGP I and II). Sesame sector in Ethiopia is millions of dollars industry that supports the livelihoods of thousands of small farmers and hundreds of medium- to large- scale private farms along with thousands of other actors involved in the chain of production-to-consumption/export continuum.

World production of sesame seeds is estimated at 3 million tons and is steadily growing. Currently, Ethiopia is among the top five producers of sesame seed in the world, ranked in fourth place by covering about 8.18 percent of the total world production (FAOSTAT, 2012). Sesame in Ethiopia is commonly cultivated in areas ranging in altitude from 500 to 1300 m above sea level with the annual rainfall of 500-800 mm under rain-fed condition. Due to its attractiveness in its export market, the area covered with sesame and the total production in Ethiopia showed an increment for the last ten years. According to CSAE 2013, the area under sesame cultivation in small private holders was estimated to be 91,520ha with total production of 61,460 tons and productivity of about 0.67tons/hectare. In 2012/2013, the area under sesame was 337,500ha with a total production of 244,780 tons and productivity of 0.73 tons/ha.

Sesame is known to be attacked by many insect pests at both pre and post-harvest stages around the world. In Ethiopia, Sesame webworm (*Antigastra catalaunalis* Hubner), Sesame gall midge (*Asphondylia sesami*), Green stink bug (*Nezara* *viridula* L), the green peach aphid (*Myzus persicae* Sluzer), Sesame seed bug (*E. sordidus* Fabicius), African bollworm (*Helicoverpa armigera* 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*), Ants, termites, Aphids and White flies constitute as the major pest species of sesame (Bedigian, 2006; Bissdorf, 2007; Ermias *et al.*, 2009, Berhe et al, 2008 and Murali Baskaran et al, 1998).

Sesame seed bug, *Elasmolomus sordidus* (Fabricius), locally known as 'Setayto' is a Hemipteran species which belong to the order Hetroptera and family Lygaeidea (Schmeutterer, 1969). In Ethiopia, it is found in all sesame growing areas with a large cluster in the northwestern part of the country. *E. sordidus* is considered as one of the most important harvest and post-harvest insect pests at filed and warehouses which causes both quality and quantity damage to sesame and groundnut (Biswas, 2014) seed at the field as well as in warehouse conditions. A significant sesame weight loss, a maximum of 94.7%, during harvesting and threshing time was recorded in Ethiopia (Berhe et al, 2008). Osman *et al.,* (2009), also reported that 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. Weiss (2000) also reported that insects reduce about 25% of the potential yield of sesame in the world.

Sesame seed bug adults are sized from 7-9 mm length up to 3 mm wide, (Dick, 1987, Schumutterer, 1969). The head and eyes are dark brown to black with a four jointed and cylindrical shape antennae (Hamdan, 2015). The egg of the bug is sausage shaped, changing its color from pale yellow to pink and red during the incubation period (Schumutterer, 1969). The adults and the nymphs were found in the sesame stacks, the stores and outside under the shades of coarse grass. The bugs move outside their shelters for feeding just before sunset to just after sun-rise and scatter in a wide area around their original shelters (Schumutterer, 1969). The adult bugs are attracted by large dark objects like sesame stacks in the field. During the day, when the temperature is hot, the bugs stay on the base of the stakes or inside the stores to keep themselves away from the heat. As stacks dry out or threshed, migration of the pests is observed from one stack to another (Selemun, 2011).

Laboratory and filed experimental results from different areas indicated that the life cycle of sesame seed bug was varied within different parameters such as temperature, season and diet. According to Osman *et al.,* (2009) in West Kordofan state the egg incubation period of the bug was 4.5 ± 0.17 days, while the developmental period from egg to adult stage is 32.1 ± 0.52 days. The lifespan of an adult female and male is 19.2 ± 0.38 and 9.85 ± 0.39 days, respectively. The mean fecundity of fed and the mated female was 112.6 ± 5.65 eggs. Peak egg lying period was attained on the second day of an average oviposition period of 4.9 ± 0.07 days (Tarig, 2005). In Nigeria, the whole development period from the egg to the adult was found to last about 45 days under laboratory conditions (Schmeutterer, 1969).

Sesame harvesting in northwestern Ethiopia, the study area, was completed in October and the weather afterward was dry, how the bugs continued in outbreak proportion up to January and survived the whole year, was an interesting question. Harvesting begins mostly when most (about two-third) of the plant and seed pods turn yellow and is taken by cutting the stems near the ground level. It is then bundled in bunches and stacked in racks (Figure 2) in the field to ripen the seed for about 12-15 days. Each stack locally known as **Hilla** contains 400 bunches. Then it is threshed by shaking the bunches by hand to dislodge the seeds on mats. After threshing, farmers usually bag the seeds in 100 kg sacks and leave the stock there throughout the dry season. During the sesame- free periods, these stocks locally known as "**Jewjaw**") are the best breeding site, source of food and shelter for the sesame seed bugs in the studying areas.

Generally, the sesame seed bug was reported to attack sesame, groundnut, safflower soybean and other plants long ago in different countries. However, its life cycle, distribution and its ecophysiology were not yet studied in Ethiopia in general and the North Western Ethiopia, where more than 70% of the sesame production was obtained in particular. The loss caused by *E.sordidus* in this area was also reported very high, 94.7% (Berhe et al., 2008). Hence, conducting this investigation to study the biology, incidence, host range of this disastrous pest is timely and mandatory. The results obtained from this study could be an input for designing an integrated sesame seed bug management program in Ethiopia.

MATERIAL AND METHODS

General Description of the Study Area

The research area, Kafta-Humera district (Figure 1), is located $13^{0}45'$ to $14^{0}28'$ North latitude and $36^{0}20'$ to $37^{0}31'$ East longitude (NUPI, 2002). It has flat topography with an altitude range between 500 - 800 meters above sea level.

This area is generally characterized by arid climatic condition with an annual temperature of 30^{0}C and mean annual rainfall of 581.2 mm, which ranges from 380 mm to 870 mm. The rainfall distribution is limited to four months in a year, June to September.

 ISSN 2313-0008 (Print); ISSN 2313-0016 (Online)

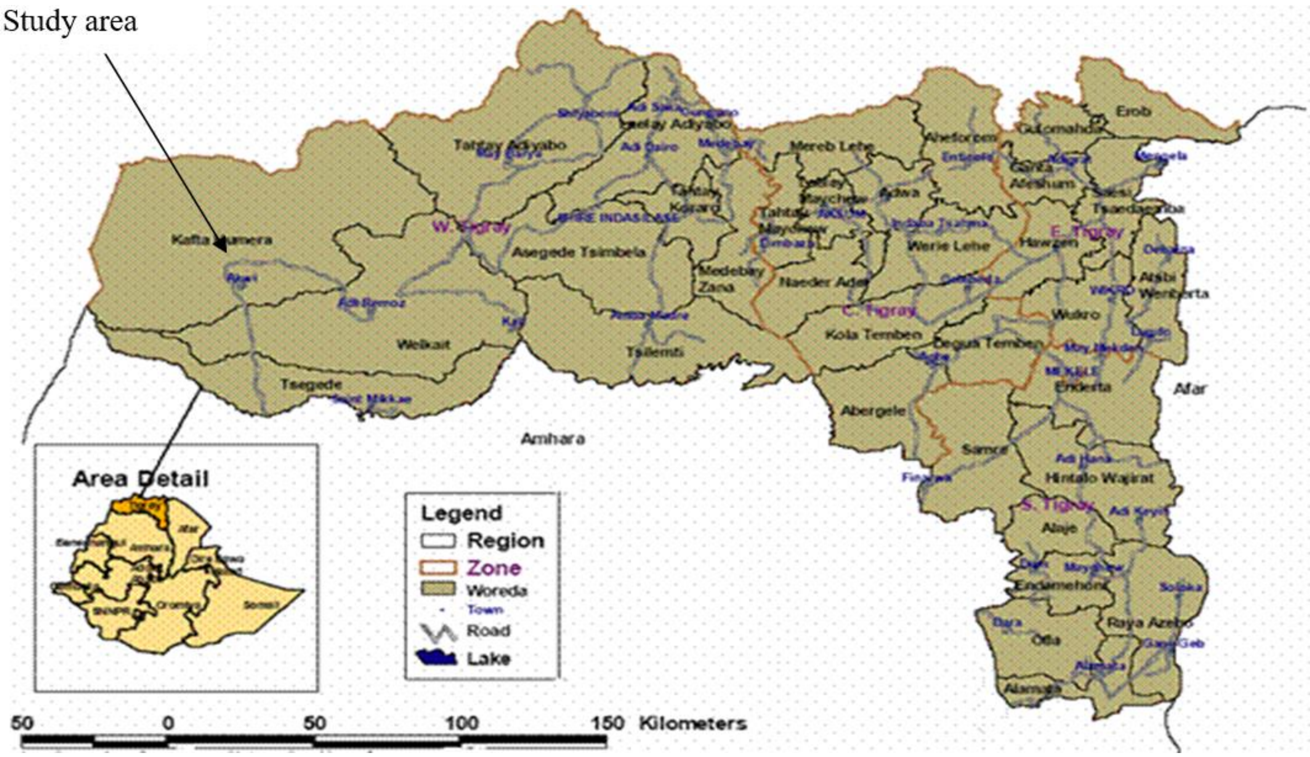

Figure 1: Map of Tigray Region and Kafta-Humera district

Survey of Sesame Seed Bug Incidence

The survey study of *E. Sordidus* was conducted in 2013/14 in western Tigray, northern Ethiopia (Figure 1) in six different geographical locations which were selected purposely (high potential sesame producing areas). In each of these selected areas, two hectares of sesame fields were assigned as sample fields based on the presence of threshed sesame stocks, locally known as **Jewjaw**.

During the survey period, October 2013 to June 2014, each threshed sesame stock, Jewjaw, and from June to October 2014 weeds, grasses, decayed debris and standing sesame crops were inspected for the presence or absence of eggs, nymphs and adults at the end of each month. During this study, a total of 12 hectares was inspected. The sample fields with the threshed sesame stocks in each selected location were randomly inspected in an interval of 3-5 km. In addition to the presence and absence recording of the bug, investigations on which stage of the seed bug could survive throughout the year, especially during the sesame-free periods were also made. During surveying elevation (altitude) was measured using Garmin GPS for each location, sample field.

Survey of Host Plants

To identify the alternate host of sesame seed bug all plants, including cultivated and uncultivated crops, weeds and grasses in the sesame fields were inspected for harboring the bugs.

Sex identification

To study the life cycle, behavior and morphology of the insect, knowledge of the sexes were important. The following activities were done to help determine sexes.

- A pair of adult bugs was selected randomly from the breeding cages which contained many adults and nymphs collected from two stores found in the town (Setit-Humera) and then any difference and/or similarity in morphology, color, size, abdominal shape and size between the pair was critically observed using hand lenses and recorded in two categories as X and Y to indicate the observed differences.
- From each group which was identified as X and Y, five adults were collected and each adult was kept separately in a total of ten cages. Daily follow up was then continued for egg production.
- More than 20 mating pairs were also collected and handled safely using plastic test tubes. Then after mating was completed each bug was kept separately and follow up was continued for eggs. The differences seen were then recorded.

Rearing and Life Cycle of Sesame Seed Bug

The experiment was conducted in the laboratory of the Department of Crop protection in Humera Agricultural Research Center (HuARC) found in Humera town. Adult insects of sesame seed bugs were collected from fields around HuARC and stores found in the town using a big plastic buckets which were used as rearing cage. The buckets were then kept in the laboratory for rearing. The rearing process was done in the laboratory in natural environment setting. To mimic the natural condition in the laboratory, soil, sesame stacks, plant host leaves and debris and sesame seed were added to the plastic bucket which keeps the laboratory conditions as similar as that of the fields where the insects normally reproduce. Sesame seeds were given as food, and water was supplied three times a day using water dropper to control the high temperature created inside the cages. The laboratory conditions were set at a temperature range of 28 – 330C and a relative humidity of 50-65%.

From the rearing cage one to five pairs of opposite sex adults were removed and placed in different labeled cages for ovipositon and checked twice a day (early in the morning and late afternoon) for eggs. Newly laid eggs were collected from the labeled cages (Fig.2) using fine camel brushes and placed in new cages for hating. The newly hatched nymphs were transferred into the new cage with sesame grains and the nymph growth period was recorded.

To observe the reproductive parameters freshly emerged adult obtained from the separate cage of *E. sordidus* was placed in plastic jars (of 1L capacity) with 20 g of sesame grains for feeding. The fecundity, the rate of oviposition and incubation period, of the pest on sesame were observed and recorded. A similar set up was done to observe adult longevity The duration of the egg stage was determined by counting the number of days from the time the eggs were laid until the hatching of the firs nymph. Nymphal stage was determined by calculating the difference in time between the first nymph and the last nymph molt. The longevity of adult stage was determined by counting the number of days since the last molt or the emergence of the adult until it dies. The trial for each observation was replicated more than 25 times in a Completely Randomized Design (CRD)

Data analysis of the laboratory experiment

Data obtained from the rearing of the insect was subjected to the analysis of variance (ANOVA) appropriately to Completely Randomized Design (CRD) according to Gomez and Gomez (1984). The means were separated using the Student-Newman Keuls (SNK) at 0.05 level of probability according to Fisher and Hedge (1935).

Figure 2: Set up of rearing cages for studying the life cycle of a sesame seed bug

Result and Discussion

Sex Identification

By observing the morphological structure variation among the adult bugs, adults were identified as male and female sexed. The females had a groove like structure in its posterior ventral side (Figure 6a) which is an ovipositor prone from its abdominal end point to the inner ventral side. During oviposition, this sharp-pointed ovipositor rose up and extended to its back side. This structural adaptation enables the female to deposit its eggs under the upper soil surface. This groove-like structure which was absent in male (Figure 6b) was the best morphological character to identify the sexes. Also, the female sesame seed bug was larger especially the abdomen part than the male bug.

Incidence of Sesame Seed Bug

Prevalence of sesame seed bug was recorded in all the surveyed six geographical locations which contain every two hectares of sample field. The infestation of this insect in all areas indicates that buildup of the *E. sordidus* across the major sesame growing area of the country. The survey result also showed that all the all the sample fields assessed were found positive to all developmental stages of *E. sordidus* (egg, nymph and adult) throughout the surveyed period.

Level of Infestation in Different Seasons of the Year

The ideal climate for the survival of sesame seed bug was warm (about 30°C) and cloudy weather condition and moist soil. Dry weather, hot temperature, and sloppy landscape were observed to reduce their occurrence. There was high sesame seed bug outbreak at harvest (October) time and continued up to January, which afterward declined until the next harvest time (Table 1). This was similar to Schmutterer's finding in Kordofan province in the Sudan in 1969. From this, it is logical to say that the climatic condition, probably next to the availability of sesame seed, has a direct effect on the biological activities of the bug.

Depending on some physical and climatic factors, the degree of infestation and severity varies not only from one year to another but also between the seasons of a year.

Table 1: Level of infestation at different seasons of the year in Kafta-Humera

Phases	Period (seasons)	Stage of sesame	Inspection done on	Developmental stage			Sesame seeds	Infestation level
				adult	nymph	egg		
1	Mid October to February	Harvesting	Hilla and Jewjaw	x	x	x	x	High
2	March to the beginning of June	Sesame crop free-period	Jewjaws, weeds and grasses	x	x	x	x	Medium
3	Mid June to beginning of October	Seedling	Jewjaws, weeds and grasses	x	x	x	x	Low
		Standing crops	Farm boundaries and standing crops	x	x	—	—	

X= Present, — = Absent

High= when adult bugs are > 200 in number per sample unit, medium= 100-200 adult bug and low when adult bugs < 100 in number

As it can be seen in Table 1, the infestation was very high from October to January and medium from April to June, but the bugs survive the remaining season too. During the drying period, seeds are scattered by the explosive nature of the capsules. In addition, while threshing the crops significant amount of the seeds remain in the threshing ground. This process according to Wiemers and Longhan (2002) equates to half of the total yield. The bugs survive feeding on the unharvested seeds and the Jewjaws were served as shelter for the long unfavorable period. Jewjaw is ventilated, resourceful and shady even during the hot months. All the developmental stages of the sesame seed bug were feeding, reproducing and sheltering inside this Jewjaw unless it was disturbed.

Generally, the result obtained from the field survey done for one year indicated that sesame seed bugs were surviving and reproducing throughout the year inside the leftover Jewjaws in the fields in which many remained seeds were available. Hence it is very important to carefully harvest the sesame seeds and clear the remains at harvesting time. In addition to the presence of left over seeds and well-ventilated shelters (Jewjaw), the soil cracks near or under the Jewjaw (Figure 3D) were found to be the best hiding places of sesame seed bugs during the hot daytime. The sesame seed bugs start feeding late in the evening and continue throughout the night up to early morning. No insect was seen outside the Jewjaw or soil cracks during the sunny day. They hide themselves in the soil cracks, sesame pods, and any other shading areas available in the sesame fields. During the daytime it is very difficult to see the pests unless you lift the top bundles of the Hilla. From late evening to sunset, the adult sesame seed bugs were flying short distances from Hilla to Hilla or nearby green plants or grasses mostly in a group and sometimes individually. They were also observed hiding and reproducing in dark corners and crevices as well as in thatched-roof huts and stores.

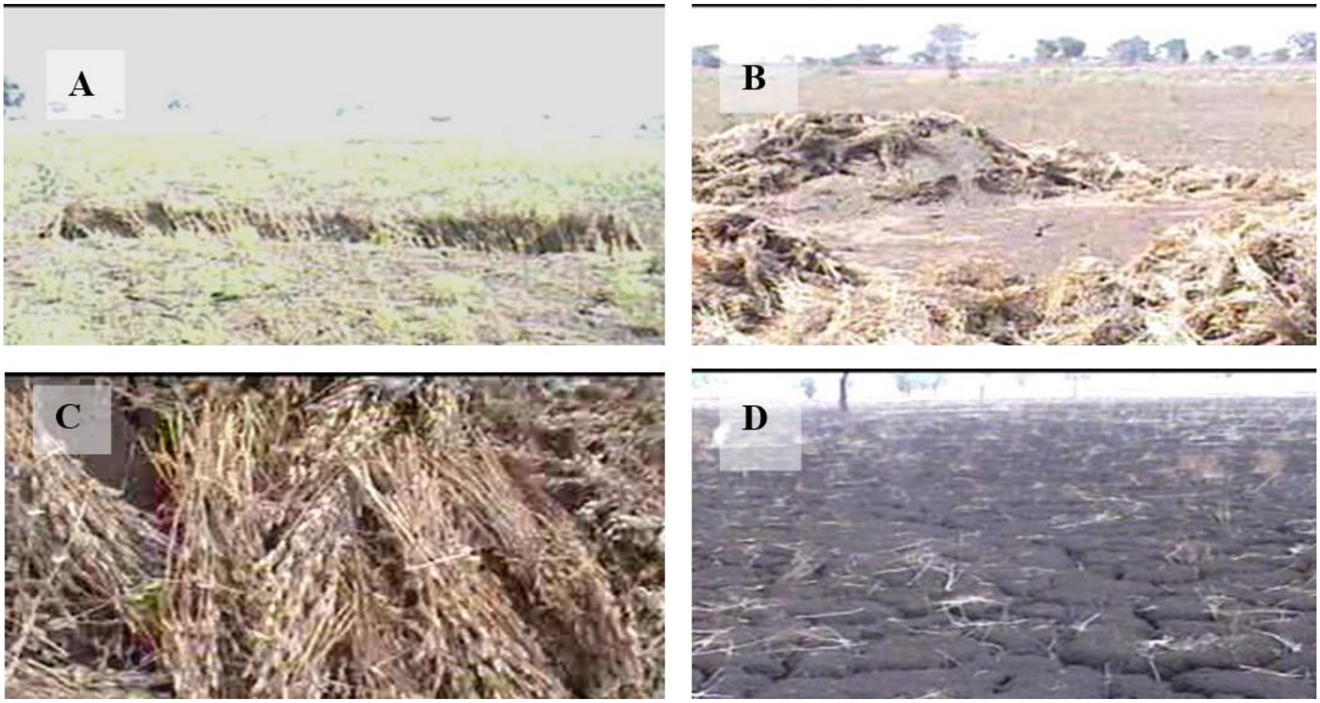

Figure 3: Hilla (A), left over Jewjaw (B and C) after threshing the bunches of sesame and cracked soils (D) serve as safe havens for the seed bugs during the unfavorable seasons of the year.

Alternate host range of *E.sordidus*

In this study, a wide range alternative host for the bug was recorded (Table 2). From the middle of June to the beginning of October, there were no seeds and Jewjaws in the fields because they all got decayed by the climatic condition (rainy season). Starting late evening, the bugs came out of the stock or soil cracks and fed on the leaves and fleshy stems of grasses, weeds and on annual and perennial plants found 10-30 meters away from their hiding area. It was also reported that sesame seed bug is a polyphagous insect attacking a wide range of crop (Palanisamy and Kalaiyarasan, 2002). Schmuitterer in 1969 also reported that besides of sesame seeds, sesame seed bug was also recorded feeding on groundnuts, grasses, sedges and banana in Nigeria. Generally, the insect was not selective and was feeding on any green plants found near its reproductive site.

Table 2: Alternate host plants of sesame seed bug in Kafta-Humera Woreda

Number	Local name	Scientific/ common name
1	*Humeray	*Corchorus triloc*
2	*Shico sar	*Helitropium cinerascens*
3	*Driya/ Hareg	*Ipomia triloba*
4	Mashila	*Sorghum bicolor*
5	*Hiletay	*Rottboellia cochinchinensis*
6	*Topas	---
7	*Chomer	*Osimum spp*
8	*Wariat	*Digitaria abyssinica*
9	Adar	Wild sorghum spp
10	*Teneg	Hibiscus
11	*Demayto	Lactuca
12	*Chiwchiwit	Unidentified
13	Komedere	Tomato
14	Full	*Arachis hypogeae*
15	**Mekie	*Balanites aegyptiaca*
16	**Geba	*Zizyphus spina-christa*
17	**Ktrit	*Accacia mellifera*
18	**Semok	*Acacia senegal*
19	**Nyme	*Azadirachta indica*
20	**Papaya	*Papaya carica*
21	**Shewit-hagay	----

*common sesame weeds, **Perennial plants

Note: Identification of host plants (MoARD, 2007), (Schmutterer, 1969) and (Tadele Made, 1996)

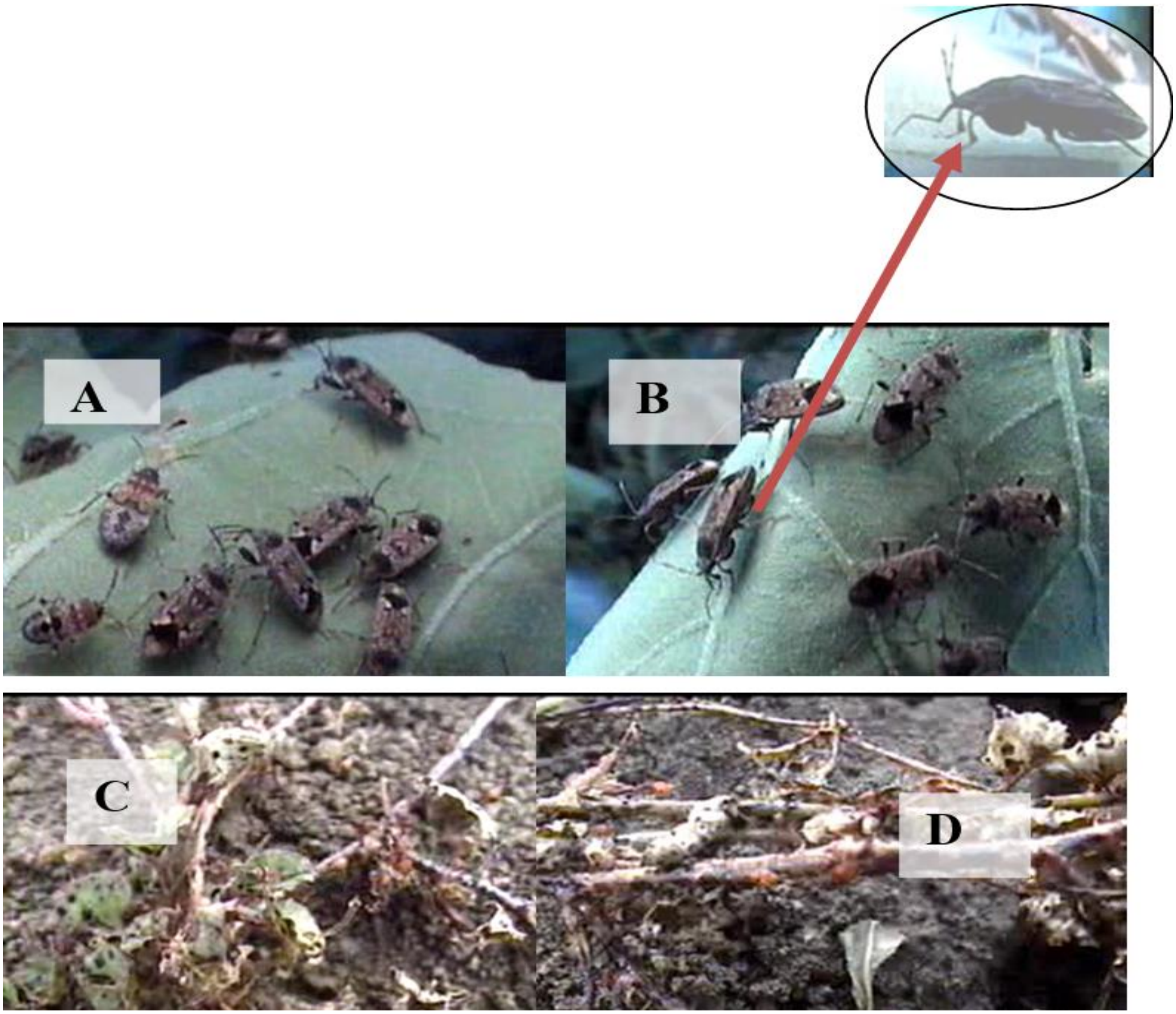

Figure 4: Sesame seed bug is fed by sucking the juice of plants until young plant dries (Fig. 4A and 4B sucking and Fig. 4C and 4D dead).

Life Cycle of *E.sordidus*

The laboratory results on the biology of *E.sordidus* indicated that average the incubation period of eggs varied from 3 - 7 days, the nymphal period from 16-20 days and the adult longevity from 13-27 days while the total life cycle duration of the bug varied from 32-54 days (Table 3). Previously researched under laboratory condition in Nigeria indicated that the time taken for the whole developmental period from egg to adult was found to last about 45 days (Schmutterer, 1969) which similar to our result. Another biological study of this bug was also reported (Samaila, 2012). Experiments conducted in Sudan under laboratory condition indicated that egg incubation period of *E.sordidus* was 4.5 ± 0.17 days, while the respective nymphal duration from the 1st, to the 6th 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 and the total developmental period from egg to adult stage was 32.1 ± 0.52 days (Osman, 2009). The result obtained in this study was not far apart from the studies reported by other researchers.

Table 3: Developmental period of different life stages of *E.sordidus in laboratory*

Growth stage	**Duration (days)**
Incubation period/egg stage	5.4±0.05
Nymph period	18.44±o.10
Adult longevity	20.24±0.19
Reproductive period	7.08±o.26
Total life cycle duration	44.08±0.11

The newly laid eggs of *E.sordidus* were white and sausage-shaped which then changed to pale yellow, pink and finally to full red during its incubation period. The red color is an indication of maturity of the embryo. When the red egg was seen under magnifiers, it was highly transparent, in which the embryo could be seen clearly. So, the red color observed was not the color of the egg shell but the embryo. This was true because, after hatching the egg shell appears to be white. Under this study, most eggs, i.e., 58% and 29% were seen hatched on the 5^{th} and 6^{th} day of incubation, respectively.

Figure 5: Morphology of eggs (left), cluster of eggs (right)

Figure 6a: Side view of female sesame seed bug

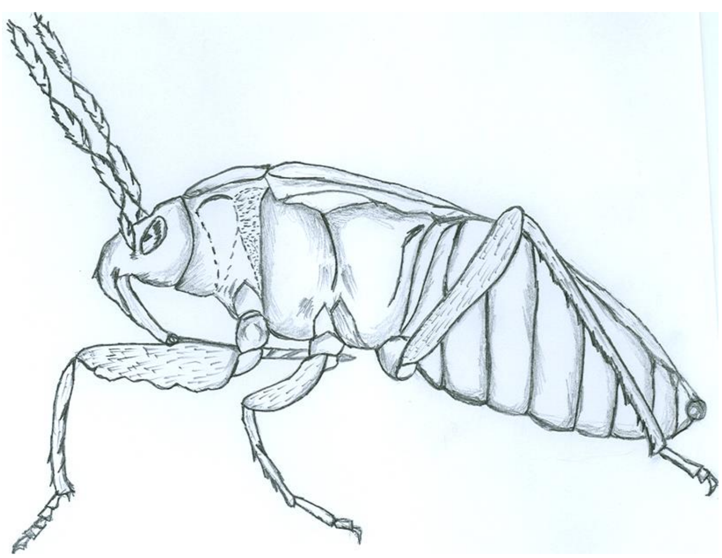

Figure 6b: Side view of male sesame seed bug

The fecundity recorded in the laboratory was 8.43± 0.34 eggs /female per day while the average reproductive periods in which female sesame seed bug continue laying eggs regularly was 7.88±0.26 days. During its reproductive period the mean fertility of the bug were 71.78 eggs, which ranged from 10-426 eggs while the hatchability of the eggs to nymphs (hatching efficiency) was varied from 19 % to 100 %. The average peak egg lying per day was recorded during the first-second reproductive days and it was observed constantly declines with the age of the bugs. However, some bugs did not follow this pattern and laid more eggs between 4 and 8 days of adulthood. This variation was because of immaturity (virgin) and aging. On the other hand, Tarig, 2005, reported that the mean fecundity of fed and mated female *E. sordidus* in groundnut was 112.6 ± 5.65 eggs while the Peak egg lying was attained in the second day of an average oviposition period of 4.9 ± 0.07 days. The variation in fecundity and oviposition period recorded in this result from Tarig could be due to the difference in diet and the climatic condition where the study was conducted.

Eggs were laid singly in the sesame stalks or the soil near the base of the stalks. During the field survey, areas where the threshing processes took place had had thousands of white and red eggs covered by the soil surface. Eggs were laid singly but could be clustered in groups and pointing up by the elongated sides (Figure 5). The clustered eggs covered almost all the surface areas where the Jewjaw was stocked and they could only be seen by removing the surface soil. Being covered by the soil surface, the eggs are adapted to escape from predation and direct effect of high temperature.

The newly hatched nymph (first instar) was fully light red, but within half a day its anterior part, head, changed to dark brown and through time its color was changed from dark brown to black. The dorsal side and the wing pads were brown, usually extended over the abdominal segment. Under this experiment, the complete nymphal instars were not fully studied because individual nymphs were unable to molt beyond the third instars under this laboratory conditions. When a newly hatched nymph was put singly in a separate cage it died following a few molts. Despite repeated trials the complete nymphal instar study was not successful in the laboratories. However, if many nymphs were put together in a cage they can survive and develop into adults passing through different molting stages; but in this case, it was very difficult to identify which nymph got molted in a given time. This is due to the gregarious behavior of the pest which resulted in death if a single nymph kept lonely. During the field observation, a mixture of different nymphal stages, especially the lower stages, was seen harboring and actively feeding on the fleshy part of different green plants found near the sesame stocks, Jewjaws. However, this behavioral study needs detail research work. The larger nymph was looked like the adult in color and appearance except for the lack of fully developed wings. Like the adult sesame seed bug, the nymphs were also seen feeding on sesame seed using their proboscis. They were observed piercing the sesame seed and moving from place to place while carrying the seed by their mouth part, the beak.

The adult sesame seed bug which lived an average of 20. 2.4±0.19 days were brown to dark in color. Its feeding mouth part, proboscis, was a needle-like structure which was used for piercing the seed and absorbing the oil contents and carrying the seeds from place to place by piercing through the sharp and thin end pointed beak. During movement or resting, the proboscis bends to its ventral side of the thorax and extends up to the bases of its anterior forelimbs.

Conclusion

The pest, *E.sordidus* was observed feeding on sesame grains starting at late evening and continues throughout the night up to the early morning. During the daytime the pests hide in places where the shadow was available. Both the nymph and the adult were causing serious damage to sesame crops, and the damage was high during the harvesting time. From this study, it can be concluded that *E.sordidus* is an economically important pest of sesame and it is a threat to sesame production and quality in Kafta-Humera in northwestern Ethiopia. Hence, the identification of its alternate host plants, incidence, its ecophysiology, and other knowledge of its possible habitat or niches are major steps towards understanding and planning an effective management and control program. In general, the present investigation in biology and ecophysiology of E.sordidus in Ethiopia will contribute a great role in designing and formulating priority research strategies for minimizing if possible controlling the economic loss caused by this pest.

Reference

Bedigian, D., (2006). Assessment of sesame and its wild relatives in Africa. In: *African plants: biodiversity, ecology, phytogeography and taxonomy.* (Ghazanfar, S.A. & Beentje, H. eds). Royal Botanic Gardens, Kew, United Kingdom. pp. 481–491.

Berhe, M., Abraha, B., Terefe, G., & Walle, M. (2008). Sesame harvest loss caused by sesame seed bug, Elasmolomus sordidus F. at Kafta-Humera sesame fields. *SINET: Ethiopian Journal of Science*, *31*(2), 147-150. http://dx.doi.org/10.4314/sinet.v31i2.66645

Bissdorf, J. k. (2007). Field Guide to Non-chemical Pest Management in Sesame Production. Hamburg, Germany. http://www.agmrc.org/media/cms/field_guide_sesame_8CBDCBAE271E8.pdf

Biswas, G. C. (2014). Insect pests of groundnut (Arachis hypogaea L.), nature of damage and succession with the crop stages. *Bangladesh Journal of Agricultural Research*, *39*(2), 273-282. http://dx.doi.org/10.3329/bjar.v39i2.20429

CSAE (Central Statistical Authority of Ethiopia) (2012). Federal Democratic Republic of Ethiopia: Central Statistics Agency. Agricultural Sample survey 2010/11 (2003 E.C) (Sep-Dec 2010). Vol I. Report on Area and Production of major crops (private peasant holdings, Meher season). Statistical Bulletin. Addis Ababa. Pp. 12-96. https://harvestchoice.org/publications/ethiopia-agricultural-sample-survey-20102011-2003-ec-september-january-201011-volume-vi

Dick, K. M. (1987). Pest management in stored groundnuts. Information Bulletin no. 22. International Crops Research Institute for the Semi-Arid Tropics. Patancheru, Andhra Pradesh 502 324, India http://oar.icrisat.org/id/eprint/862

Ermias Shonga, Geremew Terefe, Bayeh Mulatu, Zeray Mehari and Bayou Belay (2009). Research on insect pests of oil crops in Ethiopia. **In:** *Increasing crop production through improved plant protection*. Volume II. (Abraham Tadesse Ed.). Plant Protection Society of Ethiopia, Addis Ababa.

FAOSTAT of the United Nations, 2002-2017. "Production Crops: sesame seeds. accessed from. http://faostat3.fao.org.

Fisher, R. A. and Hedge, G. (1935) Inheritance in Man: data Studies by the method of analysis of variance. *Ann. Evag.* Vol.8(14)

Hamdan, E. T. A. A. (2015). *Studies On The Morphology Of The Bug Elasmolomus Sordidus(F.) (Hemiptera: Lygaeidae) And Its Feeding Effects On The Stored Sesame Seeds* (Doctoral dissertation, UOFK). http://khartoumspace.uofk.edu/bitstream/handle

Murali Baskaran R.K., Mahadevan N.R., Sathiyanandam V.KR. And Thangavelu S. (1998). Approaches for prevention and control of sesame pests. In: *Recent Advances in Ecobiological Research*, Volume 2 (Manoranjan P. Sinha, P. N. Mehrotra eds) A.P.H. publishing corporation New Delhi pp 133-143.

NATIONAL URBAN PLANNING INSTITUTE (NUPI), (2002). *Report on the development plan of Humera town*. (Unpublished).

Osman, A. K., Abdalla, A. M., & El-Balaa, T. A. (2009). Biology and damage inflicted by the sesame seed bug, elasmolomus sordidus (Hemiptera: Lygaeidae) on groundnut. *Sudan Journal of Agricultural Research (Sudan)*.

Palanisamy S. and Kalaiyarasan S. (2002). Influence of different host seeds on the development of Sesame pod bug, *E. sordidus* Fabricius. *Madras Agric. J*. **89** (**10-12**)**:** 594-597

Samaila, A. E., & Malgwi, A. M. (2012). Biology of the Groundnut Sucking Bug (Rhyparochromus Littoralis Dist.)(Heteroptera: Lygaeidae) On Groundnut in Yola, Adamawa State–Nigeria. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, *1*(6), 53-57. http://www.iosrjournals.org/iosr-javs/papers/vol1-issue6/J0165357.pdf?id=1797

Schmutterer, H. (1969). *Pests of Crops in Northeast and Central Africa*. Gunter Fisher Verlag Stuttgart. Portland- USA.

Selemun, H. (2011). *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* (MSc Thesis, AAU).

Tarig, A. M. (2005). *Biology, Infestation and Damage Inflicted by Sesame Seed Bug, Elasmolomussordidus (Fabricius), Hemiptera: Lygaeidae, on Groundnuts* (Doctoral dissertation, , University of Kordofan).

Weiss, E.A. (2000). *Oilseed crop*.2nd ed. Black well science, Inc. Malden, MA.

Wiermers,T. And Longhan, D. R. (2002). *Progress in mechanized sesame in the US through breading*. ASHS press, Alexanderia, VA, USA. https://hort.purdue.edu/newcrop/ncnu02/v5-157.html

-- 0 --