Lepidopterous stem borers of maize (*Zea mays*): agro-ecological and regional composition and distribution of their parasitoids in Southern Ghana

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ABSTRACT: The study aimed at finding out the level of infestation of maize stem borers, their agro-ecological and regional composition and distribution of their parasitoids. Farms were made at University of Cape Coast in the major and minor cropping seasons and maize sown. Plant infestation was recorded weekly. Stem borer larvae and pupae collected from plants were reared until either parasitoids developed from them or they developed into pupae or adults. Rate of parasitization of each stem borer was calculated. In two national maize field surveys, field infestation by pests and parasitism were determined. Parasitoids that emerged from stem borer larvae and pupae were identified to species level. Diversity and distribution of parasitoids according to agro-ecological zones and national administrative regions were determined. Higher stem borer infestation was recorded in the minor season experimental plants. Also, higher number of stem borers was collected from plants during the minor season. *Eldana saccharina* was the most parasitized stem borer in the experimental farms. Surveys showed more parasitization of stem borers in the minor season. Ashanti and Western regions recorded the highest diversity of parasitoids and Eastern Region recorded the most abundant parasitoids. From both experimental farm and survey results *Syzeuctus* sp. was the most important parasitoid species of maize stem borers. These results provide useful information on the biology and activities of parasitoids that can be exploited for managing maize stem borers.

Key words: Agro-ecology, *Busseola fusca*, lepidopterous, management, parasitoid, *Syzeuctus*.

INTRODUCTION

Maize (*Zea mays*) serves as the source of food for people worldwide. It is the principal staple crop produced and consumed by most farming households in Ghana. This crop is well adapted and grows in most of the ecological zones of Ghana including the Northern Savannah (Adu, et al., 2014) where maize growing seasons and sowing dates vary according to the agro-ecological zones.

Despite the numerous use of maize, the crop is affected by many pests including insect pests that cause low levels of yield. According to Ntambo et al. (2015), in Africa, lepidopterous stem borers are generally considered to be the most damaging insect pests of maize and sorghum. Kfir et al. (2002) observed that *Busseola fusca* is considered to be the most destructive lepidopteran pests

of maize in Africa. Estimates of crop losses vary greatly in different regions and agro-ecological zones. Yield losses of about 40% were reported in monocropped maize fields (Chabi-Olaye et al., 2005; Chabi-Olaye et al., 2008).

Currently, *B. fusca* presents a major constraint to the production of maize in areas where they are abundant (Paul-André et al., 2014). *B. fusca* larvae damage all plant parts of the cultivated crops they attack (Paul-André et al., 2014). In West Africa, it is of minor importance in the southern humid zones, but it is the dominant species on cultivated sorghum in the northern dry savannah zones (Harris and Nwanze, 1992).

The first instar larvae of most stem borer species initially feed on young leaf tissues, while older larvae tunnel into

the stem tissues and feed internally (Bosque-Pérez and Schulthess, 1998). However, after hatching, *Sesamia calamistis* bores directly into the stem (Bosque-Pérez and Schulthess, 1998) and cause considerable damage leading to yield and financial losses. The larval stage can last for 25 to 58 days and may have 6 to 8 instars where pupation takes 5 to 14 days after which adult moths emerge (Harris 1990; Maes 1998). Maize stem borers pupate close to the tunnel exit or even partly outside the stem (Smith et al. 1993) and this increases their accessibility to parasitoids (Ndemah et al. 2001).

In Ghana, the major insect pests of cultivated maize in the field are the lepidopterous stem borers in the family Noctuidae (Agrotidae) which include *Sesamia (nonagrioides) botanephaga* Tams and Bowden, *S. penniseti* Tams and Bowden, *S. calamistis* Hampson, *Busseola fusca* and the Pyralidae comprising *Eldana saccharina*, *Chilo* spp. and *Coniesta ignefusalis* Hampson (Maafo, 1975; Kumar and Sampson, 1982).

Considering the destructive nature of the lepidopterous stem borers on maize in Ghana in particular and Africa as a whole, it is clear that these pests have become nuisance to maize production. In some agro-ecological zones of the country it is common to see maize stems conspicuously damaged by the stem borers and as a result the plants die. This gives farmers much problem because they do not attain the anticipated yield from their maize fields due to the damage caused by the stem borer pests.

Though a number of researches have been undertaken on these pests in maize fields in Ghana (Maafo, 1975; Kumar and Sampson, 1982) much needs to be done to understand the level of infestation, borer prevalence and parasitization, especially in relation to regional agro-ecological distribution and abundance of the parasitoid species. Therefore, this study was to determine the infestation of Lepidopterous maize stem borer pests, as well as their agro-ecological and regional composition and distribution of their parasitoids in southern Ghana.

The study was guided by the following research questions:

1. What is the extent of infestation by stem borers in relation to the age of the maize plants in the experimental farms?
2. What is the rate of parasitism of larval stem borers at each age of the maize plants in experimental farms?
3. What are the parasitoid species and their host range in experimental farms?
4. What is the ecological and regional composition and distribution of lepidopterous stem borers in Southern Ghana?

MATERIALS AND METHODS

The study area

Ghana is made up of 10 administrative regions (Figure 1).

There are six agro-ecological zones defined on the basis of climate, reflected by the natural vegetation and influenced by the soils (AQUASTAT, 2005). The common agro-ecological zones in Ghana are rain forest with rainfall of 2,200 mm/year; deciduous forest with 1,500 mm/year rainfall; transition zone with 1,300 mm/year rainfall; Guinea Savannah having 1,100 mm/year rainfall; Sudan Savannah which has rainfall of 1,000 mm/year and Coastal savannah with 800 mm/year rainfall (AQUASTAT, 2005; Ministry of Food and Agriculture (MOFA), 2011). Rainfall distribution is bimodal in the forest, transitional and coastal zones, giving rise to major and minor growing seasons. In the remaining two agro-ecological zones, the unimodal rainfall distribution gives rise to only one growing season (AQUASTAT, 2005).

Experimental farms

Two farms were established, one in the University of Cape Coast farm and the other in the University Cafeteria. Cape Coast is along the Coastal savannah zone. The land was prepared by ploughing and harrowing. It was purely under rain-fed condition. A preliminary experimental farm was established from November 1995 to February, 1996. Two other experimental farms, one for the major (first) season (May to July) and the other for the minor (second) season (August to December) were established in 1996, in the University of Cape Coast farm. Another farm was established about 50 metres to the University Cafeteria from August to December.

The dimension of each of the farms was 30 m by 29 m. All plantings were done at a spacing of one metre between rows and 0.30 metres between hills within rows. Three seeds per hole were initially planted and thinned to two plants per hill after germination. The maize variety known as "Obatanpa" with maturity period of 105 to 120 days (Crop Research Institute (CRI), 1996) was obtained from commercial seed growers and sown. Weed control was done by hoeing. There was no weedicide or insecticide application.

Sampling for field infestation started three to four weeks after emergence of seedlings and continued until maturity of the maize. At pre-tasselling stages (stage 1 = 3 to 5 seed leaves; stage 2 = 6 to 8 seed leaves; stage 3 = 9 to 11 seed leaves and stage 4 = mid whorl or 12 leaves and above), the plants were sampled randomly for stem borer eggs, larvae, pupae and frass. This was done by choosing five one metre quadrats in the field. Plants that fell within each quadrat were examined for the presence or absence of stem borer eggs, larvae, pupae and frass (evidence of infestation).

Sampling for the percentage plant infestation was done weekly. For each week, 40 plants were examined randomly from the five quadrats to find out the level of plant infestation by stem borers in the field. Plants that had borer

Figure 1. map of Ghana showing the administrative regions.

Plate 1. Bottle depicting how the larvae were fed (X¼).

eggs, frass, borer holes, dead hearts and borer larvae or pupae were recorded as infested. On each sampling day all infested plants were uprooted. At most 15 plants out of the total infested ones were randomly selected and dissected for stem borer larvae and pupae. The percentage field infestation for each week was calculated using the following formula: total number of infested plants divided by 40 x 100. Figures obtained were used to plot graphs for each field covering the sampling time. New quadrates were chosen for the next sampling day.

All eggs collected were counted and each egg batch was kept in a petri-dish in the laboratory at room temperature. Daily observations were made for emergence of stem borer larvae or parasitoids. The stem borer larvae and pupae collected from the plants were identified and separated into the various species (*Sesamia* spp., *Eldana saccharina*, *Busseola fusca*, *Chilo aleniellus*). Each larva was put into 200 cm³ bottle. The pupae were also put into separate bottles and covered with fine-mesh net or cloth (Plate 1) for good aeration. The larvae were fed on maize stem pieces until parasitoids emerged or end of the development cycle of the insect pest. The parasitoids that emerged from each stem borer species were identified in the laboratory using keys provided by Polaszek (1994) and Polaszek and Lassale (1995). All dead larvae that did not produce any parasitoids were dissected to find out the presence of parasitoids and those found containing parasitoid pupal cases were considered parasitized. Number of larvae that produced parasitoids was recorded. The rate of parasitization for each stem borer species was weekly calculated using the formula: total number of borers from which parasitoids were collected divided by number of the borer species x 100. The calculated figures were presented in tables for interpretation.

Surveys

Two surveys, one in the major season and the other in the

minor season were carried out, each in 6 administrative regions of Ghana when the maize plants were at the tasselling and after-tasselling stages. Thus, (stage 5 = tassel or silking stage; stage 6 = cob or beans formation or milking stage; stage 7 = end of milking or soft dough stage; stage 8 = hard dough stage; stage 9 = matured maize stage; stage 10 = harvesting stage) using roadside fields approximately 20 to 30 km apart. Forty-six fields were sampled for the major season whilst 40 fields were sampled during the minor season survey. Attempts were made to sample the same fields in regions that were visited the second time during the minor season survey, but other fields were sampled when necessary. Field infestation by pests and parasitism were done as in the experimental farms.

Parasitoids that emerged from dead larvae and pupae for the different stem borer species were kept separately and containers were labeled to show the location from which they were collected. Each parasitoid was then identified in the laboratory up to the species level with reference to keys provided by Polaszek (1994) and Polaszek and Lassale (1995). The composition and distribution according to ecological zones and national administrative regions were determined.

Data analysis

Descriptive statistics mainly frequencies and percentage frequencies were used.

RESULTS AND DISCUSSION

In this study, the main stem borer species found infesting the maize plants in the experimental farms were *Sesamia* spp., *E. saccharina*, *B. fusca* and *C. aleniellus* (Strand) (Plate 2). These findings are similar to that of Kumar and Sampson (1982) who reported that the major insect pests of cultivated maize in the field in Ghana were lepidopterous stem borers, *E. saccharina*, *Chilo* spp. and *Coniesta ignefusalis*, *S. calamistis*, *S. botanephaga*, *S. penniseti* and *B. fusca*. Kwapong (1990) also made similar observations when he reported *C. aleniellus* attacking cultivated maize in the Central region of Ghana. Ntambo et al. (2015) also reported that out of the various insect pests attacking cereal crops in Africa, lepidopteran stem borers, *B. fusca* and *C. partellus* were by far the most injurious causing maize yield losses in many countries.

The average percentage plant infestation for the preliminary studies was 18.13% (Figure 2) while that of the major season was 15.29% (Figure 3). In the two cases the highest percentage plant infestation was recorded when the plants were 11 weeks old (30 and 43% respectively). Higher rates of infestation were recorded for the minor season studies. Averages of 51.5% (20 to 84.5%) and

Plate 2. Some stem borers collected from the experimental farms: (A) Larvae of *Sesamia* spp. in maize stem piece (X4); (B) Adult *Sesamia* moths (X4); (C) Larval *E. saccharina* in maize stem piece (arrowed) (X5); (D) Adult *E. saccharina* moth X4; (E) *Busseola fusca* larva in maize stem piece (X3).

Figure 2. Percentage infestation by stem borers in relation to age of plants during preliminary study in the University farm.

61.63% (18 to 86%) were recorded for work in the University Cafeteria and the farm respectively (Figures 4

and 5). The highest (84.5%) infestation was recorded when the plants were six weeks old at the University

Figure 3. Percentage infestation by stem borers in relation to age of the plants during major season study in the University farm.

Figure 4. Percentage infestation by stem borers in relation to age of plants during the minor season study at the University Cafeteria.

Cafeteria (Figure 4), while in the University farm the highest infestation (86%) was recorded when the plants were ten weeks old (Figure 5).

The study revealed that *Sesamia* spp. infestation of the maize plants began as early as three weeks when the seedlings were about 28 cm tall and remained till harvest. Similarly, *B. fusca* infested the plants about the same time as *Sesamia*. Shanower et al. (1991) and Kaufman (1983) reported that *Sesamia* spp. affect young maize when the maize seedlings are about 30 cm tall and increase until the pre-tasseling stage.

Infestation by *E. saccharina* occurs late in the development of the maize plant (Bosque-Perez and Mareck, 1991), especially from the seventh week of emergence of the crop. In this study, *E. saccharina* attack began when plants were 7 weeks old, 9 weeks old and 11 weeks old for minor season experiments, preliminary experiments and major season experiments respectively, which corroborates the reports of Bosque-Perez and Mareck (1991).

Ntambo et al. (2015) reported severe damage caused by the larvae of *B. fusca* and *C. partellus* that feed on the plant

Figure 5. Percentage infestation by stem borers in relation to age of plants during the minor season study in the University farm.

from early stage up to maturity causing a devastating impact on maize yield. The results of this study however indicated that infestation by *C. aleniellus* began when the maize plants were between 7 and 9 weeks old. The cumulative effects of early as well as the late infesting pests, coupled with overlapping generations of the stem borers might have contributed to the high infestations when the plants were 6 to 11 weeks old.

However, from 12 weeks onwards, the maize plants were matured and drying had set in. The crop at that stage was less attractive to adult female stem borers for oviposition. Furthermore, the plants had become less suitable for larval feeding. The adult stem borers might have also left the maize plants for new ones elsewhere or enter into their wild hosts which resulted into the reduction in number of the stem borers infesting the maize plant from the 12th week, hence the low infestation after the 11th week.

Tounou et al. (2013) reported that percentage of infested plants ranged from 0 to 72% in the first cropping season, and 33 to 95% in the second cropping season showing higher infestation in the second cropping season. Similar results were obtained in this study where generally, there were higher infestations by stem borers during the minor season experiments than the preliminary and major season experiments. This might be due to the fact that; the second season crop was exposed to a population of borers that have built up considerably from the previous season as reported by Ingram (1958).

Though egg scouts were made throughout the experimental period in the experimental farms, it was only during two occasions in the minor season that ten egg batches were collected. This could be due to the possibility

that eggs were laid at spots of the plant where they were difficult to locate as reported by Sampson and Kumar (1985). No egg parasitoids were found probably due to the scanty number of the eggs collected. This is at variance with the findings of Ntambo et al. (2015) who reported some parasitoids attacking eggs, larvae and pupae in their work. In the same study they observed *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) and *Platytenomous busseola* (Hymenoptera) as egg parasitoids that contribute to natural mortality of stem borers.

During the preliminary studies, a total of 105 larvae (*Sesamia* spp. = 47 and *E. saccharina* = 58) were collected while 108 larvae (*Sesamia* spp. = 55; *E. saccharina* = 20 and *C. aleniellus* = 33) were collected during the major season experiment from the maize plants. However, in all, no parasitism was recorded; as such no parasitoid emerged from any of the stem borers.

Results of stem borer larval parasitism in the minor season at the University Cafeteria are presented in Table 1. The total number of larvae of stem borers collected from maize stems was 299 (*Sesamia* spp. = 203; *E. saccharina* = 40; *B. fusca* = 49 and *C. aleniellus* = 7). For three week old plants, 2.70 and 20.00% parasitism were recorded on *Sesamia* spp. and *B. fusca* respectively. When the plants were ten and twelve weeks old, 22.22 and 10.00% of *E. saccharina* were parasitized respectively. *C. aleniellus* was not parasitized during the minor season experiment at the University Cafeteria. In the minor season at the Cafeteria, *Syzeuctus* sp. (Hymenoptera: Ichneumonidae) (Plate 3a) was reared from *E. saccharina* when the plants were ten and twelve weeks old (Table 1). An unidentified Chloropid (Plate 3b) was also reared from *Sesamia* sp. when the plants were three weeks old (Table 1).

Table 1. Number of stem borer larvae and rate of parasitism at each age of the maize plants at the University Cafeteria in the minor season.

Age of plant (in weeks)	<i>Sesamia</i> spp.		<i>Eldana saccharina</i>		<i>Busseola fusca</i>		<i>Chiloaleniellus</i>	
	No	% parasitism	No	% parasitism	No	% parasitism	No	% parasitism
3	37	2.70	0	-	10	20.0	0	-
4	14	0.0	0	-	5	0.0	0	-
6	69	0.0	0	-	0	-	0	-
7	34	0.0	16	0.0	26	0.0	3	0.0
9	29	0.0	0	-	1	0.0	0	-
10	7	0.0	9	22.22	2	0.0	2	0.0
12	11	0.0	10	10.0	4	0.0	1	0.0
14	2	0.0	5	0.0	1	0.0	1	0.0
Total	203	2.70	40	32.22	49	20.0	7	0.0

Plate 3. Parasitoids collected from borers/stem tunnels from experimental farms: (A) *Syzeuctus* sp. and pupa case (X5); (B) Chloropid (X8); (C) *Stenobracon* sp. and pupa case (6 written for identification) X6.

Chloropids such as *Epimadiza* sp., *Polyodaspis millii* Seguy (as *Oscinossoma millii*) and *polyodopsis risbeci* Seguy (as *Oscinossoma risbeci*) were listed by Risbec (1960) as parasitoids of stem borers in West Africa. However, Deeming (1972) observed that, although some Chloropid larvae were phytophagous and were often reared from shoots that had been previously damaged by shoot flies of the genus *Atherigona*, in some cases might possibly be predaceous, especially on other dipterous larvae. In other cases, they were secondarily feeding as scavengers on decaying tissues (Deeming, 1972). There are no true records of true parasitism by Chloropids. In this study, the Chloropid specimen emerged from *Sesamia* larva. This suggests further that it could be a parasitoid.

A total of 387 larvae including 262 *Sesamia* spp; 75 *E. saccharina*; 47 *B. fusca* and 3 *C. aleniellus* were collected from maize stems during minor season experiment in the University farm (Table 2). Out of these 5.88 and 25% of *E. saccharina* were parasitized when the plants were thirteen and fifteen weeks old respectively. *Stenobracon* sp. (Hymenoptera: Braconidae (Plate 3c and Table 3) was the parasitoid collected from the University farm in the minor season. Its pupa was collected from stem borer tunnel in the maize plant.

Tounou et al. (2013) reported that out of the total borer

species recovered in their study the most abundant was *S. calamistis* (76.02%), followed by *B. fusca* (21.71%) and then *E. saccharina* (2.27%). In this study also, the stem borer with the highest number of larvae collected from the plants in the experimental farms was *S. calamistis* (720), followed by *E. saccharina* (233), *B. fusca* (145) and *C. aleniellus* (50). These findings confirmed the reports of Tounou et al. (2013). Therefore, *S. calamistis* is the most important stem borer pest on maize from the experimental area. This does not mean that the other three species are not important, especially, *E. saccharina* and *B. fusca*. They all need attention for good management measures to be in place so that maize farmers can derive joy from their toil. *E. saccharina* was the most parasitized stem borer by parasitoids in the University farm and the Cafeteria over the minor season.

The results also showed that *syzeuctus* sp. was the commonest parasitoid attacking stem borers in the experimental farms. On the contrary, Mohyuddin and Greathead (1970) as well as Harris (1998) reported the Tachinid fly, *Sturmiopsis parasitica* to be the most important parasitoid in West and East Africa parasitizing number of stem borer species.

S. parasitica (Plate 4a) was collected from the larvae of *E. saccharina*, *B. fusca*, *Sesamia* spp., and *E. saccharina*.

Table 2. Number of stem borer larvae and rate of parasitism at each age of the maize plant in the University farm in the minor season.

Age of plant (in weeks)	<i>Sesamia</i> spp.		<i>Eldana saccharina</i>		<i>Busseola fusca</i>		<i>Chiloale niellus</i>	
	No	% parasitism	No	% parasitism	No	% parasitism	No	% parasitism
4	34	0.0	0	-	0	-	0	-
5	80	0.0	0	-	3	0.0	0	-
6	51	0.0	0	-	6	0.0	0	-
7	46	0.0	3	0.0	11	0.0	0	-
8	22	0.0	4	0.0	8	0.0	0	-
9	9	0.0	3	0.0	2	0.0	0	-
10	8	0.0	9	0.0	6	0.0	0	-
11	3	0.0	13	0.0	5	0.0	0	-
12	2	0.0	13	0.0	1	0.0	0	-
13	7	0.0	17	5.88	3	0.0	1	0.0
14	0	-	9	0.0	2	0.0	0	-
15	0	-	4	25.0	0	-	2	0.0
Total	262	0.0	75	30.88	47	0.0	3	0.0

Table 3. Parasitoid species and their hosts during the minor season of 1996 in experimental farms.

Age of plants (in weeks)	Site	Species	Stem borer host	Host stage	Rate of parasitism per sampling date %)
3	Cafeteria	Unidentified Chloropid	<i>Sesamia</i> spp.	L	2.70
9	Cafeteria	<i>Syzeuctus</i> sp.	<i>E. saccharina</i>	L	22.22
10	Cafeteria	<i>Syzeuctus</i> sp.	<i>E. saccharina</i>	L	10.0
11	Farm	<i>Stenobracon</i> * sp	-	-	-

L = Larva, *Collected from borer tunnel.

Syzeuctus sp. (Plate 3a) was also collected from larval *E. saccharina*, and *B. fusca*; *Enicospilus* sp. (Plate 4b) from larval *B. fusca*; *Pediobus furvus* (Plate 4c) was collected from *B. fusca* pupae; unidentified Muscid (Plate 4d), unidentified Phorid and unidentified Diptera (Plate 4e) from *B. fusca* larvae; *Dolichogenidea* sp. (Plate 4f) and *Aphanogmus fijiensis* (Plate 4g) were collected from stem borer tunnels. These findings corroborate that of Harris (1998) which reported *S. parasitica* as an important larval parasitoid of gramineous stem borers in Africa. In Ethiopia the Braconid, *Dolichogenidea fuscivora* was found to be the major larval parasitoids of *B. fusca* with parasitism of 71% during the dry season and 18% in the wet season (CIMMYT, 2011). *Pediobus furvus* is a gregarious primary pupal parasitoid of *B. fusca* in maize and sorghum in Ethiopia. According to CIMMYT (2011) *Stenobracon rufus* is a solitary pupal parasitoid of *B. fusca* in Ethiopia with parasitization rate of 14%. Studies by Tefera (2004) in Ghana reported that the exotic species *Trichogramma* have high fecundity and helped to control stem borers, including *B. fusca*. In Southern Benin, *Telenomus busseola* (Ghana) (Hymenoptera: Sclionidae) and *Telenomus isis* (Polaszek) (Hymenoptera: Sclionidae) are the most important natural control factors of stem borers, including *B. fusca* on maize (Tefera, 2004).

Mailafiya et al. (2011) reported that in maize, plant infestation, stem borer density, larval parasitism and total parasitism were significantly different amongst localities. Similarly, Chinwada and Overholt (2001) observed many natural enemies associated with maize stem borers on the Highveld region and outside. These suggest the distribution and abundance of the parasitoids according to ecological zones and regions.

During the surveys, *Syzeuctus* sp. was collected from 5 regions (Ashanti, Greater Accra, Eastern, Western and Central Regions); *S. parasitica* was collected from 3 regions (Western, Eastern and Ashanti regions), *Dolichogenidea* sp. from two regions (Western and Central regions); *A. fijiensis* from two regions (Eastern and Western Regions); *Pediobus furvus*, a pupal parasitoid from two regions (Ashanti and BrongAhafo regions) and each of the three unidentified parasitoid species was collected from one region each (Muscidae from Western Region, unidentified Diptera from Greater Accra Region and the Phoridae from Ashanti Region) (Table 4). Throughout the survey, no parasitoid was collected from Volta Region. However, parasitoid pupal cases were removed from dead larvae indicating parasitism in some fields in the Region.

Taking the data in Table 4 into consideration, Ashanti

Plate 4. Parasitoids collected during the survey: (a) *Sturmiopsis parasitica* (X5); (b) *Enicospilus (Ophion)* sp. and pupa case (X4); (c) *Pediobus furvus* (mass) X10; (d) Unidentified Muscid (X5); (e) An unidentified Diptera (X5); (f) *Dolichogenidea* sp (X10); (g) *A. fijiensis* and pupa case (cocoon) X10.

and Western regions had the highest diversity of parasitoids species (5 different types each) followed by Eastern and Central regions (4 different types each), Greater Accra Region (2 different types) and BrongAhafo Region (1 type). However, Eastern Region was the Region with the most abundant parasitoids (14 parasitoids) followed by Ashanti Region (8 parasitoids), Western Region (5 parasitoids), Central Region (4 parasitoids), Greater Accra (2 parasitoids) and Brong Ahafo Region (1 parasitoid) as in Table 4. The differences in regional diversity and abundance of the parasitoids may be attributed to different geographical and agro-ecological

conditions in the various regions. On large scale, Ashanti, Western and Eastern regions of Ghana are dominated by forest conditions, suggesting that such agro-ecological zone might have encouraged the abundance and diversity of the parasitoids in the three regions. This may be useful to maize farmers in the three regions because it may cause increased yield of maize and thus boosting the income of the farmers.

Syzeuctus sp. was the parasitoid species with the highest number of regional distribution (4 regions), followed by *S. parasitica* and *Enicospilus* sp. (3 regions each), *Dolichogenidea* sp. and *Pediobusfurvus* (2 regions

Table 4. Regional distribution of larval and pupal parasitoids.

Season	Parasitoid species	Number of fields per region					
		BA	Ashanti	GA	Western	Central	Eastern
Major	<i>Sturmiopsisparasitica</i>	-	1	-	-	-	-
	<i>Syzeuctus</i> sp.	-	-	1	-	-	-
	<i>Pediobusfurvus</i>	1	-	-	-	-	-
	Unidentified Muscid	-	-	-	1	-	-
	Unidentified Diptera	-	-	1	-	-	-
Minor	<i>Sturmiopsisparasitica</i>	-	1	-	-	1	7
	<i>Syzeuctus</i> sp.	-	3	-	1	1	4
	<i>Dolichogenidia</i> sp.	-	-	-	1	2	-
	<i>Aphanogmusfijiensis</i>	-	--	-	1	-	1
	<i>Enicospilus</i> sp.	-	1	-	1	-	1
	<i>Pediobusfurvus</i>	-	1	-	-	-	-
	Unidentified Phorid	-	1	-	-	-	-

BA = BrongAhafo Region; GA = Greater Accra Region.

Table 5. Ecological distribution of larval parasitoids of lepidopterous maize stem borers in Ghana - 1996.

Season	Parasitoid species	Percentage number in each ecological zone	
		Transition forest	Coastal Savannah
Major	<i>Sturmiopsisparasitica</i>	20.0	0.0
	<i>Syzeuctus</i> sp.	40.0	0.0
	Unidentified muscid	0.0	20.0
	Unidentified dipteral	0.0	20.0
	Total	60	40
Minor		Transition forest	Forest
	<i>Sturmiopsisparasitica</i>	0.0	28.57
	<i>Syzeuctus</i> sp.	2.38	47.62
	<i>Dolichogenidia</i> sp.	4.76	2.38
	<i>Aphanogmusfijiensis</i>	2.38	2.38
	<i>Enicospilus</i> sp.	2.38	4.76
	Unidentified phorid	2.38	0.0
		14.28	85.71

each), *A. fijiensis*, unidentified Muscid, Diptera and Phorid (1 region each). In terms of number of fields also, *Syzeuctus* sp. was the parasitoid with the widest distribution (Table 4). This is surprising because thorough literature search on parasitoids of lepidopterous maize stem borers shows high level of paucity of information on *Syzeuctus* sp. However, findings from this study suggest that *Syzeuctus* sp. is a prominent stem borer control agent in Ghana.

During the major season survey, only five parasitoids emerged from stem borers. These five parasitoids were from two ecological zones, namely, transition forest and coastal savannah (Table 5). Sixty per cent of the

parasitoids emerged from borers in the transition forest zones. Forty percent of this was *Syzeuctus* sp. whilst 20 was *S. parasitica*. None of the unidentified species was collected from the transition forest but rather from the Coastal savannah. Twenty percent of the parasitoids from the Coastal savannah were unidentified muscids and another 20% were unidentified diptera.

During the minor season, 42 parasitoids emerged from stem borers. Out of this 85.71% were obtained from the forest zone. Out of the 85.57%, 47.62% was *Syzeuctus* sp., 28.57% was *Sturmiopsis parasitica* and less than 5% of each of the others emerged from the stem borers in the forest zone. The remaining 14.28% of the parasitoids

emerged from stem borers in the transition forest. It is generally clear that very low percentage of parasitoids was recorded for borers in the transition forest (Table 5).

The relatively high number of *Syzeuctus* sp. and *S. parasitica* in the forest zones could be as a result of high relative humidity (RH) (Sampson and Kumar, 1986) and shade in the forest zones. This could explain why in the heavy rains of the major season where humidity was high, the parasitoids were found in the savannah areas compared to the minor season when RH was relatively low.

Human activities in the various ecological zones could lead to destruction of the ecosystem that would attract or affect the parasitoids. Similarly, bush fires can kill the parasitoids which are less effective fliers. So, the very poor performance of the parasitoids in other ecological zones (coastal savannah and grassland savannah) may also be attributed to bush fires and constant human activities in these ecological zones.

Conclusions and recommendations

The stem borer pests infesting maize plants in the experimental farms are *Sesamia* spp., *E. saccharina*, *B. fusca* and *C. aleniellus*. Also, *S. calamistis* proved to be the most significant borer infesting maize plants around the experimental areas. The findings show that in the experimental areas in Cape Coast, high numbers of stem borers could be obtained in the minor season compared to the major season. Low infestations can also be obtained when the maize plants are matured above 11 weeks old.

The present study has established that there are parasitoids in the experimental areas controlling stem borer species. Meanwhile, low rates of parasitism were recorded in the experimental farms suggesting that more thorough research needs to be conducted in the area to ascertain the true nature of stem borer parasitism in the area. Notwithstanding, *E. saccharina* appear to be the most parasitized stem borer in the University farm and the Cafeteria over the minor season. This suggests that if conditions are created in the research area to protect parasitoids, stem borers may be controlled, especially *E. saccharina*.

It can also be concluded that in southern Ghana, Ashanti and Western regions have higher diversity of the parasitoids whereas Eastern Region harbours them most. Therefore, efforts should be made to study the factors in the three regions that favour the parasitoids in order to harness their multiplication to control the borer complex. *Syzeuctus* sp. with the highest regional distribution (4 regions), suggests that it is of prominence and needs to be exploited for controlling maize stem borers in Ghana. It is further evident that forest zones are the two important agro-ecological zones having the highest number of parasitoids.

Since the effects of stem borers on the maize plants can be felt most when plants are less than 11 weeks old, agricultural officers need to educate farmers to initiate control measures in the earlier weeks of the plants. Once there are parasitoids in the wild controlling the stem borers, agricultural officers should team up with research scientists to know more about these parasitoids and appropriately help farmers. In the meantime, farmers should desist from indiscriminate synthetic insecticide control measures that can exterminate the parasitoids. Going forward, research scientists should develop the mechanism of mass rearing of *S. parasitica*, *Syzeuctus* sp., *Enicospilus* sp., *P. furvus*, *Dolichogenidea* sp., *A. fijiensis* and other parasitoids that coexist with the stem borer complex in the research area and use the best strategies to release them in their populations to control stem borers.

Agricultural officers should study the factors responsible for relative abundance and diversity of borer parasitoids in Ashanti, Western and Eastern regions as well as in the forest zones so that the appropriate steps can be taken to educate farmers in the areas to protect the parasitoids for effective maize stem borer control.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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