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Assessment of major field insect pests and their associated losses in maize crop production at West Hararghe Zone, Ethiopia

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Abstract
Assessment of major field insect pest species and their losses in maize (*Zea mays* L.) crops production was conducted during the crop seasons of 20l8 to 2019 at Chiro and Darolebu districts of West Hararghe Zone, Oromia Region, Ethiopia. Sampling technique was purposive for identifying districts that had high maize crops production potential from the zone. From each district, three localities were selected purposively. During the study period, three economically important insect pests were listed out from maize cultivated fields. Among the insect pests, American Fall Army Worm (*Spodoptera frugiperda*), Maize Stem Borer (*Busseola fusca)* and African Ball Worm (*Helicoverpa armigera)* were major pests recorded on maize crop fields. Among the insect pests the first rank priority in maize cultivated fields at both districts, *S. frugiperda* were more abundant and dominant followed by *B. fusca* and lastly *H. armigera*. The respondents were estimated as yield losses of 10-30% by *S. frugiperda*, 3-15% by *B. fusca*, 3-15% by *H. armigera* on maize crop fields at Darolebu and Chiro districts, respectively. The greatest yield loss caused by insect pests was 10-30% by AFAW for maize crop at Darolebu and Chiro districts. The training should be given for both farmers and extension workers on insect pests identification and their management, so they should be produced proper operation to early protect their maize crops from insect pests to reduce the yield losses.

Keywords: Maize, Abundance, Infestation, Assessment, Identification, *S. frugiperda*, *B.fusca*, *H.armigera*, Yield losses

1. Introduction

Maize (*Zea mays* L.) was originated from tropical zones of America and has now become the highest production of cereal crops grown worldwide and the crop was introduced into Ethiopia during the 16 and 17 centuries [30]. In Ethiopia, maize occupies more land than any other cereal crop after teff and accounts for 36 percent of all grain production and it grows from low rainfall to high rainfall areas [38]. It is one of the high priority crops to feed the increasing human population of the country due to its adaptation and total yield [34] and it has starch (60%-80%), protein (8%-12%), fat (3%-5%) and minerals (1%-2%) [35] and also considered to be the cheapest source of calorie intake in the country, providing 20.6% of per capita calorie intake nationally [20]. Approximately 88% of maize produced in Ethiopia is consumed as food, both as green and dry grains. The total grain crop production area, maize is second next to teff and first in productivity which comprises 21114876 hectares (16.91/%) of land and 71508354.11 (26.80%) quintals productivity with average yield of 3 tons/ha, respectively as compared to sub-Saharan Africa that estimated to 1.8 tons/ha which is still far below the global average yield of maize 5 tons/ha [9].

Despite its vital importance, the yield and production potential of this crop is under pressure due to different constraints. The performance of the maize crop has been constrained by biotic and abiotic factors, which reduces crop production and productivity in the country. Insect pests are amongst the major biotic constraints causing losses in quantities and qualities in the maize crop. Numerous maize insect pests have been documented in the country particularly in the last two decades but only few of them are considered as economically important pests which continue to have negative impact in maize production. So far stem borers and termites are considered as the most abundant and economically important field insect pests of maize. Yield losses reported due to stem borers varied greatly but the average yield losses can be estimated between 20 and 50% [15].

Studies conducted in different locations of western and southern Ethiopia indicated that Termites can caused up to 100% losses in maize.But information on prevalence, distribution, abundance and damage level of different field insect pests of maize crop under Chiro and Darolebu conditions are scarce, although the farmers of these areas faces great losses in maize crop yield due to different insect pests. It is important to know/identify the types of insect pests, their prevalence, distribution, abundance and level and/or nature of damage in maize for taking timely and feasible control measures in order to have good protection and getting better yield. Therefore, the present study was initiated with the objective to assess, identify and prioritize major field insect pests of maize and their associated yield losses in Darolebu and Chiro districts of West Hararghe Zone in Ethiopia.

2. Materials and Methods

2.1.1 Description of the study areas

Survey was carried out in West Hararghe Zone of Oromia Regional State in two selected districts namely Chiro and Darolebu during the main cropping season in 2018/19.

Chiro district is located in West Hararghe Zone of the Oromia Regional state at about 324 km East of Finfine, the capital city of Oromia Regional state and is found at an average altitude of 1800 m. a. s. l. The topography of the district 45% is plain and 55% steep slopes. The district is mainly characterized as steep slopes and mountains with rugged topography, which is highly vulnerable to erosion problems. It has a maximum and minimum temperature of 23ºC and 12ºC, respectively and the maximum and minimum rainfall of 1800 mm and 900 mm, respectively. Soil type is sandy, clay (black soil) and loamy soil types covering 25.5, 32, and 42.5%, respectively.

Darolebu district is situated between 7^{0}52'10" and 8^{0}42'30" N and 40^{0}23'57" and 41^{0}9'14" E and characterized mostly by flat and undulating land features with altitude ranging from 1350 up to 2450 m. a. s. l. The temperature of the district ranges from 10 to 28°C. Rainfall is ranging from 800 up to 1200 mm/year. The pattern of rain fall is bimodal and its distribution is mostly uneven. The topographic areas of the district have plain areas 80%, mountains /hilly 10%, rugged terrain 5% and others 5%. Soil types of the district includes sandy 48%, loam 10%, clay (Black soil) 27%, red 15%, and others 3%.

2.1.2 Sampling and data collection

West Hararghe zone was targeted for this study. Districts within the selected zone were selected purposively. Locations within the selected districts, and lastly the maize fields within the selected locations were selected randomly. Finally, the maize plants in each field were assessed after random selection. Three localities in each district, three fields in each locality and 40 to 50 plants in each field were visually assessed. Data regarding farmers' experiences in major field insect pests of maize, their local name and associated yield losses were obtained by conducting face to face structured and semi-structured interviews using questionnaire. Group interviews were also conducted.

Random selection of the maize plants was done by moving in a 'Z' or 'W' walking pattern to make the sampling representative to the field. By moving 5 m from each point and selecting 10 plants from each point. The study fields were surveyed twice during the maize crops growing period at vegetative and reproductive stages. Follow W or U-shaped sampling was used in the square shaped field. In long narrow field, a zigzag or Z sampling pattern was used. In the fields, selected plants have been sampled, depending on field shape and size. If the sampling is being conducted in a field which is either much smaller or larger than 0.4 ha, the sample size was proportional to the size of the field. Both distractive and non-distractive sampling were employed. Destructively sample of each plant, which has typical insect pests' damage symptoms, Search plant parts and check for presence of larvae. If the crop is at young stage and, check for presence of larvae on reproductive parts and injury symptoms on developing plant parts and to determine the identity of the larvae and record numbers of each per plant.

The sampling of plants was carried out with the help of quadrant and sweeping net, depending on the target insect and its damaging stage behavior. All the plants falling within a quadrant/selected plants were visually examined for the typical symptoms of the insect damage, which include leaf chewing, leaf mining, leaf rolling, leaf defoliation, stem tunneling, stem cutting, killing apical growth point, cutting roots, eating out growing tassels. Finally, data on the type and number of insects, their damage level and type of damage symptom were collected. Appropriate data collecting sheets for gathering insect data, damage data and type of symptoms was prepared and communicated with enumerators. Additional GPS data including: altitude, latitude, longitude, variety, insect history/field history, and metrological data were also taken. Specimens were labeled by code and specimen photos were also being taken. Polythene bags, plastic Petri dishes, specimen tubes and vials were used to collect different stages of insects.

2.1.3 Identification of insect pests

Field collected larvae were first identified by using type of damage symptom and their morphological characters and then taken to laboratory for rearing and further identification of adult moths using morphological features. At the same time, the caught moths, flies, maggots, Aphids and spider mites were identified using morphospecies and then preserved in labelled vials containing 70% ethanol for further identification. In case of Nuctudae family, adult moths were killed and wrapped lightly in tissue paper, and place in a crush-proof to keep its scale coloration until identification. Voucher specimens were deposited at the Ambo Agricultural Research Centre laboratory, Ethiopia. Besides, the identification and confirmation of identified samples were done based on the appropriate keys. The insect pests on maize crops were identified using manuals protocols and based on morphological characteristics of the larvae collected: larval forms, body and head pigmentation, damage symptoms related to each insect species. Fall army worm identification was done using morphological characters of the insect (larvae & adult moth) and its specific injury symptoms.

2.1.4 Relative abundance of insect species

The species composition was identified after the larvae were collected and identified. The relative abundance of each insect species was calculated based on the number of the larval population counted using the formula:

$$\text{Relative abundance\%} = \frac{\text{Total number of larval counts for species}}{\text{Total number of larval counts for all species}} \times 100$$

2.1.5 Infestation and crop damage assessment

Infestation level and leaf damage on maize crops were assessed when maize reach 0.5m height and final at tassel/ cobs forming stage. This was done by counting the number of crops showing leaf damage symptoms in respective of a particular insect species from fifty randomly selected maize plants. Percentage infestation level and leaf damage were calculated using the formula below adopted from (Singh *et al*., 1983).

$$\text{Infestation levels\%} = \frac{\text{Number of plants showing damage symptom}}{\text{Total number of plants inspected}} \text{x100}$$

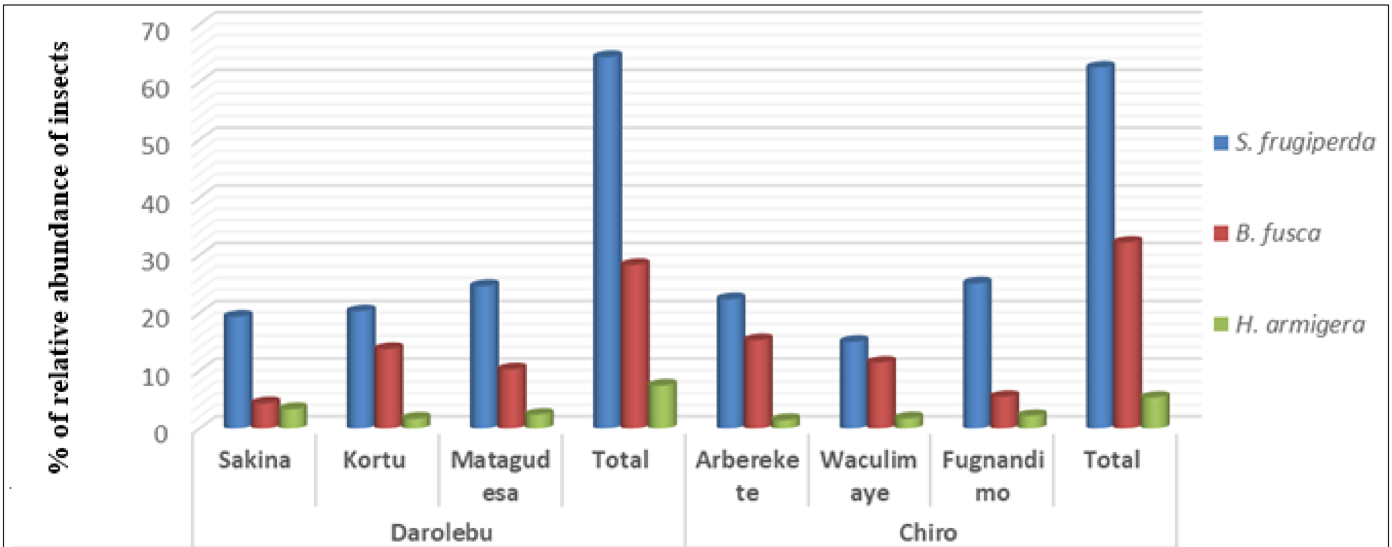
2.1.6 Data analysis

The Survey Data Processing System software was imported into Statistical Package of SAS software (SAS version 9.4) for analysis. The population of different insect pests of maize and their percent infestation were analyzed using Analysis of variance and descriptive statistics to determine percent abundance of insect pests their infestation level. Means were separated with Tukey's HSD (honest significant difference) test at the P = 0.05 level (SAS Institute 2009).

3. Results and Discussion

3.1 Types of insect pests and relative abundance recorded on maize crop at both study districts

During the study period, a total of three important field insect pests were listed out from different
maize fields. Among the listed insect pests, Fall Armyworm (*Spodoptera frugiperda*), Maize Stem Borer (*Busseola fusca)* and African Ball Worm (*Helicoverpa armigera)* were found the major field insect pests recorded in maize crop fields.
A total of 1,407 larval populations were collected in 2018 main crop season at both Darolebu and Chiro districts, of which 714 were from Darolebu (459, 202 and 53) and 693 were from Chiro (433, 223 and 37) representing *S. frugiperda*, *B. fusca* and *H armigera*, respectively. The relative abundance of each three insect pests occurred at Darolebu district was 64.29, 28.29, and 7.42% respectively, while and at Chiro district 62.49, 32.18 and 5.33% relative abundance of each three species were recorded, respectively (Fig. 1). In terms of their abundance and priority fall army worm stands 1st followed by stem borer and ball worm in both districts and localities (Fig.1).



	Darolebu: Sakina	Kortu	Matagudesa	Total	Chiro: Arberekete	Waculimaye	Fugnandimo	Total
S. frugiperda	19.33	20.31	24.65	64.29	22.37	15.01	25.11	62.49
B. fusca	4.34	13.73	10.22	28.29	15.3	11.4	5.48	32.18
H. armigera	3.36	1.68	2.38	7.42	1.44	1.73	2.16	5.33

Fig 1: Types and abundance of maize insect pests at different localities in Darolebu and Chiro districts.

3.2 Percent infestation of maize plants due to different insect pests

The highest percent infestations of 42.97 and 41.16% at Darolebu and chiro districts, respectively, were recorded from *S. frugiperda*. Similarly, Lemmessa and Emana [26] reported the highest percentage infestation of 40-90% in maize at Ziway Dugda areas due to *S. frugiperda*. Hruska and Gould [19] also reported 55-100% infestation of maize plants due to *S. frugiperda* while, another study reported 63% infestation which resulted in 20.9% yield reduction under natural conditions.
The percentage infestations due to *B. fusca* were 37.29 and 34.89% at Darolebu and Chiro districts, respectively. Similar results have been reported by different authors. Sithole [36] reported 30% to 70% infestations of *B. fusca* in maize fields of resource–poor farmers but only 30% infestation in commercial farms where insecticides were used in Tanzania [41] and Kenya [42], loss of about 12% maize grain for every 10% plants infested by *B. fusca* were reported. Yield loss in maize by *B. fusca* was significantly correlated with leaf damage, but a higher correlation was observed with stem-boring damage [2]. A recent study in Cameroon found that stem borers, primarily *B. fusca*, were responsible for a 9-g loss in grain yield per plant per borer and caused an 11% loss of plants owing to dead heart [7]. The lowest percentage infestation and leaf damage was recorded from *H armigera*, it was almost similar at both study areas (Table.1).

Table 1: Mean percentage infestation on maize plants at Chiro and Darolebu districts.

Insect pests recorded	Mean percent infestation of maize (%)							
	Chiro district				Darolebu district			
	Arberekete	Wacu limaye	Fugnan dimo	Average	Sakina	Kortu	Mata gudesa	Average
Fall army worm	40.48^{ab}	38.09^{ab}	44.90^{a}	41.16^{a}	40.88^{ab}	43.74^{a}	44.30^{a}	42.97^{a}
Maize stem borer	39.01^{ab}	36.33^{b}	36.52^{ab}	37.29^{a}	29.33^{c}	35.67^{bc}	39.67^{ab}	34.89^{b}
African ball worm	9.50^{c}	6.00^{c}	6.00^{c}	7.17^{b}	13.87^{d}	1.33^{e}	7.33^{de}	7.51^{c}
LSD (0.05)	8.39			5.74	7.64			9.643
CV %	17.14			10.19	15.65			16.96

Note: Means with the same letter(s) are not significantly different for each other and different letters showed significantly difference (*P*< 0.05) by using Tukey's grouping analysis. Source: Computed from producer's survey data, 2018/19.

3.3 Estimated yield losses of maize due to major insect pests

During focused group discussion interviewed, farmers explained and estimated percent yield losses of maize caused by different insect pests particularly, FAW, MSB, and ABW.

In Darolebu district, among the interviewed farmers about 92.6% of the respondents estimated 10-30% yield losses due to FAWs but the remaining 7.4% of the respondents didn't able to estimate any losses, whereas in Chiro district, about 87.5% of the respondents estimated losses of 10-30%, 4.17% of the respondents estimated losses of 31-70% and the remaining 8.3% of the respondents didn't estimate any yield losses percent due to infestation of FAW (Table 2).

Table 2: Estimated percent yield losses of maize due to FAW.

Estimated Losses (%)	Chiro district		Darolebu District		Average
	Frequency	Percent	Frequency	Percent	
10-30	21	87.5	25	92.6	90.05^{a}
31-70	1	4.17	-	-	2.09^{b}
Don't know	2	8.3	2	7.4	7.85^{b}
Total	24	100	27	100	100
CV %	8.54				
LSD (0.05)	9.09				

Means with the same letter are not significantly different and different letters showed significantly difference (*P*< 0.05).

This result indicated that many respondent farmers in Darolebu (92.6%) and Chiro (87.5%) districts estimated losses ranging from 10-30% on maize crop by FAW, which is in lined with previous study in Ethiopia by Teshome [37] who reported that FAW caused up to 30% yield loss unless the pest is timely controlled. Similarly, Hruska and Gould, [19] reported infestations during mid-to-late maize growth stages can resulted in yield losses of 15–73%.

In Darolebu district, about 51.8% and 70.37% of the respondents estimated 3- 15% yield losses due to MSB and ABW, respectively, whereas in Chiro district about 70.8% and 66.7% of respondents estimated 3-15% yield losses due to MSB and ABW, respectively (Tables 3 & 4). About 44.44% of respondents from Darolebu district and 29.2% respondents from Chiro district were not able to estimate any yield losses due to infestation of MSB (Table 3). Regarding ABW, about 25.9% of the respondents from Darolebu district and 33.3% respondents from Chiro district didn't able to estimate any losses (Table 4).

Table 3: Estimated percent yield losses of maize due to MSB.

Estimated Losses (%)	Chiro district		Darolebu District		Average
	Frequency	Percent	Frequency	Percent	
3-15	17	70.8	14	51.8	61.30^{a}
>15	-	-	1	3.70	1.85^{b}
Don't know	7	29.2	12	44.44	36.82^{a}
Total	24	100	27	100	100
CV %	30.18				
LSD (0.05)	32.01				

Means with the same letter are not significantly different and different letters showed significantly difference (*P*< 0.05).

Table 4: Estimated percent yield losses of maize due to ABW.

Estimated Losses (%)	Chiro district		Darolebu District		Average
	Frequency	Percent	Frequency	Percent	
3-15	16	66.7	19	70.37	68.54^{a}
>15	-	-	1	3.70	29.60^{b}
Don't know	8	33.3	7	25.9	1.85^{c}
Total	24	100	27	100	100
CV %	11.09				
LSD (0.05)	11.76				

Means with the same letter are not significantly different and different letters showed significantly difference (*P*< 0.05).

The present finding is in agreement with the previous reported in Ethiopia, by MSB and *C. partellus* insect pests, with reported yield losses of 0 to 100, 39 to 100, 10 to 19 and 2 to 27% from South, North, East and Western Ethiopia, respectively [28, 29]. ABW are estimated at approximately US$5 billion on different crops worldwide. Yield loss by this pest varies from country to country as well as crop to crop. For instance, in India, 29.93 to 31.28% yield loss was recorded on chickpea [10]. In Ethiopia, estimated yield loss on chickpea ranged from 21 to 36% [14], on faba bean it ranged from 3.5 to 57.5% pod damage, while on field pea it ranged from 32 to 42% yield loss [22].

3.4 Local name, morphological appearance and damaging symptoms of insect pests identified from maize crop in the study areas.

Different morphological appearances and damaging symptoms of insect pests were identified and considered initially on the information obtained from local farmers producing maize crop. In both districts, the local name of fall armyworm (FAW) was Geri America. Its morphological appearance is with dafferent colors at larvae stage and the damaging symptoms eat the growing point widowing the leaf parts in maize cultivated fields. The local name of African bollworm (ABW) was Buketa or Ramo in maize cultivated fields at Chiro district whereas the local name of ABW was Buketa in maize cultivated fields in Darolebu district. The morphological appearance was listed as differerent colors in maize cultivated fields in Chiro district whereas green in Darolabu district (Table 5). It is similar with the report made by Nasreen and Mustafa [31]. The symptoms were the same in both districts on maize cultivated fields (eat cobs on maize). The stem borers were encountered on maize cultivated fields in both districts (Table 5). At both districts, the same local name, Urtu-ageda (Ramo); the same morphological appearance, grey whitish color larvae and the symptom were also the same only to eat leaves of maize and then inter the stem and boring.

Table 5: Local name, morphological appearance and damaging symptoms of insect pests on maize crop in the study areas.

Name of the pests	Chiro district			Darolebu District		
	Local Name	**Morphological appearance**	**Symptoms**	**Local Name**	**Morphological appearance**	**Symptoms**
FAW	Geri America	Different colors of larvae	Eat the growing point of the maize	Geri America	Different colors of larvae	Eat the growing point of the maize
ABW	Buketa	Different colors based on the crop types feeding on	Eat cobs on maize	Ramo	Green color on maize	Eat cobs on maize
MSB	Urtu-ageda (Ramo)	Grey whitish color larvae	Eat leaves of maize and then inter the stem and boring	Urtua-geda (Ramo)	Grey whitish color larvae	Eat leaves of maize and then inter the stem and boring

***Source*:** Key informants and group discussion discussants, 2018/19.

3.5 Description of morphological features and damage symptoms of identified major insect pests

The present study results provided basic information on insect pest identifications that were carried out through discussion with farmers and scientific approach in lab. The observation results obtained from both farmers and researchers in the study areas are almost similar

3.5.1 Fall army worm (FAW)

Morphological features

Larval forms

There are six instars in FAW. Young larvae are greenish with a black head, the head turning Oranges in the second instars. But particularly the third instars, the dorsal surface of the body becomes brownish, and lateral white lines begin to form. In the fourth to the sixth instars the head is reddish brown, mottled with white, and the brownish body bears white sub dorsal and lateral lines (Fig. 2). Elevated spots occur dorsally on the body; they are usually dark in color, and bear spines [4, 6]. Newly hatched larvae are gregarious and feed on the leaves of the host plant on which the eggs were deposited, but when they grow larger, they will disperse to other plants. The first and second instars feed on one side of the leaf and skeletonizing it, but as they grow, they eat and making a hole through the leaf. The face of the mature larva is also marked with a white inverted "Y" and the epidermis of the larva is rough or granular in texture when examined closely. The four black dots at the last abdominal segment are also distinctive to FAW larvae. Duration of the larval stage tends to be about 14 days during the summer and 30 days during cool weather [6].

FAW larvae is morphologically distinguished from other similar caterpillars by white inverted Y-shaped suture on the front of the head of a mature larva; distinctive pale or yellowish dorsal lines running lengthwise along the body (Fig. 2A) and four distinctive dark spots (tubercles or "bumps"); which are arranged in a square-like pattern on dorsal surface of the 8^{th} abdominal segment of a full-grown caterpillar (Fig. 2B).

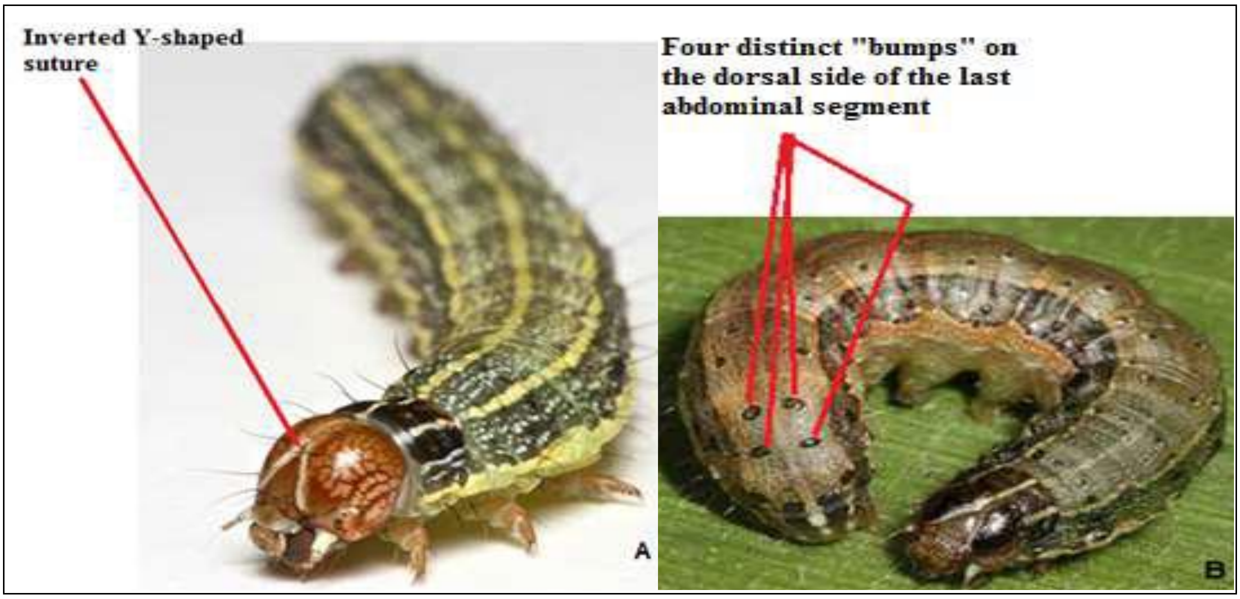


Fig 2: A - Mature FAW larva showing the characteristic white inverted Y-shaped suture on the front of the head, B – Four square pattern spots on the last abdominal segment of a FAW larva

Each of the other body segments also has four spots, but they do not form a square pattern (yellow circles) rather it forms "trapezoid" pattern.

Similar caterpillar species found on corn (left-right): African armyworm, Fall armyworm and Corn earworm

Although other caterpillars can also show an inverted Y-shaped suture on the front of the head this is usually a similar colour to the rest of the head.

Adult forms

Main distinguishing morphological features of adult FAW moth from other common caterpillars encountered in Ethiopia is forewing of the male moth generally has shades of grey and brown, with triangular white spots at the tip and near its center (Figure 3A, B). Whereas forewing of the male moth of African armyworm has kidney shaped whitish mark near its center (Figure C).

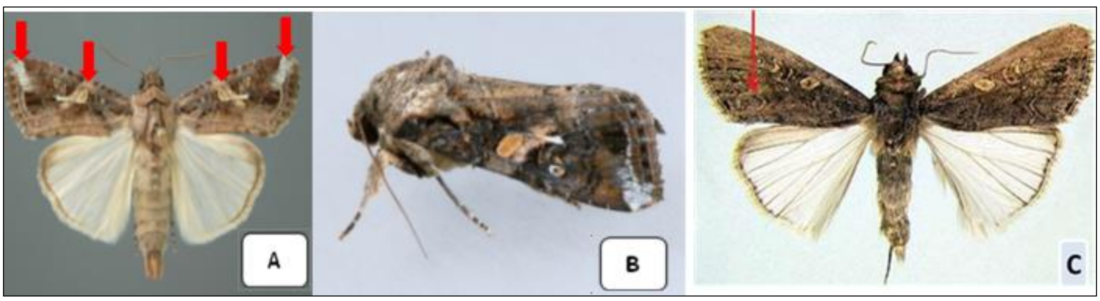


Fig 3: FAW male moth with wing deployed (A) and at rest (B), AAW male moth (C)

Nature of Damage Symptom of FAW

There are some characteristic differences in damage symptom and feeding behaviour in maize which an experienced scout can use to provide rapid pest diagnosis. However, an inexperienced scout can easily misidentify the cause of "windowpanes", whorl and tassel damage, and cob-boring on maize to be FAW when in fact the pest will be a stem-borer. Thus, it often requires confirmation using direct identification of live larval specimens during surveys or field scouting activities. Early feeding by FAW can appear to be similar to other stem borers but leaf damage by FAW is usually characterized by ragged feeding, torn and moist sawdust-like frass (Fig. 4A) near the whorl and upper leaves of the plant unlike stem borer feeding which often produces a characteristic rows of holes on the leaves (Fig. 4B).Though FAW larvae can burrow deep into the whorls of maize plants, they do not tunnel into stems like stem borers.

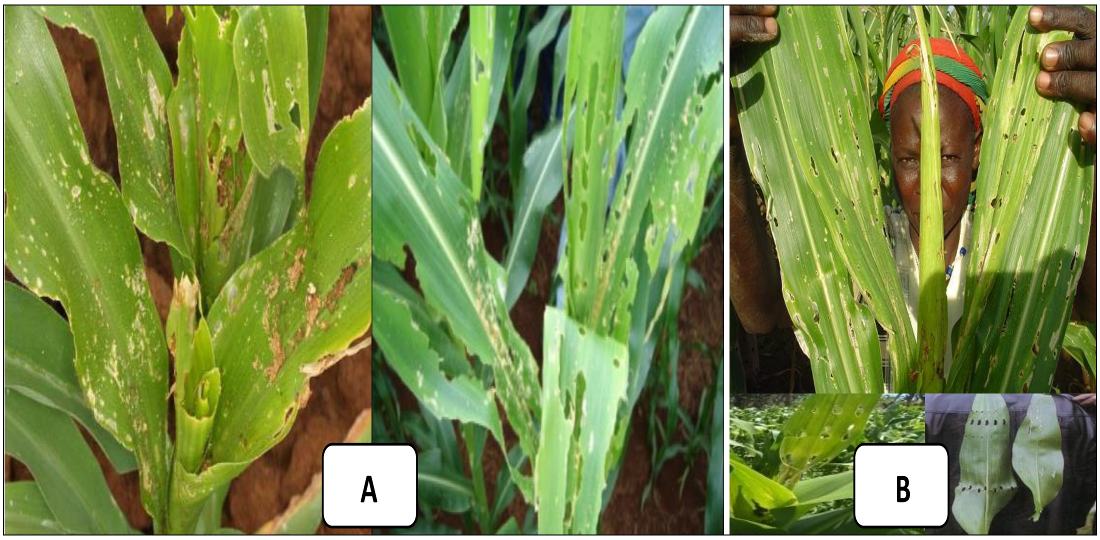


Fig 4: Characteristic leaves feeding due to FAW larva (A) and stem borer larvae (B)

FAW larva produces copious amounts of yellowish-brown frass during feeding which aggregated in the form of "balls" (Fig. 5A). In contrast, the frass produced by the stem-borers tends to be loosely aggregated, often sticking to the plant at the larval entry hole into the stem or cob (Fig. 5B).

Fig 5: Characteristic frass produced by FAW larva (A) and by stem-borer larvae (B)

Source**:** Photo from own insect rearing in Ambo research center and maize field, 2019.

Fig 6: Different stages and damaging symptoms of AFAW on maize.

3.5.2 Maize Stem Borer, *Busseola fusca* (Fuller, 1901)

The maize stalk borer was found as the second priority insect pests of maize crops in the study areas (Fig. 7) *Busseola fusca* is a species of moth that is also known as the maize stalk borer.

The taxonomic position of *Busseola fusca* is from Class Insecta, (Lepidoptera: Noctuidae).

Morphological features

Larval forms

Larvae migrate first to the whorl where they feed on young and tender leaves deep inside the whorl. In contrast to stem borer species from the *Sesamia* and *Chilo* genera, young *B. fusc*a larvae do not consume any leaf tissue outside of the whorls of plants. Larvae can remain in the whorls of especially older plants (6–8 weeks old) up to the 4th instars [25]. From the 3rd instar onwards, larvae migrate to the lower parts of the plant where they penetrate into the stem. Some larvae do however migrate away from natal plants with approximately 4% of larvae leaving the natal plant immediately after hatching [39].

Adult forms

The adult wingspan is about 20-40 mm, with females generally larger than males. The forewings are light to dark brown, with patterns of darker markings, and the hind wings are white to grey-brown (Fig.7). Its hind wings are almost white with a smoky tinge and dark longitudinal lines indicating the veins.

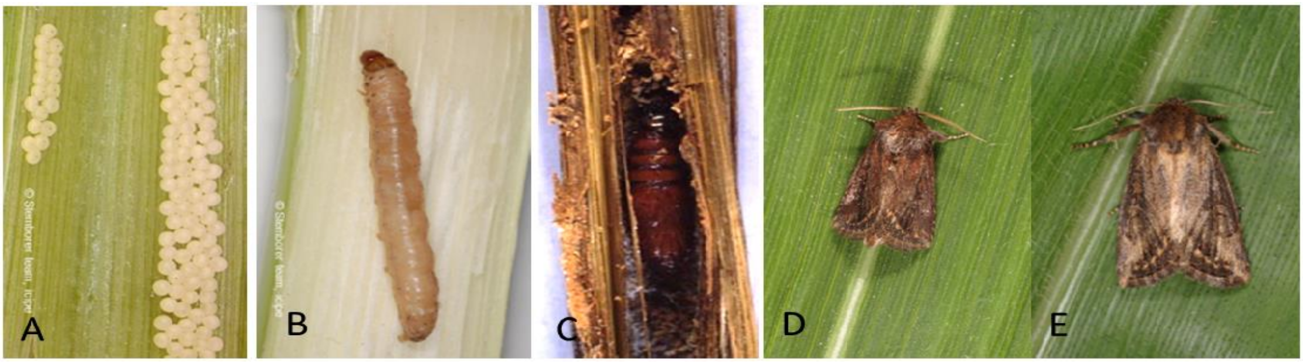


Fig 7: Developmental stages of the maize stalk borer, *Busseola fusca*: (A) egg, (B) larva, (C) pupa, (D) adult male, and (E) adult female. Photos: Courtesy of icipe.

Nature of Damage Symptoms of MSB

Busseola fusca larvae damage all plant parts of the cultivated crops they attack (Fig. 8). In South Africa, before the advent of genetically modified (GM) Bt-maize, *B. fusca* often occurred in mixed populations with another stem borer, *Chilo partellus* (Lepidoptera: Crambidae) [40]. *Busseola fusca*, *S. calamistis* and *C. partellus* larvae were often observed in mixed populations in the same planting as well as in individual plants. Multiple species attacks are also frequently observed in the different agro-climatic areas in Kenya [32]. Mixed infestations of *B. fusca* and *C. partellus* were also observed in the Highveld region of South Africa [1]. Although [23] speculated that *B. fusca* tended to avoid plants, which were previously infested by *C. partellus*, both species are often recorded on the same plant. In the humid forest zone of Cameroon, mixed populations of *B. fusca*, *S. calamistis* and the pyralid *Eldana saccharina* Walker are common [8].

Source: Photo from own maize field survey, 2019

Fig 8: Damaging symptoms of MSB on maize crop from the study areas.

3.5.3 African bollworm, *Helicoverpa armigera* (Hübner, 1805)

Morphological features

Larvae forms

Six instars typically observed for *H. armigera*. Coloration can vary considerably ranging from green, green with stripes, brown, and black [43]. Freshly emerged first instars are translucent and yellowish-white in color. The head, prothoracic shield, supra-anal shield and prothoracic legs are dark-brown to black as are the spiracles and raised base of the setae. The larvae have a spotted appearance due to sclerotized setae, tubercle bases, and spiracles [3, 24]. Second instars are yellowish green in color with black thoracic legs. Third instar larvae are green brown in color, as this pass-through 4th, 5th and 6th instar larvae their body color changes according to food, which can be blue-green, yellow green, yellow, light green, pink or light brown to reddish brown [31]. Five abdominal prolegs are present on the third to sixth, and tenth abdominal segments. The full-grown larvae are highly variable and are brownish, reddish, or pale green with brown lateral stripes and a distinct dorsal stripe; larvae are long and ventrally flattened but convex dorsally (Fig.10).

Adult forms

The stout bodied moth has a wing span range of 35 – 40 mm. and a body length range of 18–19 mm. [24]. *H.armigera* males had yellowish olive to yellowish-grey heads and thoraces while females had light reddish brown heads and thoraces. The forewings are yellowish - olive in the male and dark reddish brown in the female (Fig.9).

Fig 9: Female (left) and male (right) adult moth of *Helicoverpa armigera* [44]

Nature of Damage Symptoms of ABW

Helicoverpa armigera larvae prefer to feed on reproductive parts of hosts (flowers and fruits) but may also feed on foliage. Feeding damage results in holes bored into reproductive structures and feeding within the plant. It may be necessary to cut open the plant organs to detect the pest. Secondary pathogens (fungi, bacteria) may develop due to the wounding of the plant. Frass may occur alongside the feeding hole from larval feeding within eaten by the first and second instars. Third to fifth instars larvae invade the ears, staying hidden from natural enemies, and the developing grain is consumed [18]. Larvae are absent from the plants late in the season when the stalks have dried out [21]. They will frequently be near the tip but may feed down the ear creating a track of damaged kernels. The injury creates an ideal environment for ear fungi to invade and may lead to a quality problem at harvest.

Fig 10: Damaging symptoms of ABW on maize crop. Source: from own field survey, 2019

4. Conclusions and Recommendation

In this study, three insect pests were identified from the maize fields at Darolebu and Chiro districts. Among the insect pests fall army worm, maize stem borer and African ball worm were found as major pests on maize both at both Darolebu and Chiro districts. The study revealed that among the insect pests the dominant one was FAW followed by MSB, and lastly ABW. A major finding of the survey was that among maize field insect pests fall army worm is the dominant and most important pest in the study areas. These pests were found in more abundance and higher damage level in all assessed areas.

The average estimated yield losses of 10-30% by FAW, 3-15% by MSB and 3-15% by ABW at Darolebu and Chiro districts respectively on maize crop. The majority of the respondents in Darolebu (92.6%) and Chiro (87.5%) districts reported greatest yield loss of 10-30% due to fall armyworm.

This information was fundamental importance to the local communities and the country as it seeks to prevent actual and potential losses by developing effective and sustainable insect pest management strategies for the future. To give training for both farmers and extension workers on insect pest identification and their management, so they should be produced proper operation to early protect their maize crops from insect pests to reduce the yield losses. The Government should facilitate supply of improved resistance and drought tolerant varieties of maize to the farmers for planting. It should be recommended that an integrated insect pest management implementing to prevent maize crop losses incurred so as to contribute towards family food security in west Hararghe Zone. Screening of farmer preferred varieties to tolerance against insect pests of crop is of paramount important and should be coupled with yield loss estimated to guide rational management options. Detailed studies on yield losses due to those priority insect pests are required to support provide tangible information.

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