Assessment on Distribution, Biology and Management of Maize Stem Borer (Busseola fusca Fuller) in Ethiopia

Addis Tadesse Tekle
Ethiopian Biodiversity institute, crop and horticulture directorate, P.O.Box 30726 Addis Ababa Ethiopia

Abstract
Cereal crops (maize, sorghum, millet, rice) are extremely important crops grown in Africa for human intake. Of the various insect pests attacking cereal crops in Africa, lepidopteran stem borers are by far the most injurious. A parasitoid, *Cotesia flavipes*, was introduced from Pakistan for biological control of *C. partellus* and caused a 32–55% decrease in stem borer densities. Stem borers, encompassing the larvae of a group of lepidopterous insects, and parasitic witch weeds, particularly *Striga hermonthica* and *S asiatica*, cause major yield losses in subsistence cereal production throughout the country, Ethiopia. Studies are described that have led to the development of a 'push-pull' strategy for minimising stem borer damage to maize and sorghum. This involved the selection of plant species that could be employed as trap crops to attract colonisation away from the cereal plants, or as intercrops to repel the pests. The two most successful trap crop plants were Napier grass, *Pennisetum purpureum*, and Sudan grass, *Sorghum sudanensis*. In terms of stem borer control, the plant chemistry responsible involves release of attractant semiochemicals from the trap plants and repellent semiochemicals from the intercrops. With *M minutiflora*, parasitism of stem borers was also increased by certain chemicals repellent to ovipositing adults. This review provides information on B. fusca for the production of maize and sorghum in Ethiopia, with emphasis on their distribution, pest status and yield losses, diapause, natural enemies, cultural control, host plant resistance, and biological control. Special attention is given to *Busseola fusca* the most important pests of maize and grain sorghum.
Keywords: Botanical: push-pull stem borers; trap crop; intercrop; rotation: semiochemical

Introduction

Busseola fusca was first mentioned as Sesamia fusca in a report by Fuller in 1901 and described under the same name by Hampson in 1902. In 1953 African species of Sesamia and related genera were morpho-taxonomically revised and finally S. fusca was placed in the Busseola Thurau genus (Tams, 1953).

The first description of the oviposition site eggs, larval behavior and damage symptoms caused by Busseola fusca stemmed from South Africa. Since 1920, B. fusca is considered as an important pest of maize and sorghum in sub-Saharan Africa, and first recommendations on how to control this pest. Since then, a plethora of information on its distribution, pest status and injuriousness were produced B. fusca is considered to be the most destructive lepidopteran pests of maize (Mally, 1905) in Africa. Estimates of crop losses vary greatly in different regions and agro-ecological zones. In Kenya alone, losses due to B. fusca damage on maize fluctuate around 14% on average (Muyekho,2005) while in the humid forest zone of Cameroon losses of around 40% are common in mono cropped maize fields. Currently, this pest still presents a major constraint to the production of maize in areas where they are abundant. Inaccurate information from various reports is still propagated on its distribution and host plant range (Alata, 2008). Contrary to these reports, B. fusca does occur in the lower altitudes in East Africa and it feeds on only a few host plant species. During the last decade, the interactions of this insect pest with plants as well as its reproductive biology have been well documented. In the past 10 years, research on options to control cereal stem borers in Africa has increasingly focused on biological control and habitat management. Habitat management techniques include management of soil nutrients (Wale *et al*., 2006), crop rotation (Chabi-Olaye *et al*., 2005a), trap plants and mixed crop (Chabi-Olaye *et al*., 2005b). African small-scale farmers traditionally practice intercropping to improve total land productivity and to overcome the impact of crop failure and falling prices in the market of any single crop. Furthermore, diversified crop systems often reduce pest densities, in African subsistence cereal systems, intercropping is claimed to reduce pest infestation by up to 83% (Schulthess *et al.,* 2004; Chabi-Olaye *et al.,* 2005b).

Mechanisms of pest reduction in mixed cropped subsistence cereal systems include trap plants, reduced host finding by the Ovi-positing female moth, increased natural enemy activity, or mortality due to starvation and/or predation of migrating larvae on non-hosts in the crop mixture (Schulthess *et al*., 2004).

In Ethiopia, maize occupies more land than any other cereal crop after tef, and accounts for 36 percent of all grain production. Maize plays a critical role in food security, especially in rural areas of Ethiopia. Per capita consumption of maize in rural areas of Ethiopia is estimated at about 45 kg/year; triple the 16 kg/year consumption in urban areas. More than 80 percent is consumed at the household level, with commercial marketing largely limited to large-scale producers according to Global Agricultural information net work (Abbott, 1987) report. It is produced on an average area of over 1.2 million hectare of land. It is also the second important crop in total production following tef (Anand *et al*., 2008).

The national average yield of maize, which is about 2.2 ton per hectare is well below the world average 3.7 ton per hectare but slightly better than the previous year (Anand *et al*., 2008). The poor performance of maize in Africa in general, and Ethiopia in particular could be attributed to unfavorable agro-climatic conditions poor soil fertility, and the prevalence of numerous insect pests and diseases (Araya, 2007). Busseola fusca (Fuller) is considered by some authors to be the most important pest of maize in sub Saharan Africa (Belmain *et al*., 2001). The average yield loss of maize caused by cereal stem borers in Ethiopia can be estimated between 20 - 50% (Boeke *et al*., 2004).

The use of insecticides can be environmentally disruptive and can result in elimination of beneficial insects and accumulation of residues in the harvested produce (CIMMYT, 1999). Botanical insecticides have long been touted as attractive alternatives to synthetic chemical insecticides for pest management (Cox, 2002) Botanical pesticides are eco-friendly, economic, target-specific and biodegradable. Their greatest strength is their specificity as most are essentially nontoxic and non-pathogenic to animals and humans. Considering the importance of ecofriendly approaches to manage the pests, the experiment was designed to determine relative efficacy of different botanical extracts and other extracts against Busseola fusca. The high costs of synthetic pesticides and associated toxicity risks discourage to integrate into insect pest management systems (CSA, 2012; Echereobia *et al*., 2010).

To review different research findings on species distribution, levels of damage and status of management methods different agro-ecological zones of Ethiopia. Thus, understanding species distribution and biology of stem borer communities will constitute basic information necessary for future development of management strategies.

2. Research results

2.1. Geographic distribution

B. fusca is distributed widely throughout sub-Saharan Africa. Populations in eastern and southern Africa appear to be adapted to different environments from those in West Africa. In the eastern and southern parts of the continent, B. fusca is restricted to mid-and high elevations areas (>600m), whereas in West Africa, the same species is found at all elevations, but is most abundant in the savanna zone (Overholt *et al*., 2001). Counties in which B. fusca has been recorded include Angola, Benin, Botswana, Bukina faso, Cameroon, Ethiopia, Ghana, Guinea, Cote d"Ivoire, Kenya, Lesotho, Malawi, Mali, Mozambque, Nigeria, Rwanda, Sierra Leone, Somalia, South Africa, Swaziland, Tanzania, Uganda, Zaire, Zambia and Zimbabwe (Harris and Nwanze, 1992). The pest thrives on wide number of other cultivated and wild host plants, mostly of the grass family (Khan *et al*., 1997).

In Ethiopia, particularly in the agro-ecological conditions of suitable for maize growing areas of Ethiopia is indispensable. In Ethiopia, B. fusca and C. partellus are considered to be the most damaging 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 (Melaku and Gashawbeza, 1993; Melaku *et al*., 2006).

Previous two decades, Assefa (1985) reported that C. partellus was a predominant species at lower elevation of less than 1700 m and B. fusca was dominant at high elevation of 1160 - 2600 m.a.s.l. and in cooler areas, Emana *et al*. (2001) conducted a survey in 1999 and 2000 and reported that C. partellus widened its distribution from 500 - 1700 to 1030 - 1900 m.a.s.l. whereas B. Fusca was recorded between 1030 - 2320 m.a.s.l. However, studies were conducted in different on the compositions, distribution and damage levels of these stem borer species in northeastern Ethiopia. Thus, understanding species distribution and abundance of stem borer communities will constitute basic information necessary for future development of management strategies

2.2 Biology of B. fusca fuller

A good knowledge of the biology of Busseola fusca is a prerequisite for understanding how this species interacts with plants. Most of the information produced for B. fusca during the last century, which forms the basis of the knowledge of the biology and ecology of this pest, stemmed from South Africa However, since the majority of the studies in South Africa addressed B. fusca at high altitudes and in commercial farming systems, some aspects regarding its biology and interactions with the environment may differ from those in other agroecological zones. Furthermore, most of the following information on B. fusca biology and reproduction was obtained on maize plants.

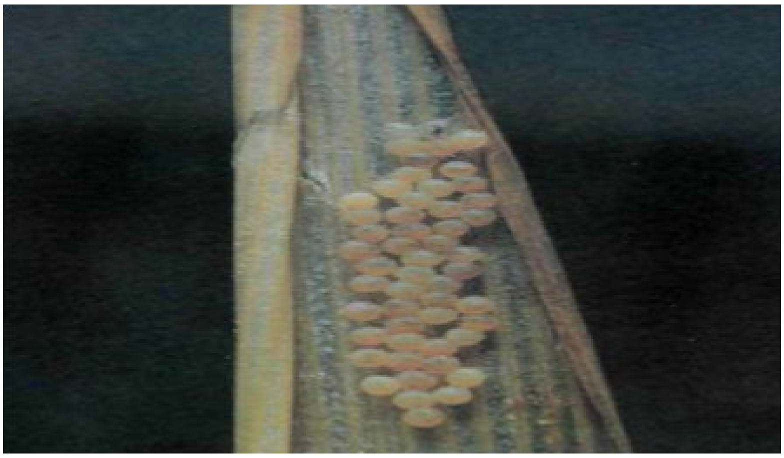
The female lays many eggs in batches of 30-50, inserted between the sheath and the stem. Incubation lasts about 1 week. After hatching, the larvae feed on the young blades of the leaf whorl and then, suspended from silk strands, spread to neighboring plants. They penetrate the stems by boring through the whorl base.

Generally, they destroy the growing points and tunnel downward. After passing through six to eight stages (30-45 days), they chew an outlet for the adult and pupate in the tunnel. Pupation lasts 10-20 days. Up to four generations are produced per year. At the end of the rainy season, larvae of the last generation enter diapause in maize and sorghum stubble or in wild grasses. They pupate a few months later, just before the start of the following rainy season. In the mid and high elevation an area of eastern and southern Africa, B. fusca is often the most important stem borer of maize. Yield losses have been estimated to be about 12% for every 10% of plants infested (Harris and Nwanze, 1992). In Sub-Saharan African countries, which include Ghana, B. fusa is considered the most important pest of maize, yield loss as high as 40% has been attributed to B. fusca infestations (www.maizedoctor.com, 2010).In Zaire for instance, B. fusca occasionally caused yield losses of 8-9% in early-planted maize, and 22-25% in lateplanted maize. In Cameroon, Cardwell *et al*., (1997) reported grain loss at 4.6g per borer in lowland fields and 8.7g per borer in highland fields.

2.2.1 Eggs

Busseola fusca females oviposit a highly variable number (from 100 up to 800) of round and flattened eggs in batches. The batches are laid behind the vertical edges of leaf sheaths of pre-tasseling plants and also, but rarely, underneath the outer husk leaves of ears. Van Rensburg and colleagues recorded eggs on 12- to 16-week old plants, but only when these were planted very late in the season. It appears that the position at which the eggs are found correlates with the developmental stage of the plant, and with increasing plant age, egg batches are increasingly found higher up on the plant. Van Ransburg and colleagues noted that leaf sheaths fitted more loosely around stems as plants gets older, and that females preferred the sheaths of youngest unfolded leaves for oviposition. Although it is rare to find more than one B. fusca egg batch per plant, van Rensburg and colleagues reported cases of between 2 and 4 egg batches per plant (Felix, A, 2008). They however attributed this to extremely high population pressure at late planting dates.

- **Figure. 1**. Busseola fusca, egg mass under a leaf sheath. (source; A handbook information Busseola fusca, 1992, India)



In South Africa, with its unimodal rainfall pattern allowing for one crop per annum, it was also observed that egg batches of spring moth generation are smaller than those of summer months. A possible explanation is that body reserves of spring moths are smaller than those of the summer months since the former would have utilized reserves during diapause. Similarly, Usual in Nigeria reported that spring moths laid approximately 65% fewer eggs than summer months.

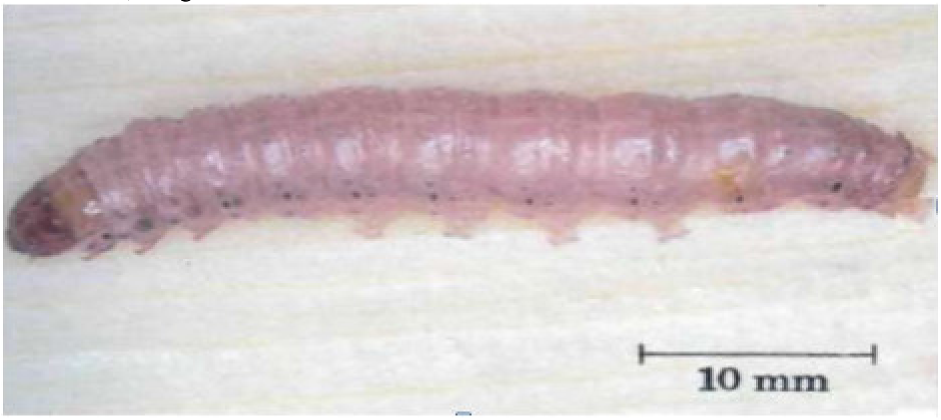
Field studies during which more than a thousand egg batches were collected in South Africa, showed that the average size of an egg batch of 1st and 2nd generation females were 22 and 33 eggs respectively. Results from van Rensburg and colleagues indicate that a single moth lays 7–8 egg batches, an observation supported by Ingram, and Kruger and colleagues under laboratory conditions. Busseola fusca fecundity has not been studied in areas with bimodal rainfall distribution, which allows for more than one cropping season per annum (Mally, C.W, 1920).

2.2.2 Larvae

Larvae hatch after about one week and they 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. fusca 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 (Kruger, M, 2012). 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 (Van Rensburg, 1997).

The larval stage lasts between 31 and 50 days and consists of 7–8 in stars with a minimum of 6. More recently, continuous observations of larvae on an artificial diet indicated that, under optimum environmental conditions (25 °C and 50%–60% r.h.), thelarval stage consisted of 5 stages and was completed during approximately 35 days (Usua, E.J, 19670). Additional instars were observed when the conditions were suboptimal or when larvae went into diapause. Although, it is well known that B. fusca undergoes a facultative diapause consisting mostly of a larval quiescence; several issues around this survival mechanism remain unclear. Although Okuda showed that water contact is a significant factor terminating diapause, the mechanisms explaining diapause physiology in B. fusca have not been fully elucidated.

Figure.2.Busseola fusca,full-grownlarva.



(Source; A handbook information Busseola fusca, 1992, India)

2.2.3. Adults

2.2.3.1. Emergence and Life Duration

The mean sex ratio of B. fusca is 1:1.1 (male:female). The adults emerge about 13–14 days after pupation and they emerge mostly between sunset and midnight (Ratnadass, A, 2001). Most males emerge before onset of the scotophase, while most females do so one hour later. The averagelife span of moths ranges between 8 and 10 days.

Figure.3 Busseola fusca,live adult male on maize(source; A handbook information Busseola fusca, 1992, India)

2.3.2. Pheromones

Only the females emit pheromones. Males and females exhibit simple and rapid courtship behavior without any particular characteristic event. The sex pheromone of B. fusca females was first identified as a mixture of (Z)-11-tetradecen-1-yl acetate (Z11–14: Ac), (E)-11-tetradecen-1-yl acetate (E11–14: Ac), and (Z)-9-tetradecen-1-yl acetate (Z9-14: Ac). More recently, an additional pheromone component, (Z)-11-hexadecen-1-yl acetate was identified and when added to the aforementioned three-component synthetic blend resulted in improved attraction of males(Felix, *et.al*. 2009).

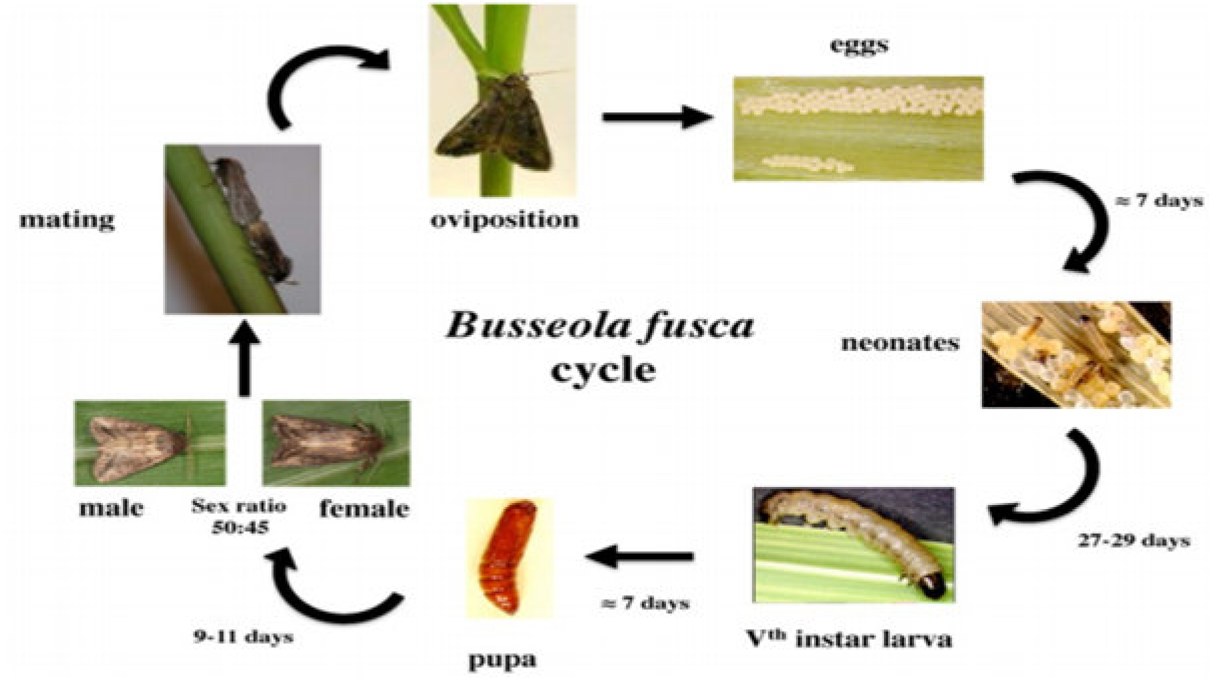
2.3.3. Mating

The females start calling a few hours after emergence, indicating absence of a sexual maturation time. The calling behavior generally commences during the fourth hour after the onset of the scot phase but it is slightly delayed for females having emerged the same night as compared to older females. Mating starts within a few hours after moth emergence. Moreover, mating occurs generally during the first six hours of the night, and the males can mate several times but only once per night.

A single spermatophore is generally sufficient to fertilize all eggs of a female throughout her life span, indicating that polyandry is not obligatory and not necessary. Laboratory studies also showed that female calling behavior and male attraction was not influenced by the presence of plants, irrespective if it was a host or non-host.

The oviposition period lasts for 3–4 nights. It commences during the first night after mating, peaks during the second and then gradually decreases until the fifth night (Unnithan, G.C, 1990). A summary of the lifecycle of B. fusca with updated information is provided in Figure 1.

Figure1. Biological cycle of Busseola fusca under optimal environmental conditions on artificial diet (photos on mating and oviposition from Felix, A.-E, 2008).



Source: - (Journals of Insect, 2014)

2.3. Management practices for control of stem borers

2.3.1Manipulation of sowing dates

Sowing date manipulations conducted at Awassa indicated that early-planted maize suffers less from the attack of B. fusca (Assefa Gebre-Amlak *et al*., 1989).Similar results were obtained from investigations carried at Areka. Plantings should not be delayed later than April.

The study showed that early planting as soon as the rain starts can off-set the damage caused by B. fusca and ensures high yield without using insect Sowing date trials conducted at Abobo (Gambela) showed that early plantings suffer less from the attack of Chilo partellus(Daniel and Belayneh, 2001). Relatively lower levels of infestation and higher yields were observed from the second (May 8) and May 23 plantings.

Research results obtained at Arsi-Negele indicated that early sowing with cypermethrin treatment doubled the yield of maize grain. If maize has to be grown without cypermethrin treatment, it should be sown between 20 April and 10 May. The highest economic return with cypermethrin treatment at the rate of 0.30 kg / ha applied at 4 and 6 weeks after crop emergence was obtained with early sowing, indicating that early infestation of stem borer is very detrimental for maize production at Arsi Negele (Emana and Tsedeke, 1999)

(Table 2). Tsedeke and Elias (1998) also reported that early sowing had a yield advantage of more than 58.2% over late sowing, cticides.

Table 2. Effect of cypermethrin versus sowing dates on economic return of maize grain at Arsi- Negele (combined over years)

Sowing date	Mean yield (t/ha) Cyper. treated	Untreated	Yield difference (±)	Cost of cypermethrin and its application (Birr)	Net benefit or loss in Birr (1 t maize grain=800 Birr)
20 March	5.75	2.90	+2.85	200	+1680
30 March	5.65	3.50	+2.15	200	+1520
10 April	5.75	3.15	+2.60	200	+1880
20 April	5.15	4.10	+1.05	200	+640
30 April	4.40	4.04	+0.36	200	+88
10 May	4.05	3.59	+0.46	200	+168
20 May	2.95	3.88	-0.83	200	-864
30 May	2.50	2.97	-0.47	200	-576
10 June	1.75	2.27	-0.52	200	-610
20 June	1.70	1.12	+0.58	200	+264

(Source; Proceedings of the Second National Maize Workshop of Ethiopia 12-16 November 2001)

2.3.2 Intercropping

Maize/bean intercropping experiments conducted at Melkassa and Awassa during the 1992 cropping season showed that sole maize had significantly higher incidence of stalk borer and cob worms as compared to intercropped treatments. Higher stalk borer incidence occurred when maize and bean were planted in the same row at both locations.

On the other hand, an inconsistent trend was observed in cob worm incidence across locations. Although the current results are not conclusive, it seems that planting time of the intercrop has an impact on the incidence of stem borer and cob worm. Higher stalk borer incidence occurred in simultaneously planted maize intercrops, whereas higher cob worm incidence occurred in maize relay cropped with beans at both locations (Negussie and Reddy, 1996).

Table 2. Indicating the effect of intercrop in controlling maize stem borer

Table 6 Effect of intercrops on cob (g/plant) and grain yield (kg/ha) (± SE) of maize and sorghum in the cool-wet ecozone of the Amhara state

	Maize cob weight (g/plant)		Maize grain yield (kg/ha)	
	Addis Zemen	Kola Diba	Addis Zemen	Kola Diba
Potatoes	115.9 ± 12.7[a]	117.0 ± 5.5[a]	735.4 ± 197.70[c]	1882.2 ± 377.60[b]
Mustard	65.6 ± 8.2[b]	95.6 ± 6.0[b]	1400.9 ± 544.76[b]	2261.2 ± 222.10[a]
Faba bean	81.1 ± 8.4[b]	66.3 ± 4.7[c]	1613.2 ± 328.60[b]	2447.7 ± 300.81[a]
Cowpea	64.4 ± 8.0[b]	64.3 ± 3.5[c]	2168.8 ± 538.21[a]	2600.3 ± 357.76[a]
Maize monocrop	50.8 ± 7.4[b]	82.7 ± 5.6[b]	1015.4 ± 354.46[b]	2130.6 ± 171.92[a]
F	7.08	17.70	4.68	3.12
d.f.	4325	4,738	4,15	4,15
P	<0.0001	<0.0001	0.0310	0.0423

Means of cob weigh or grain weight within a column followed by the same superscript letter(s) are not significantly different at $P = 0.05$ (SNK).

Source: - Journal of Agricultural and Forest Entomology (2007)

In Addis Zemen, maize intercropped with cowpea produced greatest yields followed by maize intercropped with faba bean. Similarly, earlier agronomy studies in the same area showed that faba bean intercropped plots had 37 – 61% more grain yield than maize alone (Minale *et al*., 2001). In addition, Songa (Kenyan Agricultural Research Institute, Nairobi, Kenya, personal communication) found increased yields in a bean-maize intercrop and attributed this to reduced evaporation of soil water (Kariaga, 2004) and weed suppression.

In western Amhara, significantly lower borer densities compared with maize monocrops were observed on potato and mustard plots at Addis Zemen, but only during the vegetative stage. By contrast, in eastern Amhara, borer attacks did not vary significantly between cropping systems.

In the present study, the effect of mixed cropping, with the exception of mustard and potatoes, on pest infestations was not as clear-cut as that observed in similar studies in western Africa. so according to M.wale

(2007), Emphasis should be given to cereal mustard systems because mustard, besides suppressing pest densities, is a high value crop. Furthermore, an insecticide treatment should be included to assess the efficiency of a cropping system in terms of yield under both low and high pest infestations.

Similar Experiments that was under taken in Melkassa Ethiopia, Defabachew (2008), shows the profitability of maize-haricot bean intercropping techeniques to control maize stem borers under low pest density. Table 3; Shows the profitability of maize-haricot bean intercropping techeniques to control maize stem borers under low pest density Defabachew (2008).

Table 5 Percent haricot bean pod damage by *Helicoverpa armigera* and yield (mean±SE) in a maize (M):haricot bean (HB) intercropping experiment at Melkassa (2004 and 2005) and Mieso (2005)

Treatment	Melkassa 2004 Yield (g)/ 5 plants	Melkassa 2005 % ABW pod damage (non-sign.)	Mieso 2005 Yield (g)/ 5 plants	% ABW pod damage (non-sign.)	Yield (g)/ 5 plants
1M:1HB	22.4±0.9b[a]	34.3±6.8	58.7±5.7ab	34.5±7.1	25.6±1.2bc
2M:1HB	19.5±2.2b	25.2±5.2	36.9±7.5b	34.±6.1	44.9±8.4 a
3M:1HB	27.7±2.0b	25.2±4.1	31.9±5.8b	44.3±2.3	40.1±3.9ab
4M:1HB	20.3±4.2b	29.8±6.1	33.9±8.4b	44.4±4.1	32.9±2.9ab
Haricot bean sole	47.0±7.5a	30.9±6.1	75.0±20.3a	49.3±11.7	15.3±1.8c

[a] Within columns, means followed by a common letter do not differ significantly at *P*=0.05 (SNK)

Source: - (Academic journal of crop protection, 2010)

2.3.3Natural enemies of stem borers

Surveys carried out to study the species composition of indigenous parasitoids associated with stem borers attacking maize and sorghum and percent parasitism in west, north and central Ethiopia (Mulugeta, 2001) revealed that the major parasitoids are Apanteles sesamiae (Cameron) (Cotesia); Bracon hebetor (Say); Bracon sesamiae (Cameron), Procerochasmias nigromaculatus (Cameron) (Ichneumonidae) and a Sarchophagaspp. (Diptera). An unidentified predaceous ant was also recorded. The survey revealed that Cotesia spp. is the dominant parasitoid group that attacks the stem borers among which C. sesamiae (Cam.) was found to be widely spread in all surveyed areas. Preliminary observations on the extent of parasitism showed that C. sesamiae can cause 20-60% larval mortality. The number of adult parasitoids emerging from a single borer larva depends on the instar parasitized and varied with environmental conditions of the localities and availability of host. Up to 60 adult parasitoides can emerge from a single parasitized larva. The 4th to 6th instar larvae were found to be most suitable larval stage for egg deposition. The results of this study showed that C. sesamiae (Cam.) is an important natural control agent of stem borers (Mulugeta, 2001).

The impact of the principal larval parasitoid of maize stalk borer, Cotesia sesamiae, was studied at Awassa by counting the number of cocoons at 15 day intervals by dissecting 20 randomly sampled infested maize stalks (Assefa Gebre Amlak and Ferdu Azerefegne, 1997). The parasitoid cocoons were rarely observed from field dissection of actively growing maize (April-October). Dissections of dry stalks of maize indicated that the proportion of parasitised larvae steadily increased during the dry period (November-April). The result shows that the parasitoid has little effect in reducing the population of B. fusca larvae during the cropping season. However, they reduce the carry-over population which may give rise to the initial infestation during the start of the next growing season. On the other hand, integration of sowing date and botanical application for the control of stalk borer conducted at Areka using neem seed powder showed that the highest cob damage and the lowest yield (45.1 q/ha) were obtained on the 4th sowing date (22 June, 1998) with the application of neem seed powder 30 and 45 days afteremergence. The earliest sown maize (June 1, 1998) treated with neem seed powder 30 days after emergence resulted in the lowest cob damage and highest yield (65.5 q/ha) (EARO, 1998/99).

According to Asmare Dejen (2013), conducted at three zones of northeastern Ethiopia (Wollo), Cotesia flavipeswas found to be the key larval parasitoid of cereal stem borer species in all areas.

Table.4; elevation (m), stem borers species composition (%) and natural parasitism rates of Cot. flavipeson maize and sorghum in Amahara zone in 2010/11.

Districts	Elevations (m)	Parasitism (%)			
		Maize	Sorghum at		
		Cp	Maize	Booting	Harvesting
Dawa Chefa	1640–1669	100	54.6 ± 7.2[a,b]	35.8 ± 8.9[a]	64.8 ± 1.9[a]
	1432–1669	100	42.4 ± 5.5[b]	45.6 ± 10.0[a]	73.9 ± 1.6[a]
	1419–1431	100	62.5 ± 10.3[a]	41.5 ± 14.8[a]	75.2 ± 5.0[a]
	1471–1490	100	32.2 ± 5.2[b]	33.1 ± 4.5[a]	60.1 ± 3.3[a]
		F	13.3	0.18	3.0
		P	0.000	0.14	0.06
		df	15	15	15
Bati	1555–1576	100	72.7 ± 6.3[a]	48.6 ± 10.4[a]	82.2 ± 7.3[a]
	1640–1657	100	65.3 ± 6.3[a]	52.5 ± 3.4[a]	79.2 ± 4.7[a,b]
	1412–1515	100	54.8 ± 4.7[a]	45.0 ± 10.1[a]	60.8 ± 3.2[b]
		F	0.02	1.9	12.3
		P	0.35	0.45	0.000
		df	11	11	11

Notes: Mean (±SE) within columns, along each district, followed by the same letters do not differ significantly at the 5% (multiple range test).
Abbreviations: *Bf, Busseola fusca; Cp, Chilo partellus.*

Source:- (Journal of Entomology and Nematology, 2014)

This research showed that the distribution and extent of parasitism of this parasitoid varied with agro-ecological zones and subsequently affected its major host, C. partellus. Moreover, C. partellus was a dominant species in lowlands (, 1750 meters) with high temperatures (28 °C–32°C). Rates of parasitism were higher in lower elevated areas where C. partellus was the dominant species. In contrast, the rate of parasitism was lower in highlands (.1850 meters) where B. fusca was dominant.

Levels of parasitism were higher at the harvesting than booting stage of sorghum and ranged between 5%–62% and 0%–45%, respectively. Because the third and the fourth instars came out at the booting and harvesting stages of the crops respectively, the later larval stages of the host, which is suitable to the parasitoid, were available at later stages of the crop.

2.3.4 Chemical control

Dressing maize seeds with carbosulfan (Marshal 35 ST) did not protect maize from the attack of maize stalk borer (Tsedeke and Elias, 1998). Similar investigations carried on the protection ability of carbosulfan (Marshal) at different rates (0, 0.9, 1.8, and 2.7 kg/qt of maize) at eight locations indicated that the insecticide did not protect maize from stem borers, leafhoppers and aphids (EARO, 1996/97). On the other hand, chemical screening of thirteen insecticides was carried out at Awassa and Areka. Compared with the untreated check, the lowest cob infestation at both locations was observed on Ethiosulfan 35%, Diazinon 60%, Ethiosulfan 5%, Thionex 25%, Actellic E.C., Decitab and Cypermethrin G sprayed plots. At Awassa, the highest yield (98.4 q/ha) was obtained from plots treated with Cypermethrin G (EARO, 1998/99). Screening of insecticides conducted by the Crop Protection Division of the Awassa College of Agriculture showed effective control of B. fuscawith Carbaryl, Decis tablet, Cypermthrin G, Bulldock G, Chloropyrifos G, Diazinon G, Endosulfan EC, Endosulfan D, Lamdacyhloahterin Sachet (Ferdu Azerefegne and Yibrah Beyene, unpublished).

2.3.5 Botanicals

A preliminary field test in 1993/94 showed that application of extracts of fruits of chinaberry (Melia azedarachL.), Endod (Phytolacca dodecandra L.) and pepper tree (Schinus molle L.) significantly reduced the levels of leaf infestation and dead heart injury due to larvae of the maize stalk borer, Busseola fusca (Fuller), and resulted in increases in crop yield (Assefa and Ferdu, 1999).

Extracts of both leaves and fruits of chinaberry (either fresh or dried) were effective in reducing the number of larvae (Table 3). All the rates (2, 10 and 20 kg/ha for fresh leaves; 1, 2 and10kg/ha for dried leaves; 10, 20 and 30 kg/ha for fresh fruits, and 2, 10 and 20 kg/ha for dried leaves) used significantly reduced the number of larvae relative to the untreated controls. Fresh leaves and fruits of endod were also effective against B. fusca. Fruits of pepper tree were superior to leaves. Fresh leaves of this plant did not reduce the number of larvae.

Two applications of any of the three botanicals were not sufficient to provide complete protection of maize against second generation larvae. This suggests that these botanicals have only brief persistence, and more than two applications of the extracts would be necessary to reduce pestnumbers (Assefa and Ferdu, 1999).

Neem berries (A. indica), pyrethrum flowers (Chrysanthemumspp.), garlic bulbs and abasoyo-hotpepper pods were tested against 2nd and 3rd instar of maize stalk borer larvae under laboratory conditions. Applications of extracts of neem berries (seed) and pyrethrum flowers at 8% concentration resulted in 90 and 100% mortality to I to II instar of B.fusca within three days, respectively (EARO, 1998/99).

Source; (Proceedings of the Second National Maize Workshop of Ethiopia 12-16 November 2001)

Table 3. Efficacy of three botanicals for *B. fusca* control (1993)

Dried fruit	Rate (kg/ha)	Percent infestation: Leaf infestation	Deadheart injury	Tunneled stalks	Yield (qt/ha)	Yield increase (%)
P. dodecandra	32	14.5±6.6b	2.3±0.5b	7.2±3.7b	28.1±2.1ab	67.9
S. molle	40	9.3±3.8b	4.6±1.4b	6.4±2.4b	32.4±2.2a	94.1
M. azedarach	60	5.7±2.0b	2.5±0.9b	6.8±3.3b	24.7±1.8b	47.9
Control		65.9±7.8a	34.4±7.3a	93.3±1.7a	16.7±3.2c	

± = Standard error of the mean; Means within the same column followed by the same letter are not significantly different (LSD, P>0.05).

Maize stem borer is an internal feeder and the different larval stages normally develop successfully inside the maize stem. However; the two treatments, viz., Cypermethrin dust and C. cineraria folium completely inhibited the mortality rate of Maize stem borer, B. fusca under laboratory condition according to an experiment conducted at ambo by Tadele (2013).

Table; - Efficacy of some botanicals powder against Maize stalk borer, Busseola fusca mortality (%) under laboratory condition at ambo.

Day after application of mortality (%) Treatments	1st day	2nd day	3rd day
Nicotiana spp. (local variety)	8.33cd	58.33b	75.00b
Securidaca longepedunculata	16.67c	25.00c	50.00c
Chrysanthemum cinerariaefolium	58.33b	58.33b	100.00a
Cymbopogon citratus	25.00c	25.00c	83.33b
Cypermethrin	100.00a	100.00a	100.00a
Control	0.00d	0.00d	0.00d
MSE	10.87	14.91	5.89
CV(%)	21.29	23.54	8.66

Note: Means with the same letter(s) are not significantly different.

Source; - (International Journal of Agriculture and Crop Sciences, 2013)

2.3.6 Host-Plant Resistance

Host-plant resistance has potential to provide effective control of B. Fusca (Van Rensburg, 1993) and has been indicated to be compatible with other control methods (Bosque-Perez, 1998). However, maize varieties resistant to this pest are still not available in Africa (Kfir, et al. 2002). Evaluation of maize and sorghum genotypes for resistance to B. fusca was performed in South Africa after the development of a method to collect large numbers of overwintering larvae (Van Rensburg,1993).

Using this method, winter-collected B. fusca larvae can be kept in diapauses in the laboratory for extended periods and the diapauses can be terminated at will to provide moths and large numbers of neonate larvae for artificial infestation of plants in the field (Van Rensburg,1993). Maize inbred lines resistant to North American lepidopteran pests of maize were evaluated in South Africa and they have been shown to be highly resistant to B. fusca (Van Rensburg, 1990). Viable resistance to B. fusca was later identified in several lines developed by CIMMYT in Mexico (Van Rensburg, 1995).

After mass screenings and elite line developments, 42 stem borer resistant maize breeding red lines were released in South Africa during 2004 (Rensburg et al.2004). All of this was, however, eclipsed by advances in molecular genetics and development of genetically modified maize. The value that stem borer resistance in sorghum hybrids could have in suppression of pest populations was shown by van den Berg (Van den

Berg,1995). However, screening of more than a 1800 sorghum breeding lines for resistance to B. fusca showed that antibiosis resistance levels were low and that tolerance to damage and recovery resistance were the mechanisms that resulted in reduced yield losses in some lines (Van den Berg,1994).

2.3.7 Genetically Modified Maize

Genetically modified (GM) maize expressing insecticidal Cry proteins (Bt-maize) have been deployed with success against B. fusca in South Africa until 2006 when the 1st case of resistance was reported (Kruger, 2012). The reasons provided by farmers for the high adoption rate of Bt-maize were largely given as ease of management (Kruger *et al.* 2012). Nevertheless, Bt-resistant B. fusca populations have been reported throughout the maize production region of South Africa (Kruger, 2012). The resistance was shown not to be recessive as previously assumed (Campagne, 2013). GM maize will be approved for control of several lepidopteran stem borer species in Africa within the next few years. Due to the unique nature of African farming systems (e.g., seed sharing practices) this will provide new challenges to managing this pest in subsistence farming systems (Assefa, 2010).

2.4 Economic threshold level

The accepted action threshold level for spraying against B, fusca is when the average catch from three traps per site exceeds two month per week for 4 consecutive weeks (Revington, 1987). According to Van Rensburg (1987) when stalk feeding was initiated during the 10-leaf, 16- leaf, blister, and dough stages of plant development were 5.94, 5.01, 3.13, and 2.41% per larva per plant, respectively this level shows the economic Injury level.

2.5 Integrated Pest Management

Stem borer control strategies must be politically practical, socially acceptable, economically feasible, and technically effective.

farmers in Ethiopia, and elsewhere in Africa, traditionally use a combination of several pest management practices of cultural control, biological control, use of botanicals, Chemicals, and host plant resistance is the option for managing stalk borers in maize under a smallholder production system (Abate *et al.* 2000).

3. Conclusion

Most studies in Central, East and Southern Africa showed that B. fusca occurs in all agro ecological zones from the lowlands to the highlands and that the host plant range was much narrower. This narrow host plant range was due to physical and chemical plant characteristics that influence the interactions between B. fusca and its host plant.

Stem circumference, plant pubescence and the tightness of the leaf sheath strongly influence host plant acceptance by gravid females for oviposition. Plant volatiles are used by the gravid females for host plant finding. After landing, the cuticular chemical composition of the plant surface conditions the host plant acceptance by the ovipositing females.

Lepidopterous stalk borers, including the spotted stalk borer, Chilo partellus (Swinhoe)(Lepidoptera: Crambidae); the maize stalk borer, Bussoela fusca (Fuller) (Lepidoptera:Noontide) and the pink stalk borer, Sesamia calamistis (Hampson) (Lepidoptera: Noctuidae)are among the most important pests of sorg hum and maize in Ethiopia**.**

Application of any pest management should be incorporated to the control of insect pest, based on the field assessment for the particular insect pest.

An integrated pest management (IPM) approach combining two or more of cultural control, biological control, use of botanicals, chemicals and host plant resistance is the option for managing stalk borers in sorghum and maize under a smallholder production system.

4. Research gap

- The tendency of farmers to solely depend on pesticide chemicals for the control of insect pests should be discouraged and the concept of IPM (Integrated Pest Management) should be promoted. This, in turn, calls for the active involvement of farmers themselves in the planning and implementation of research so that their indigenous pest management practices will be explored.
- Although information on the natural enemy complex of important insect pests of maize is available, little or no work has been done to quantify their contribution and promotion in the farming community for the control of pests. Hence, it is important that an initiative be taken to address the knowledge gap in this area.
- Capacity building in terms of trained human resources, research laboratories and facilities.
- It has also identified lack of effective coordination, collaboration and networking mechanism in IPM implementation.
- The other gap identified was low awareness of policy and decision makers on the relevance of IPM which

has worsened the situation.

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