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Pest management of sesame in Ethiopia: A review

Manejo de plagas de sésamo en Etiopía: una revisión

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Abstract

Sesame is Ethiopia's most significant oil crop, especially Tigray, Amhara, and some lowland Oromia, Somalia, and the Gambella region. Consequently, the crop is exposed to a wide range of insect pests feeding on leaves, flowers, pods, and seeds affecting sesame yields. This article review provides information on the biology, nature of the damage, and management methods of economically important sesame pests. Sesame webworm, *Antigastra catalaunalis* (Duponchel) is the most common and frequently encountered pre-harvest pest of sesame. Sesame seed bugs, *Elasmolmus sordidus* (Fabricus) is also the most serious under field and storage conditions. Gall fly, *Asphondylia sesami* (Felt) could become a severe insect issue because of sesame gall formation, and Indian meal moth, *Plodia interpunctella* (Hubner) is a critical stored pest and a significant challenging of crop sesame in Ethiopia. Reports on minor pests are also listed. This paper summarizes current knowledge on pest management strategies, including cultural, biological, and botanical methods, and pesticide applications. The information gathered here indicates that the bioecology, host range, host plant resistance, the occurrence of insecticide resistance, and the development of integrated pest management methods for economical insect pests need to be addressed.

Keywords: *Gall fly, Indian meal moth, infestation, seed bug, webworm, pest management.*

Resumen

El sésamo es el cultivo oleaginoso más importante de Etiopia, especialmente en Tigray, Amhara, y alguanas tierras bajas de Oromia, Somalia, and the Gambella region. En consecuencia, el cultivo está expuesto a una amplia gama de plagas de insectos que se alimentan de hojas, flores, vainas y semillas afectando los rendimientos de sésamo.La revisión de este artículo brinda información sobre la biología, la naturaleza del daño y los métodos de manejo de plagas de sésamo económicamente importantes. El gusano tejedor del sésamo, *Antigastra catalaunalis* (Duponchel), es la plaga más común y frecuente durante la pre-cosecha del sésamo. El chinche de sésamo, *Elasmolmus sordidus* (Fabricus) es la más grave en condiciones de campo y almacenamiento. La mosca de las agallas, *Asphondylia sesame* (Felt) puede convertirse en un grave problema debido a la formación de agallas, y la polilla india de la harina, *Plodia interpunctella* (Hubner) es una plaga crítica de almacén y un desafío para el cultivo de sésamo en Etiopía. Este documento resume el conocimiento actual sobre las estrategias de manejo de plagas, incluidos los métodos culturales, biológicos y botánicos, y las aplicaciones de pesticidas. La información recopilada indica que es necesario abordar la bioecología, el rango de hospedantes, la resistencia de la planta hospedante, la aparición de resistencia a los insecticidas y el desarrollo de métodos de manejo integrado para plagas de importancia económica.

Palabras clave: *Mosca de las agallas, polilla india de la harina, infestación, chinche de las semillas, gusano tejedor, manejo de plagas.*

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Introduction

Sesame (*Sesamum indicum* L.) is a centuries-old culinary oil crop that is mostly grown in any part of the world for its oil-rich seeds (Pandey et al., 2018). It plays a significant role in the agricultural economy of developing countries, like Ethiopia. In Ethiopia, it is one of the foremost important and economically vital oil crops (Fiseha & Muez, 2019), and it is also an export crop after coffee (*Coffea Arabica* L.) (Desawi et al., 2021). It's grown within the northern part mainly in Tigray (Humara, Welkayit, and the Tahtay Adiabo), Amhara (Wollo and Metema), Benshangul, and Gambella regions with annual rainfall, of 600 mm to 1100 mm, and temperatures of 27 °C (Geremew et al., 2012; Zerihun, 2012; Abadi, 2018). Ethiopian sesame is among the best quality in the world, this might be due to the higher quality of seeds in terms of color, taste, and nutty aroma (Taghouti et al., 2017).

Ethiopia is one of the major global producers and exporters of sesame seeds (Teshome & Esubalew, 2022). Currently, it is grown on 520 000 hectares of land which contributes to 255 000 metric tons of sesame seed for the world's production as a source of income and foreign currency (MoTI, 2021). However, the national average yield of the crop is poor (0.6 t/ha). (Desawi et al., 2021). Besides the low yield of the crop obtained by the farmer, other various factors endanger crop production and productivity such as the lack of improved varieties, low yield of landrace cultivars, indeterminate flowering nature, shattering of capsules at maturity, drought, mono-cropping system, weeds, insect pests, and diseases (Daniel, 2017).

Many insect pests can attack sesame, and the number and importance of these insect pests have grown and varied from place to place, time to time, and season to season. Among them, sesame webworms, seed bugs, gall flies, and meal moth are the common insect pest that damages crops both during field and storage (Kinati, 2017). In this regard, we suppose that quantifying the economic importance of insect pests and the potential effectiveness of current control strategies can provide the necessary to develop improved pest management and control systems. It can also help policymakers prioritize their resource allocations for the effective management of sesame pests. Therefore, in this paper, the major insect pests of sesame and their management methods are reviewed.

This review paper is based on systematic review techniques and a thorough search of research findings across many databases to ensure comprehensive article retrieval.

Insect pests of sesame

Sesame has been attacked worldwide by more than 200 insect pest species belonging to 55 genera (Dilipsundar et al., 2019). Of those, India has reported 55 species of arthropods (Thangjam & Vastrad, 2018), Bangladesh 29 insect pests (Biswas et al., 2001), Uganda 38 insect pests (Ssekabembe et al., 2006), and Nigeria 16 insect pests (Zakka et al., 2018), were identified as pests species of sesame.

Sesame webworm, *Antigastra catalaunalis* (Duponchel) (Lepidoptera: Pyralidae), gall fly, *Asphondylia sesami* (Felt) (Diptera: Cecidomyiidae), seed bug, *Elasmolomus sordidus* (Fabricus) (Heteroptera: Lygaeidae), and meal moth, *Plodia interpunctella* (Hubner) (Lepidoptera: Noctuidae), have been identified as major insect pests in Ethiopia (Assefa et al., 2020). Additionally, termites (Termitidae: Isoptera) are major pests of sesame, causing damage from seedlings to harvesting and shocks (Kinati, 2017). Other notable storage pests include the red flour beetle, *Tribolium confusum* (Herbst) (Tenebrionidae: Coleoptera) and also the rice moth, *Corcyra cephalonica* (Hubner) (Lepidoptera: Noctuidae) (Negash, 2015). The mealybug, *Phenacoccus solenopsis* (Tinsley) (Homoptera: Pseudococcidae) is a recently introduced invasive sesame pest (Zenawi, 2018).

To protect the crop from pest damage, different pest management strategies have been used in Ethiopia to assist farmers in raising production and productivity, as well as to influence the national economy (Geremew et al., 2012).

Sesame webworm, *Antigastra catalaunali*

Sesame webworms are the most economically important insect pests found wherever sesame is cultivated (Zerabruk & Ferdu, 2020). It is a holometabolous insect whose developmental stages have the following characteristics:

Eggs are laid singly, minutely, conical in shape, and white in color (Pandey et al., 2018). The size of eggs is between 0.4 mm to 0.5 mm in length and 0.2 mm to 0.3 mm in width (Pandey et al., 2018). The egg development period lasts 2.5 days (Pandey et al., 2018) and records 73.3 % to 90 % egg viability (Table 1).

Larvae take 9.9 days to 13.1 days and include five distinct instars (Table 1). The first instar larva period is 4.0 days to 5.5 days, the second is 1.5 days to 2.0 days, the third is also 1.5 days to 2.0 days, the fourth is 1.0 day, and the fifth instar larva is 2.0 days to 3.0 days (Pandey et al., 2018).

Pupae first emerge as green and then turn brown. It happened inside a silken cocoon that is transparent and pale white. The pupa's length and width are 7.4 mm and 1.4 mm, respectively. The pupal period varies from 5.3 days to 7.3 days with 76 % ± 6.5 % adult emergence (Pandey et al., 2018). Suliman et al. (2013) reported a pupal period of 4.9 days ± 0.21 days. It's found both in soil and on webbed leaves when the feeding period of the larva is completed (Suliman et al., 2013).

Table 1. Duration of developmental stages of *Antigastra catalaunalis* (Modified of Pandey et al., 2018)

Developmental stage		Duration (days)
Egg	Total	2.3-2.4
Larva	1st instar	4 – 5.5
	2nd instar	1.25 – 2.0
	3rd instar	1.5 – 2.0
	4th instar	1.0
	5th instar	2.0 – 3.0
	Total	9.9 –13.1
Pupa		5.3 – 7.3
Adult	Males	22.0 – 26.3
	Females	23.8 – 28.1
Total period (egg-adult)		24.1 – 26.0

Adults are light reddish-brown to dark reddish-brown. Males have less wing expanse and a slender abdomen, while females have more wing expanse and a broader abdomen. Males are 8 mm to 8.5 mm in length and 22 mm to 24 mm in breadth with expanded wings. Females are longer compared to males, 11.0 mm to 12.0 mm in length and 25.5 mm to 28 mm in width (Pandey et al., 2018). A female may produce a maximum of 53 eggs to 92 eggs (Pandey et al., 2018). Males complete their life cycle within 22 days to 26.3 days, whereas females take 23.8 days to 28.1 days in environmental conditions 30.5 °C ± 2.3 °C and 67.2 % ± 1.8 % RH. (Pandey et al., 2018) (Table 1). The developmental stages from eggs to adults take 22 days to 39 days (Ahirwar et al., 2010).

Nature of the damage

Sesame webworm is occurring and infests the crop from seedling to maturity stages (Kinati, 2017). The insect is destructive in the larval stages (Zenawi et al., 2016); causing about 25 % (Tadele, 2005), 25 % to 35 % (Geremew et al., 2012), and 17 % to 42 % reduction of yield (Zerabruk & Ferdu, 2020) in different agro-ecology of Ethiopia.

Larvae frequently showed cryptic behavior in the narrow gap between the shoot and the capsules (Pandey et al., 2018). The first instars have seen the top leaves of the plants, where they first fed on the epidermis of the leaves. The second instar was seen to damage capsules and leaves (Simoglou et al., 2017) (Figure 1 C & D). Young larvae mine young leaves and shoot tips; they bind leaves and shoots together and eat inside (Geremew et al., 2012) (Figure 1 A & D). The late instars were boring tunnels in the main stem's mesophyll of the plant. On the sesame, the larva spins leaf silk during feeding time (Suliman et al., 2013). Moreover, the larvae may multiply quickly and in dense numbers, and they eat aggressively the sesame plant. It was observed that the second stage damaged capsules and buds. Then the larva continuously feeding on the capsule.

Figure 1. Damage symptom of *A. catalaunalis.* A) Larva feeding the leaf, B) Webbed tender shoot (Geremew et al., 2012), C & D) damanged symptom on leaf and capsule (Simoglou et al., 2017)

Management strategies

Many efforts are being made in different regions to enhance productivity and increase the income of farmers.

Culturally, the pest that has been managed by adjusting planting time can reduce injuries from webworm infestation (Ali & Jan, 2014). Similarly, intercropping of sesame with other crops like black gram, green gram, cluster bean, sorghum, and pearl millet may also have a significant impact in reducing this infestation (Uddin & Adewale, 2014). Limited studies have reported resistance varieties for this pest, but the genotypes ES 22, SI 250, and UMA were found to be unfavorable for the pest genotypes (Karuppaiah & Nadarajan, 2013).

Hemipimpla sp. and Mermithid nematode are natural enemies that have been used for controlling sesame webworms (Egonyu et al., 2009). Spraying extract from datura, neem, and henna plants was effective for larvae control (Suliman et al., 2013). In Ethiopia, several broad-spectrum insecticides have been employed under smallholder conditions to reduce the damage caused by *A. catalaunali.* The application of a repeated single insecticide group is a common practice by farmers (Geremew et al., 2012), and the application of diazinon 60 EC three times on the different phonological stages of the crop (Zenawi et al., 2016b). Also integrating early sowing with two times dimethoate 40 EC during seedling and flowering (Zenawi, 2018) or integrating early planting within two and four weeks after the emergence application of Cypermethrine 720 EC, resulted effective in controlling the pest (Egonyu et al., 2009).

Sesame seed bug, *Elasmolmus sordidus*

Sesame seed bug is the major pest targeting sesame in both fields and storage facilities (Muez & Berhanu, 2016). This insect is understood within the area as "Stayto", which suggests it consumes an infinite amount of sesame oil (Muez et al., 2008). It is a hemimetabolous insect pest (Selemun, 2011) (Figure 2), whose developmental stages have the following characteristics:

Eggs' color changes from yellow to pale yellow, pink, and eventually full red. Its period is 4.5 days ± 0.2 days (Osman, 2009) or 5.4 days ± 0.1 days (Berhe et al., 2017).

Nymph color is light red, dark brown, and finally black (Berhe et al., 2017). Nymphal periods are complete through six distinct instars. The time required to end all nymphal stages is 18.4 days ± 0.1 days (Osman, 2009). Consistent with Berhe et al. (2017), the whole nymphal period is 18.4 days ± 0.1 days.

Female adults have average fertility of 71.8 eggs, (8.4 ± 0.3) eggs per female per day. Adult longevity is 20.2 days ± 0.2 days. For adult females and males, their lifetime is taking 19.2 days ± 0.4 days and 9.9 days ± 0.4 days, respectively. The reproductive period of female continue laying eggs regularly was 7.88 ± 0.26 days. The sex ratio of males and females is 1:1.2 and thus the oviposition period is 7.1 days ± 0.3

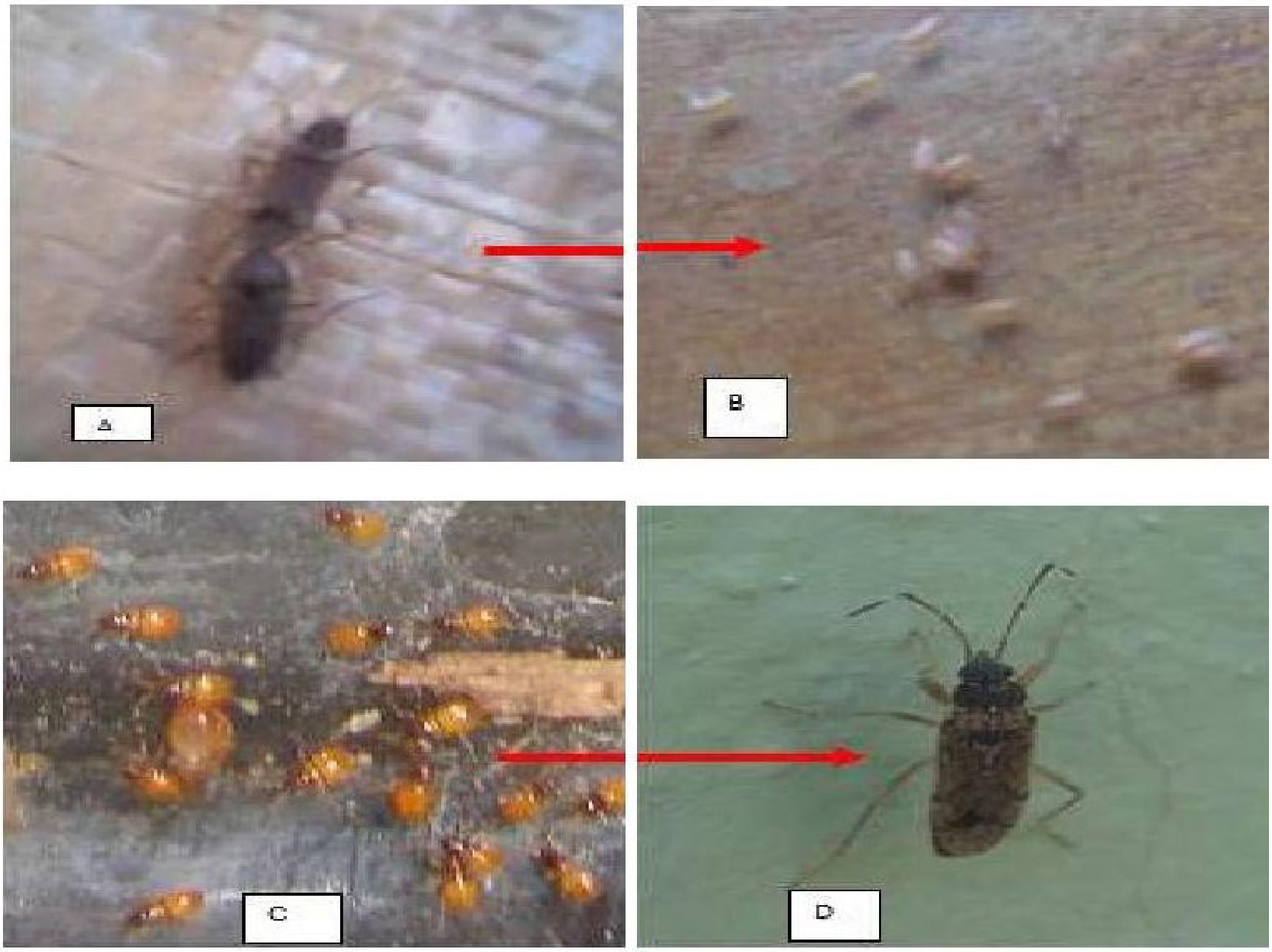

Figure 2. Schematic representation life cycle of *E. sordidus.* A) Mating of SSB B) Egg of SSB C) Nymph of SSB D) Adult sesame seed bug (Selemun, 2011) .

days in the environmental condition of 28 °C to 33 °C and 50 % to 65 % RH . The egg to the adult stage takes 32 days to 54 days (Berhe et al., 2017) (Table 2).

Table 2. Duration of developmental period of *Elasmolmus sordidus* (Modified of Berhe et al., 2017)

Developmental stage	Duration (days)
Egg	5 – 7
Nymphal stage (1-6 instars)	16 – 20
Adult longivity	13 – 27
Female reproductive period	7.88 ± 0.26
Total period (egg-adult)	32 – 54

The pest attacks a wide range of host plants (Palanisamy & Kalaiyarasan, 2002). Sesame, Humeray, Shico sar, Driya/Hareg, Mashila, Hiletay, Chomer, Wariat, Adar Wild, Teneg, Demayto, Papaya, Neem, groundnut, tomato, and unidentified local name of Chiwchiwit, Topas, and Shewit-hagay are the alternate host of the pest (Berhe et al., 2017).

Nature of the damage

Both the nymph and the adult infest sesame within the field during drying and in warehouses. The pest affects the nymph and adult life stages. The ideal climate for the survival of the sesame seed bugs is about 30 ºC, with cloudy weather conditions and moist soil. The degree of infestation and severity varies not only from one to another year but also between the seasons of the year (Berhe et al., 2017). Both the nymphs and adults suck the seed oil and its contents, causing qualitative and quantitative losses. In Ethiopia, the pest caused 50 % to 100 % seed weight loss (Geremew et al., 2012; Muez & Berhanu, 2016) weight losses, in Sudan 1 % to

2.2 % weight loss and also 11 % to 15.0 % oil content loss (Abdelmanan et al., 2015).

Management strategies

For many years different management practices have been done to alleviate the crop from infestation. Culturally, the pests are often managed by stalk removal after harvest, plowing, or alternate host destruction around fields. Other management is to harvest early when pods/stems are yellow and thresh/shake as early as possible when pods open fully (Geremew et al., 2012). Ants of varied species, spiders, wasps, egg parasite *Grionini sp*., and lizards predators for seed bug nymphs.

Extracts of neem and birbira seed powder, pyrethrum flower dust, and nimbicidine are effective in controlling sesame seed bugs in storage (Palanisamy & Kalaiyarasan, 2002; Selemun, 2011). Application of insecticides such as malathion 50 % EC, endosulfan 35% EC, and carbaryl 85 % WP at the stalk, and around the soil of the sesame stalk three times a common practice in Ethiopia (Mandefro et al., 2009). But, this method is ineffective due to re-infestation of the pest within a few days after the pesticide application (Muez & Berhanu, 2016). However, integrating the use of cultural and chemical control methods is effective in controlling the pest (Geremew et al., 2012).

Gall fly or midge, *Asphondylia sesame*

Sesamum gall flies are one of the foremost important pests of sesame (Chopada et al., 2018; Adam et al., 2020). The pest is common in countries like Nigeria (Philips, 1977), Uganda (Ubor et al., 2015), Sudan (Adam et al., 2020), India (Chopada et al., 2018), and Ethiopia (Mandefro et al., 2009). Weather factors like high relative humidity, frequent rain, and high temperatures are favorable for the buildup of the epidemic (Assefa et al., 2020). The pest is a holometabolous insect pest whose developmental stages have the following characteristics:

The egg period is 2 days to 4 days, the larval lasts for 14 days to 21 days. The pupal stages last between 7 days to 12 days and the adult stages last 23 days to 27 days (Baskaran, et. al. 1997).

Nature of damage

A female insect lays their eggs on sesame flowers and buds. The hatched larva starts feeding inside the floral buds and young capsule resulting in the formation of gall (Assefa et al., 2020; Adam et al., 2020) (Figure 3). The pest inflicts about 29 % to 34.3 % seed yield reduction (Egonyu et al., 2005); 100 % in susceptible genotypes (Mehalingam, 2012); 30 % in grain yield decrease (Geremew et al., 2012).

Management Methods

Efforts have been made to reduce the damage to increase the farmer's income and increase productivity. Timely planting, crop rotation, and intercropping with maize, sorghum, and finger millet reduce the severity of the pest (Assefa et al., 2020). Alternatively, the application of dimethoate and diazinon are insecticides (Geremew et al., 2012), and chloranthriprole 18.5 % SC effectively controls the pest (Chopada et al., 2018).

Indian meal moth, *Plodia interpunctella*

Indian meal moth is a polyphagous species that evolved in response to a significant economic impact (Filip & Snezana, 2012; Campos & Phillips, 2013). It is found in Africa, Asia, Europe, America, and Oceania (Mohandass et al., 2007). This pest is one of the critical stored product moths with a large range of feeding preferences (Athanassiou & Arthur, 2018).

The pest is a holometabolous insect pest with the following characteristics:

Eggs are grayish-white and have a length between 0.3 mm and 0.5 mm (Anonymous. 2023) (Figure 4 B). The developmental period is 4.7 days ± 0.8 days (Pérez-Mendoza & Aguilera-Peña, 2006).

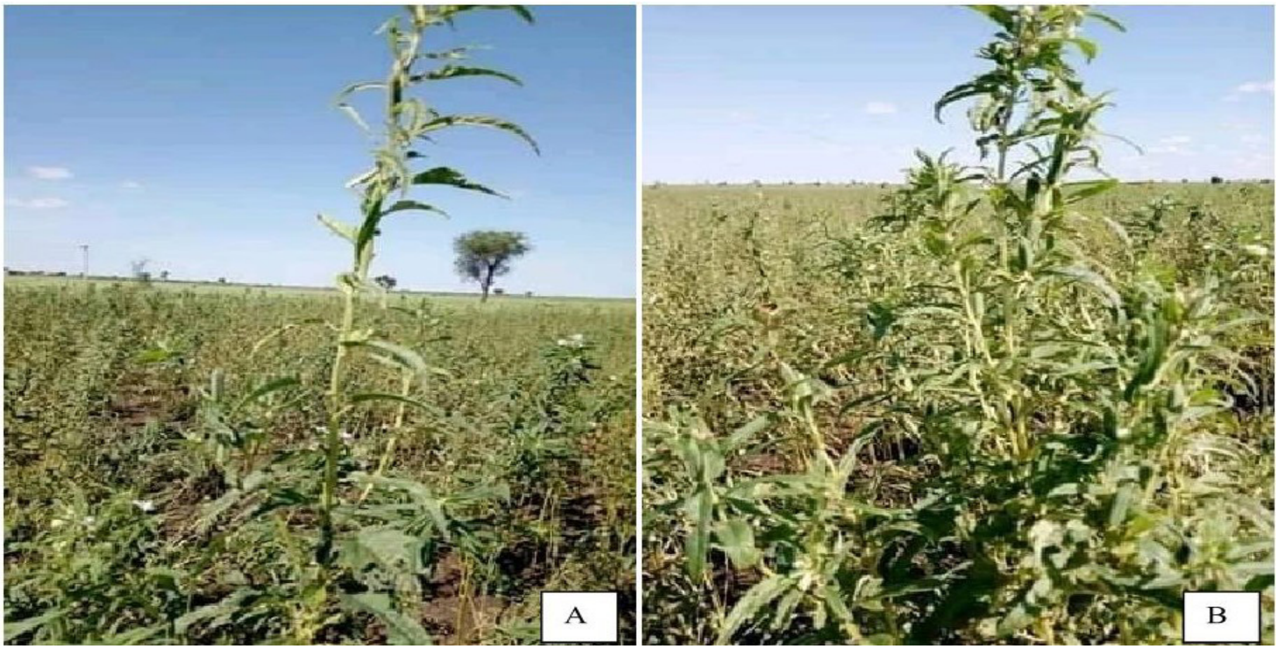

Figure 3. Damaged symptom of Gall midge on sesame plant (Assefa et al.,2020)

Larvae color can vary considerably because of diet content (Thomas & Marle, 2015). The larvae have five to seven instars (Thomas & Marle, 2015).

The pupa is 6 mm to 11 mm with a pale brown color and takes fifteen to twenty days at 20 °C to 30 °C (Thomas & Marle, 2015).

An adult female produces an average of 212 eggs ± 34 eggs and a maximum of 400 eggs (Pérez-Mendoza & Aguilera-Peña, 2006). The whole life cycle is completed within 27 days to 305 days, depending on temperature conditions (William, 2006; Thomas & Marle, 2015) (Figure 4).

Nature of the damage

The hatched larvae start feeding on grain and become large, spin webs, and leave silk threads in their path (William, 2006) (Figure 5). The pest damages the grain by making impurities in foodstuffs with its frass and webbing character (Athanassiou & Arthur, 2018). It inflicts a weight loss of 17.8 % in stored sesame grains (Zenawi, 2017), and 9.4 % weight loss and 5.7 % oil loss when packed in polypropylene bags (Kumera et al., 2020).

Management Methods

Few activities were made for controlling the pest such as creating adverse circumstances and disrupting its breeding grounds (William, 2006). Matthew and Paul (2006) found hymenopteran parasitoids of eggs, and larvae are good biological control methods for this pest.

Conclusions and recommendations

Sesame is a vital agricultural crop in Ethiopia but is significantly hampered by insect pests. The review focuses on the sesame webworm, seed bug, Gall fly, and Indian meal moth are major sesame pests causing a huge seed yield reduction in the country. Other pests of sesame included in the paper were termites, green peach aphids, cotton whitefly, and mealybug. Knowledge of the developmental characteristics, feeding behavior, and nature damage to the crop are essential before effective control strategies are developed. To reduce the economic losses due to insect pests, various control measures such as cultural, biological, botanical, and use of synthetic pesticides have been suggested under this review. Application of malathion 50 % EC, endosulfan 35 %, carbaryl 85 % WP, and dimethoate and

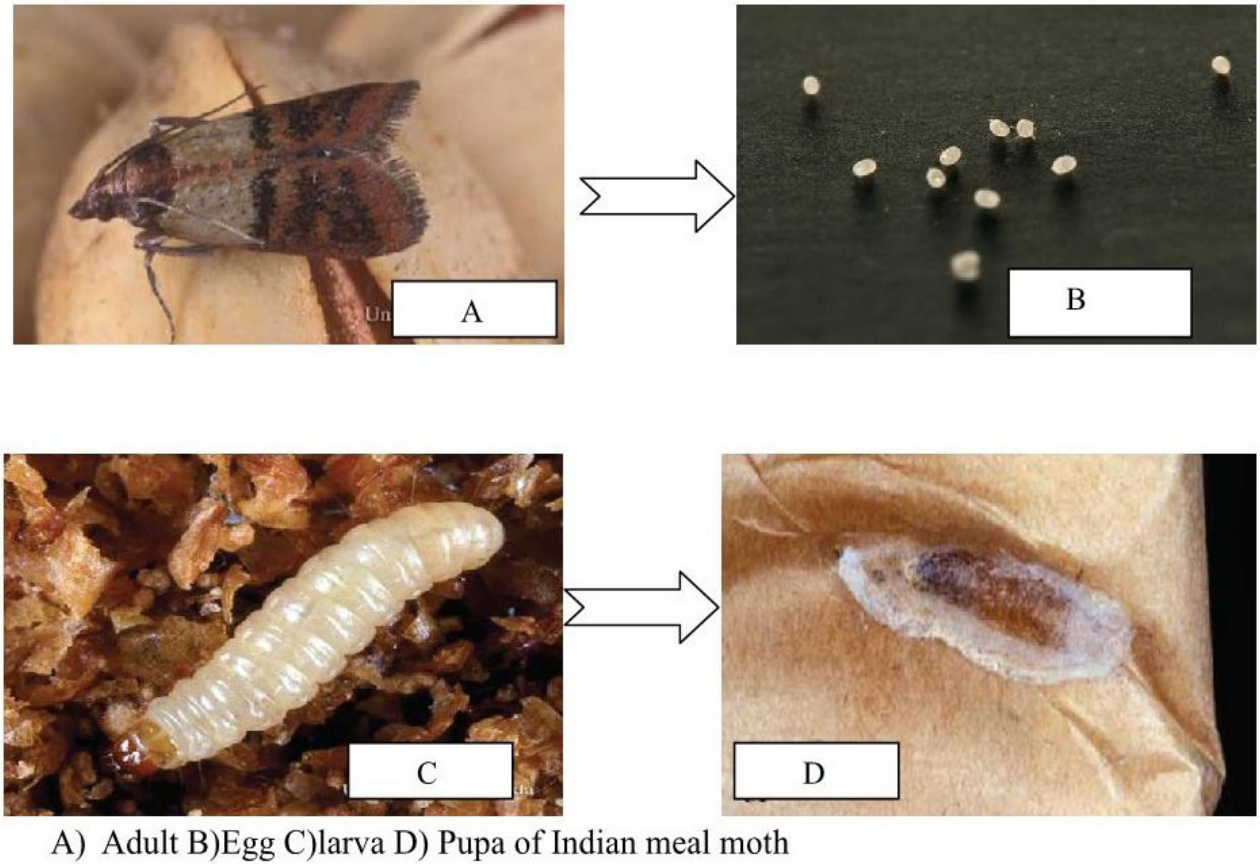

Figure 4. Life cycle of Indian meal moth, *P. interpunctella*. A) Adult B) Egg C) Larva D) Pupa of Indian meal moth. A, C & D of Thomas & Marle (2015); B of Sarefo (2008).

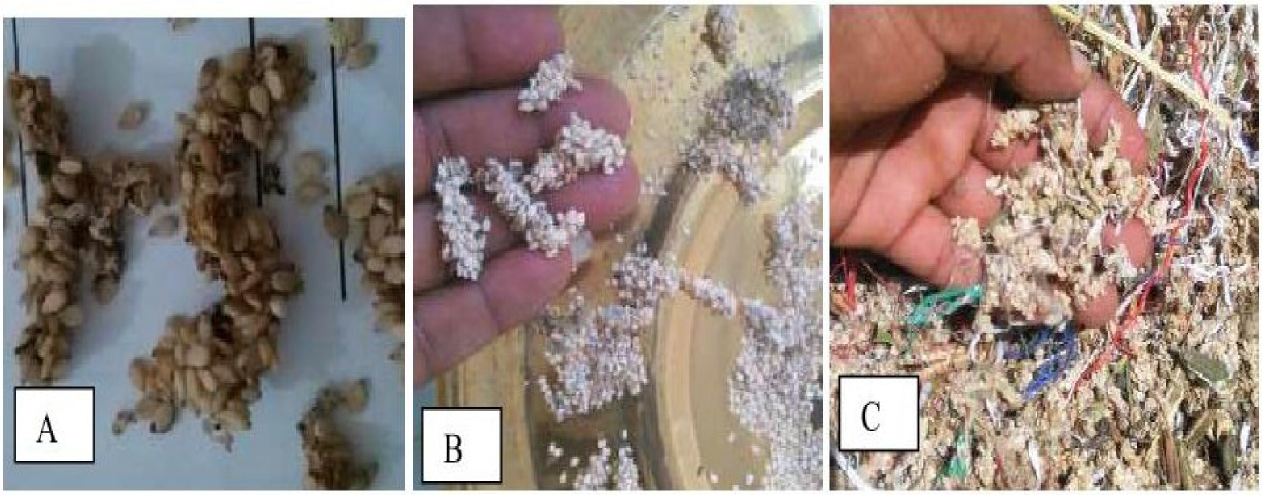

Figure 5. Damaged and webbed sesame grains by *P. interpunctella* (Zenawi, 2017).

diazinon 60 % EC are primary means of pest management in the country. Farmers frequently get caught in a cycle of increasing the quantity and/or frequency of pesticide applications, which is frequently unsuitable and harmful. Sesame producers need effective alternative pest management techniques to escape this pesticide treadmill. Even though insect pests provide the greatest threat, there has been insufficient research on pest management methods. This would entail improving the abilities required to survey fields, and appropriately mix and apply insecticides. Therefore, in the future to spice up sesame production and productivity research thinking of the biology and host range, insecticide resistance, and developing cultural, selective insecticide control alternatives is urgent. A longer-term solution to insect pest problems in sesame must develop integrated pest management solutions.

Ethics approval and consent to participate

Not applicable.

Human and animal rights

No humans or animals were used in this research.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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