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Maize stemborers distribution, their natural enemies and farmers' perception on climate change and stemborers in southern Togo

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ABSTRACT
Objective: The objectives of this study were to (i) assess the importance of the different stemborer species and their associated natural enemies on maize, and (ii) evaluate cereal producers' perception on the effect of the current climate variability, on the maize stem and ear borers and their mitigation strategies to alleviate the impact of climate change on their cropping system.
Methodology and results: Surveys were conducted in 2012 during the long cropping season lasting from March to July and the short one from September to October in southern Togo, to determine geographic distribution, relative importance of lepidopterous stemborers and their parasitism by natural enemies on maize. A questionnaire was introduced to evaluate cereal farmers' perception of climate change and its effects on maize stem and ear borers. Of the total borer species recovered, the most abundant was *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) (76.02%), followed by *Busseola fusca* Füller (Lepidoptera: Noctuidae) (21.71%) and then *Eldana saccharina* Walker (Lepidoptera: Pyralidae) (2.27%). The borers' abundance was affected by the agroecological zones and cropping seasons. *Eldana saccharina* was found in Zio and Yoto in coastal zone whereas *B. fusca* was recorded only in Yoto. *Sesamia calamistis* was the only species found in all the surveyed agroecological zones (III, IV and V). Fields were infested by all borer species at 34.4% and 83.3% in the long and short cropping seasons respectively. The percentage of infested plants ranged from 0 to 72% in the first cropping season, and 33 to 95% in the second cropping season. The borer densities varied from 0 to 3 larvae per plant in the long cropping season and 1 to 8 larvae per plant in the short cropping season. The egg parasitoid *Telenomus busseolae* Gahan (Hymenoptera: Scelionidae) was identified as the most important with a high natural parasitism rate of 82% on *S. calamistis*. The main larval parasitoid recorded was *Sturmiopsis parasitica* Curan (Diptera: Tachnidae) with mean parasitism ranged of between 0 and 8%. *Beauveria bassiana* (Bals.) Vuill. (Deuteromycotina: Hyphomycetes) infection rate vary from 0 to 5%.of borers' larvae. Data on farmer's perception showed that all producers recognized stem and ear borers and their damages. However, they perceive climate change effects differently by high temperatures, rains irregularity, floods, strong winds and to a lesser extent the proliferation of new pests such as termites (Isoptera), *Zonocerus variegatus* (L) (Orthoptera: Pyrgomorphidae) and *Cicadulina* spp. (Hemiptera: Cicadellidae). Adaptation strategies practiced

by farmers are the choice of early maturing crop varieties, the spacing of sowing period and the crop diversification.

Conclusion and application of funding: From these results, we conclude that *S. calamistis*, *E. saccharina,* and *B. fusca* and their associated natural enemies are present in all agroecological zones of southern Togo. These findings could serve as baseline data for further studies.

Key words: Climate change, ear borers, incidence, maize, parasitism, severity, stem borers.

INTRODUCTION

Cereals, especially maize, represent the most important food crops grown in most of sub-Sahara Africa (SSA), and has often been the focus of development policies. One of the challenges cereal farmers faced is the control of stem and ear borers' infestations which causes losses of up to about 10-70% in areas with severe borer problems (Bosque-Pérez and Mareck 1991; Cardwell *et al.*, 1997; Sétamou *et al.*, 2000) . Research conducted in most West African countries has shown that lepidopteran stem and ear borers are among the most economically important pests of maize. (see overview by Polaszek, 1998). The most commonly reported species are the pyralid *Eldana saccharina* Walker (Lepidoptera: Pyralidae), the noctuid *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae), and the pyralid ear borer *Mussidia nigrivenella* Ragonot (Lepidoptera: Pyralidae) found in west of Dahomey gap, and in countries such as Ghana ,Nigeria and Côte d'Ivoire (Endrody-Younga, 1968; Bosque-Pérez and Mareck, 1990; Shanower *et al.*, 1991; Gounou *et al.*, 1994; Schulthess *et al.*, 1997; Bosque-Pérez and Schulthess, 1998; Sétamou *et al.*, 2000; Buadu *et al.*, 2002). In the lowland tropics of West, East and southern Africa, the noctuid *Busseola fusca* Füller (Lepidoptera: Noctuidae) is generally of low importance but in Central African countries like Cameroon it is the predominant species across all eco-zones and altitudes (Moyal, 1988; Cardwell *et al.*, 1997; Ndemah *et al.*, 2001a). In Togo, detailed studies on cereal stem and ear borers are extremely limited. Since the surveys conducted by Silvie (1993) in restricted cereal and cotton-cropping areas, no large-scale quantitative surveys have been undertaken in the country. The abundance and distribution of stem-borer pests and their main natural enemies are expected to vary considerably with the current climate variability (Parmesan *et al.*, 1999; Batalden *et al.*, 2007; Trnka *et al.*, 2007). The objectives of this study were to (i) assess the relative importance of the different stem borer species and their associated natural enemies on maize, and (ii) evaluate cereal producers' perception on the effect of the current climate variability, on the maize stem and ear borers and on their mitigation strategies to alleviate the impact of climate change on their cropping system. This study therefore provides the baseline data and undertake analyses that will allow for assessment of changes of pest distributions and associated yield losses in maize in Togo.

MATERIALS AND METHODS

Survey sites: Surveys were conducted during the long and short cropping seasons of 2012 to evaluate the infestation levels of the different stemborer species and their associated natural enemies on maize crops in southern Togo. The southern Togo encompass three agroecological zones (AEZ) (Figure 1) and includes central plains characterized by dry forests and guinea savannah creating with grasses a mosaic (Zone III), southern part of the highlands covered by secondary forests (Zone IV) and scattered semi-deciduous forests with important lagoon depressions and associate mangroves (Zone V) (Akpagana, 1992; Kokou,. 1998; Afidégnon 1999). Rainfall levels in the three AEZs are highly variable in timing, duration and intensity. Most of the localities surveyed have a bimodal rainfall distribution that allow for two cropping seasons, the first lasting between March and July (referred to as the long cropping season , LR) and the second from September to October (short cropping season, SR). However these rainfall patterns tend to become monomodal with the disappearance of the dry spell in August (DRP, 1985).

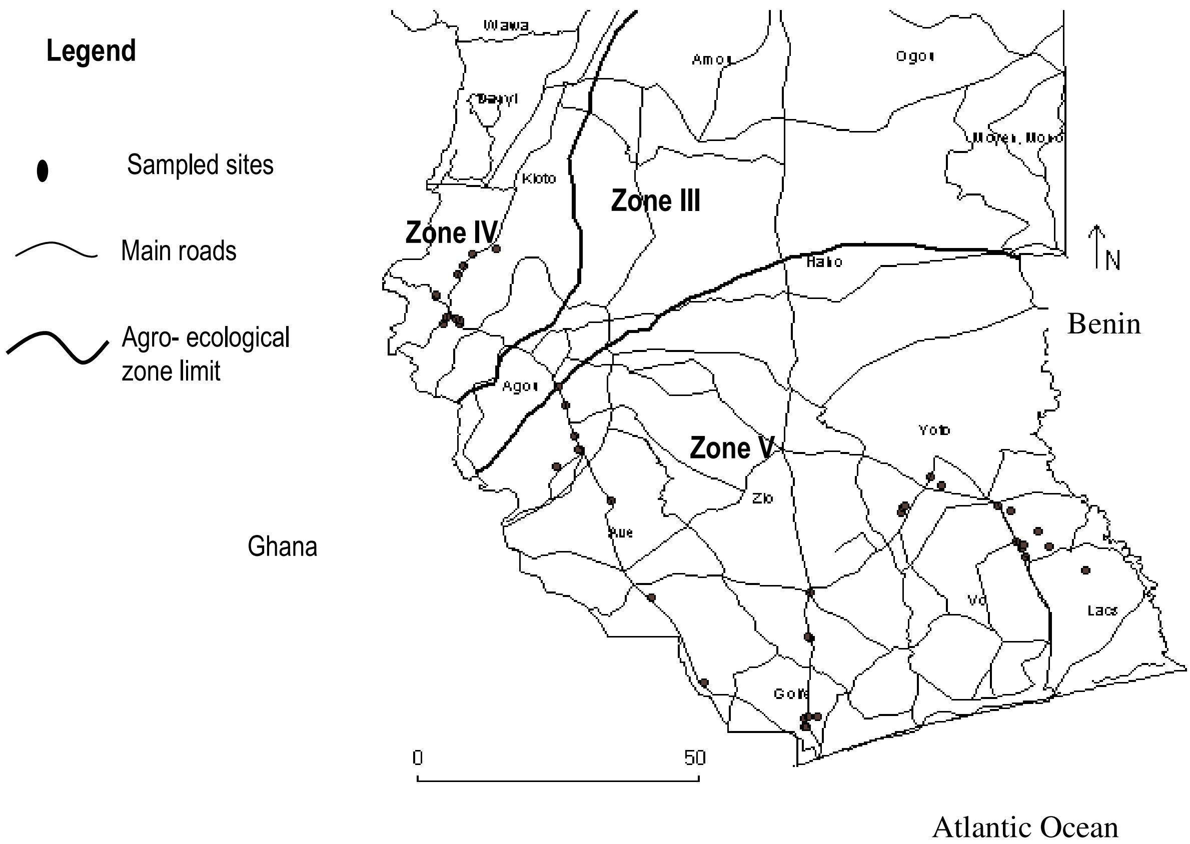


Figure 1: Agroecological zones (AEZs) and survey sites sampled in southern Togo

Sampling procedure: Destructive sampling was conducted two times, at vegetative and reproductive stage (tasseling and soft dough stages) during each cropping season. In each AEZ, evaluations were conducted in two to six districts where maize is the main cereal crop. Sampling sites were selected at 5-10 km intervals along major roads in the selected districts and each site was geo-referenced by global positioning system (GPS) (Garmin map 62stc). A total of 15-20 small scale farmers' maize fields each measuring approximately 0.5 – 1.5 ha were sampled per AEZ. During both seasonal surveys, a complex of overlapping maize growth stages was observed probably because of different sowing dates due to climate variability. Each field sampled was divided in four quadrants and from each, ten plants were randomly selected, uprooted and check for stem borer's eggs for plant at whorl stage. The number of plants with egg batches and the number of eggs per batch were recorded. Egg batches' counting was done by direct observation of oviposition site of each stemborer's species. For plant at tasseling and soft dough stages the number of plants showing borer damage was recorded, and each maize plant was dissected and the larvae and pupae of the same borer species per plant were counted and placed together in wide-mouthed jars. Larvae were maintained on a diet of young succulent stem of maize, and reared until borer pupation or parasitoid emergence. The egg batches were kept individually in plastic vial in the laboratory at room temperature until borer's larval or parasitoid emergence. Parasitoids were counted per egg mass. Borer pupae and parasitoid cocoons or pupae were kept individually in small round plastic containers for parasitoid or adult moth emergence. Parasitoid specimens were preserved in 70% alcohol for identification. For egg parasitoid, three kinds of parasitization were calculated by: (a) Mean egg parasitism per field calculated as percentage of eggs parasitized within an individual egg batch, averaged over all egg batches found in the field; (b) the percentage of egg batches with parasitoids per field referred to as "discovery" efficiency by Bin and Vinson (1991) which provides information about the searching ability of a parasitoid; and (c) the percentage of eggs parasitized within discovered egg batches, averaged over all egg batches per field termed "parasitism efficiency" by Bin and Vinson (1991). Dead larvae were placed individually in small round plastic containers (150 x 20 mm^2) and kept in the laboratory for parasitoid emergence. In the case fungal infection was suspected, mycosis tests were performed. Dead insects were therefore surface sterilized in 70% ethanol, dried and incubated on moist filter paper inside sterile Petri dishes (150 x 20 mm^2) for 5 days to confirm fungal infection. The mycosis tests were conducted at the Ecole Supérieure d'Agronomie, Université de Lomé, Togo. Adult moths were sent to both Institut de Recherche pour le Développement (IRD) and International Centre of Insect Physiology and Ecology (ICIPE) Kenya for species identification. Parasitoids emerging from borer larvae and pupae were counted according to species and preserved as indicated above for later identification by the taxonomists at the Insect Museum of the International Institute of Tropical Agriculture (IITA) in Cotonou, Benin.

On-station field experiment: Two field trials were installed in farmer's field in Yoto district in AEZ V during LR and SR seasons of 2012 to assess the population dynamics of maize stem and cob borers in relation to rainfall pattern. Yoto district was chosen because during previous observations, the presence of many species of stemborer was noticed. For borer species counts, destructive samplings were done biweekly throughout the year, depending on the availability of the maize plants. Samplings of maize began from the whorl stage and covered the entire crop cycle. At harvest, cob borers and stem borers found in the ear were collected. For computing these borers, 10 ears were sampled. On each ear, 100 damaged grains were removed, counted and weighed after removing borer pupae and grain dust by using fine brush. On the same ear, same numbers of healthy grains were selected closely to the damaged grains and weighed. The following formula was used to calculate grain loss:

P_g (%) = (P_h – P_d) x 100 / P_s
where P_g = percentage grain loss
P_h = mean weight of healthy grains and P_d = mean weight of damaged grains.

Survey questionnaire: In each village surveyed for stem borers' infestation, ten farmers were randomly selected and primary data were collected through individual interview method using pre-tested and well structured designed questionnaire. Data include the importance of maize in the farmer's agricultural income, farmer's knowledge on maize stem and ear borers, on their damage and farmer's perception of climate change and mitigation strategies.

Statistical analysis: Differences in plant infestation and pest abundance by season across AEZs were analyzed by analysis of variance (ANOVA) using STATISTICA software. Counts of borer variables were log(x+1) and percentage data were arcsine square root transformed before analysis. Means were separated with Student-Newman-Keuls (SNK) at p = 0.05. Coordinates recorded using GPS were used in a Geographic Information System (GIS) for mapping the survey sites and distribution of stemborers' species in the different AEZs. Using species diversity, borer infestation rates and borer density per plant, two plant health maps were established with DIVA 7.5.0 software. Descriptive statistics were used to analyze farmers' perception on climate change and maize insects.

RESULTS

Species richness, relative abundance and distribution across agroecological zones: Of 76 fields sampled, 42% were found infested with stem borers. Field infestation varied with the seasons, 34.4% in long cropping season and 88.3% in the short cropping season. Three lepidopteran stem borer species (*Sesamia calamistis*, *Busseola fusca*, and *Eldana. saccharina*) belonging to the families Noctuidae and Pyralidae were recorded. *Sesamia calamistis* was the most abundant borer with 76.02% of all species while *B. fusca* represented 21.71% and *E. saccharina* counting for 2.27%. *Eldana saccharina* and *B. fusca* were occasionally encountered only in AEZ V counting respectively for 15.30% and 13.00%. *Sesamia calamistis* was found in all agroecological zones surveyed representing 100% in AEZ III and AEZ IV and 71.70% in AEZ V (Figure 2). In AEZ V where the three species were represented, they were found in Yoto and Zio districts (Table 1). According to seasonal abundance *S. calamistis* was the only species found in AEZ III and AEZ IV during the two cropping seasons. In AEZ V, *S. calamistis* represents 64.62%, *E. saccharina* 19.12% and *B. fusca* 16, 25% during the LR whereas in SR, *S. calamistis* represent 100%.

Table 1: Mean number of borers per plant (± SE) according to species, relative abundance (%) and percentage of infested plants at tasseling of maize in three agroecological zones (AEZ) in southern Togo during different seasons of 2012

AEZ	Districts	% infested plants	Borer density	Relative abundance (%)		
				S. calamistis	*E. saccharina*	*B. fusca*
Long cropping season						
III	Agou	44.91 ± 5.34b	1.83 ± 0.69b	100.00 ± 0.00a	0	0
IV	Kloto	33.65 ± 7.58c	1.26 ± 0.67c	100.00 ± 0.00a	0	0
	Ave	72.03 ± 12.58a	3.64 ± 0.89a	100.00 ± 0.00a	0	0
	Lacs/Bas-Mono	0.41 ± 0.36g	0.04 ± 0.01e	100.00 ± 0.00a	0	0
V	Golfe	2.97 ± 2.52f	0.12 ± 0.11d	100.00 ± 0.00a	0	0
	Vo	25.00 ± 11.90d	1.10 ± 0.39c	100.00 ± 0.00a	0	0
	Yoto	53.34 ± 12.42b	1.93 ± 0.60b	17.86 ± 9.64c	30.19 ± 6.83b	51.95 ± 17.87a
	Zio	18.64 ± 11.25e	0.59 ± 0.35d	40.64 ± 4.17b	46.30 ± 5.07a	13.06 ± 2.54b
Short cropping season						
I II	Agou	72.67 ± 6.37a	5.60 ± 0.56a	100.00 ± 0.00a	0	0
IV	Kloto	64.36 ± 2.79b	4.96 ± 0.33a	100.00 ± 0.00a	0	0
V	Ave	68.43 ± 2.35b	5.84 ± 0.44a	100.00 ± 0.00a	0	0

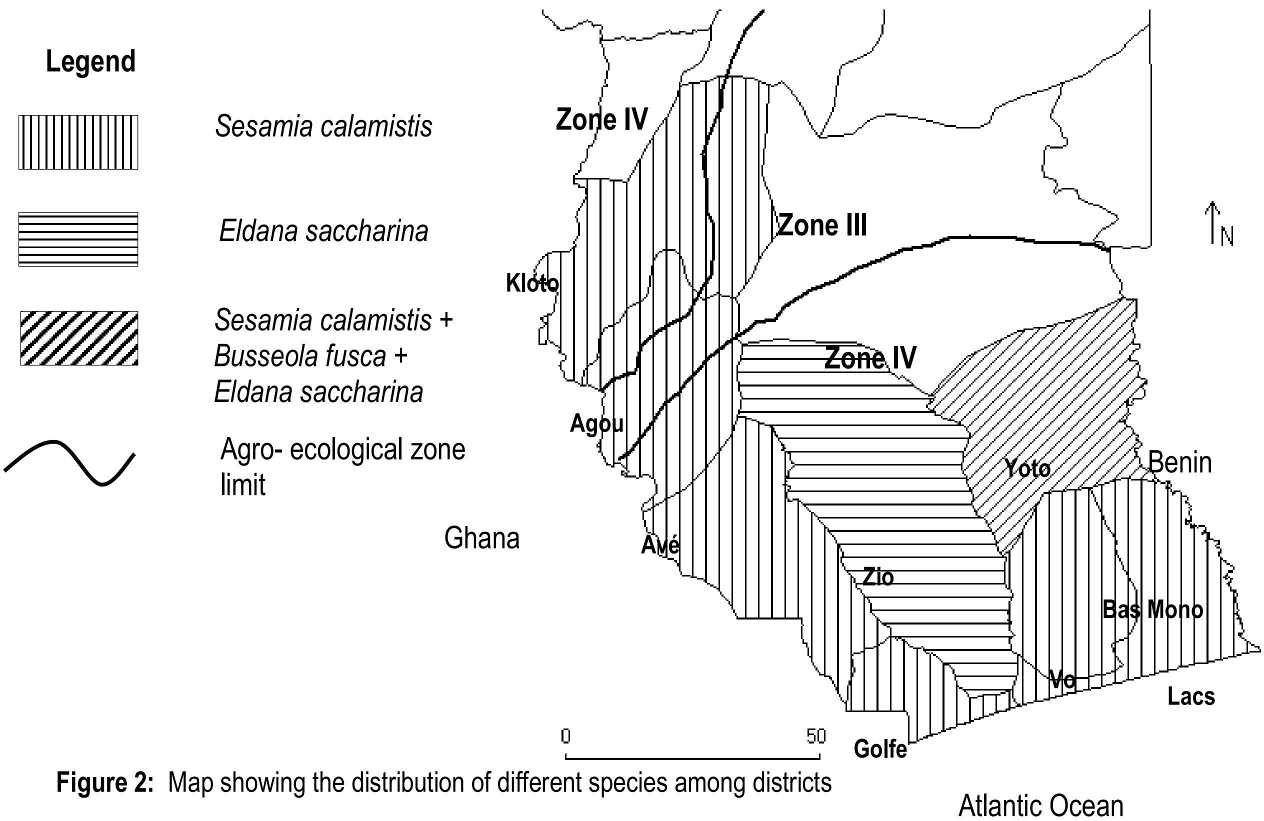


Figure 2: Map showing the distribution of different species among districts

Season variability of stem borer incidence: Borer densities varied between 0.04 ± 0.01 and 3.64 ± 0.89 larvae per plant in all AEZ during the long cropping season and between 4.96 ± 0.33 and 5.84 ± 0.44 larvae per plant during the short cropping season (Table 1). Stem borer incidence expressed as percentage of infested plants varies significantly between the AEZ (F = 6.49; P = 0.013; d.f. = 2). It was more prevalent in the southwestern of the Plateau region (zone IV) than in the other zones (Figure 3). At district level, borer incidence varied significantly from one district to another (F = 6.545; P< 0.0001; d.f. = 7) with the highest incidence in Avé, Agou, Yoto and Kloto districts. The Ave district recorded 3.6 larvae per plants (Table 1). Across AEZs, *S. calamistis* plant/field infestation and density varied with the season and were significantly higher in SR cropping (83.82% and 8.50 larvae/plant) than in the LR cropping (53.18% and 2.42 larvae/plant) seasons (F= 39.78; P< 0.0001; d.f. = 1 for incidence and F= 55.636 P< 0.0001; d.f. = 1 for borer density). Eggs were rare during the LR cropping season and the majority of the eggs were collected during the SR cropping season. In locations where eggs were collected, mean numbers of egg batch were between 1.0 ± 0.0 and 1.27 ± 0.46 batch/plant and the number of eggs per batch varied between 16.14 ± 3.63 and 22.20 ± 7.05 (Table 2).

Table 2: Mean number of *Sesamia calamistis* egg batches per plant, eggs per batch, discovery efficiency and percentage egg parasitism due to *Telenomus busseolae* at the whorl stage of maize in three localities in southern Togo during the short cropping season of 2012

Localities	Egg batches/plant	Egg/batch	Parasitism/field (%)	Discovery efficiency (%)
Gadjagan	1.00 ± 0.00b	17.20 ± 3.44b	60.00 ± 0.44b	80.03 ± 1.69a
Kévé	1.27 ± 0.46a	22.20 ± 7.05a	66.67± 0.44a	79.02 ±1.46a
Tovégan	1.00 ± 0.00b	16.14 ± 3.63b	57.14 ±0.46c	82.03 ±1.29a

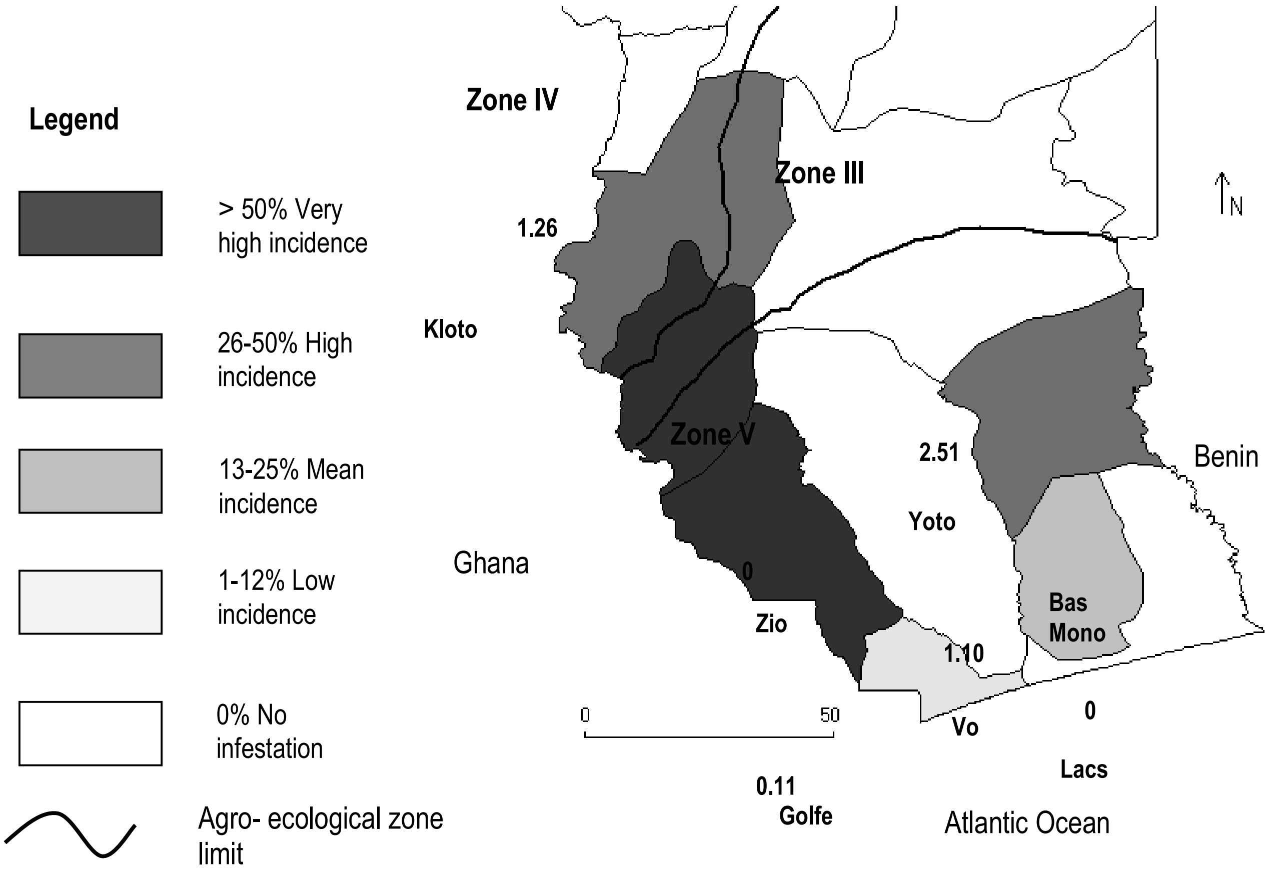


Figure 3: Map showing the incidence of *Sesamia calamistis* coupled with severity indices during the long cropping season of 2012

On-station field experiment: stem and ear borers' population dynamics: The population dynamics of various stemborers' species in on-station experiment is presented in Figure 4. Peaks in *B. fusca* larval density occurred around July-September, coinciding with maize growing periods while peaks of *S. calamistis* and *E. saccharina* were observed in August and September. With onset of the dry season, larval densities decreased to very low levels. *Busseola fusca* was the dominant species followed by *S. calamistis*. From soft dough stage to harvest, ear borers *Mussidia nigrivenella* and *Thaumatotibia leucotreta* Meyrick (Lepidoptera: Tortricidae) were found in the ear with *M. nigrivenella* the dominant species representing 83.3% of all ear borers. Other species commonly stem borers such *S. calamistis* and *E. saccharina* both account for 11.1%. The percent grain loss in the field planted maize due to feeding damage of ear borers was estimated to 31.3%.

Stem borer parasitism and infection: Parasitized eggs were found during the short cropping season in all the infested fields and belonging to the zones or districts where only *S. calamistis* occurred; the parasitoid species that emerged from those eggs was *Telenomus busseolae* Gahan (Hymenoptera: Scelionidae). The parasitism rates of *T. busseolae* recorded in field as well as mean discovery efficiencies are presented in Table 2. *Sturmiopsis parasitica* Curan (Diptera: Tachinidae) was the common larval parasitoid recovered with a parasitism rate ranging from 3 to 8% during the first cropping season according to districts (Figure 4). In the short cropping season, *S. parasitica* parasitism rates were 4.78%, 5.17% and 5.18% in Avé, Agou and Kloto districts, respectively. *Cotesia* spp. was only found in Golf district parasitizing three larvae. No pupal parasitism was observed. During the first cropping season, *B. bassiana* was isolated from up to 5% of the *S. calamistis* larvae. Similarly percents larval infection by *B. bassiana* were 4.71%, 0.43% and 2.86%, in Avé, Agou and Kloto districts, respectively. The two control agents (*S. parasitica* and *B. bassiana*) occurred more significantly in Avé, Agou, Kloto and Yoto districts than in coastal zones (Golfe, Lacs/Bas-Mono districts) (Figure 4).

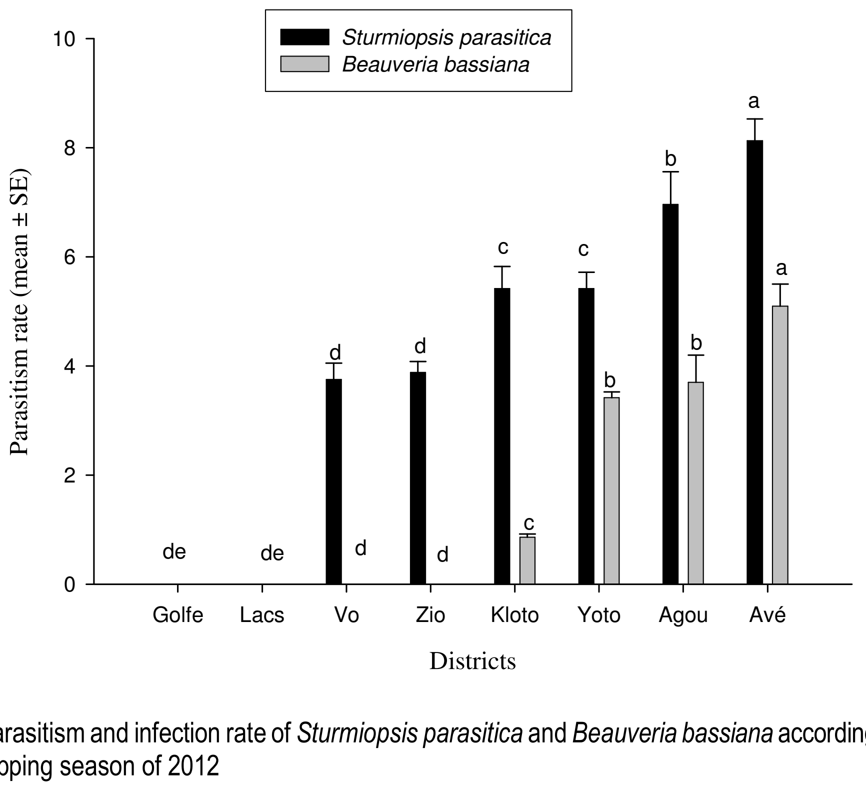


Figure 4: Parasitism and infection rate of *Sturmiopsis parasitica* and *Beauveria bassiana* according to the districts during the long cropping season of 2012

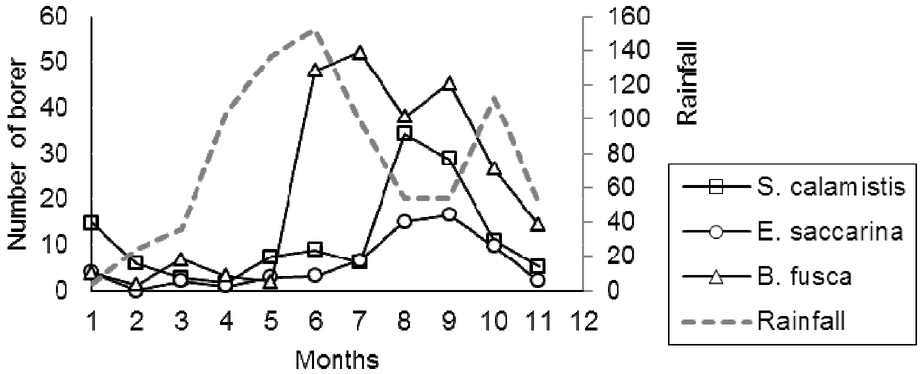
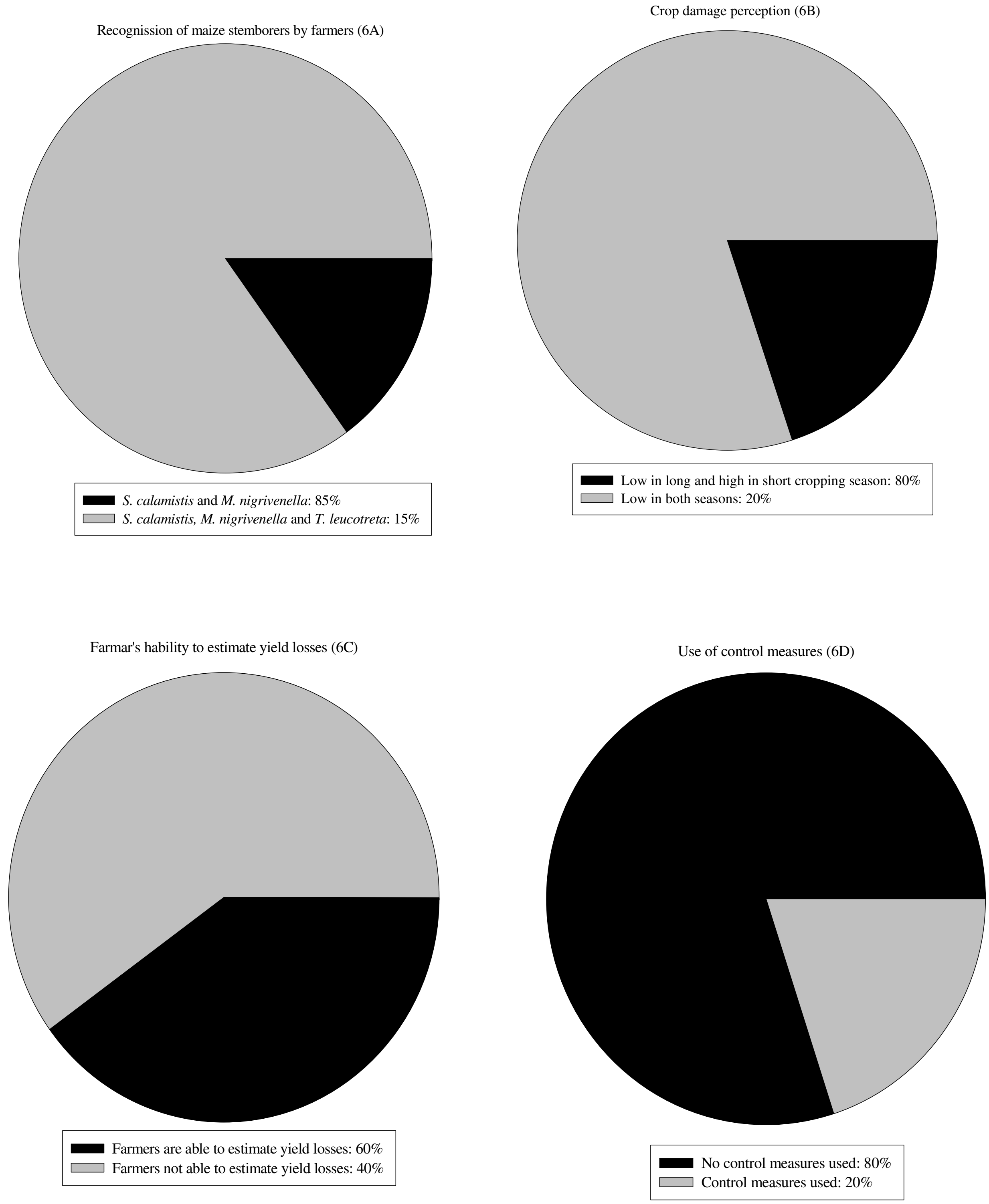


Figure 5: Stem borers dynamics on maize in Yoto district during different seasons of 2012

Farmers' perception on climate change and maize insects: Farmers' perception on climate changes and maize stem and ear bores are presented in Figures 6 A. Farmers indicated that maize represented a mean of 34% of the total agricultural income. Eighty five percent of the framers could identify stem borer *S. calamistis* and the ear borer *M. nigrivenella* whereas 15% could additionally recognize *T. leucotreta* on ear (Figure 6 A). Eighty percent of the farmers perceived that maize damage by borers (dead hearts and bored stems) is negligible in long cropping season but important in the short cropping season (Figure 6 B). Sixty percent of the farmers were capable of estimating plant infestation (damage) that averaged between 5 and 30% (Figure 6 C). As for control measures, 90% of the farmers did not have any measure of managing the stemborers while only 10% indicated that they use early harvesting to control ear borers (Figure 6 D).Sixty percent of the interviewed farmers perceived climate change as rainfall irregularity and excessive heats. In addition, 30% and 10% of the farmers mentioned repeated floods and violent winds, respectively (Figure 6 E). All of the interviewed farmers indicated that the main cause was deforestation. Farmers enumerated that new insect pests such as *Zonocerus variegatus* L. (Orthoptera: Pyrgomorphidae), termites (Isoptera) and *Cicadulina* spp. (Hemiptera: Cicadellidae) that have recently become important maize pests in western zone of Plateau region (AEZ IV). Climate change mitigating strategies included among others, the use of early maturity maize varieties and continuous sowing in relation to rainfalls or crop diversification (Figure 6 F).


Recognission of maize stemborers by farmers (6A)
S. calamistis and *M. nigrivenella*: 85%
S. calamistis, M. nigrivenella and *T. leucotreta*: 15%
Crop damage perception (6B)
Low in long and high in short cropping season: 80%
Low in both seasons: 20%
Farmar's hability to estimate yield losses (6C)
Farmers are able to estimate yield losses: 60%
Farmers not able to estimate yield losses: 40%
Use of control measures (6D)
No control measures used: 80%
Control measures used: 20%

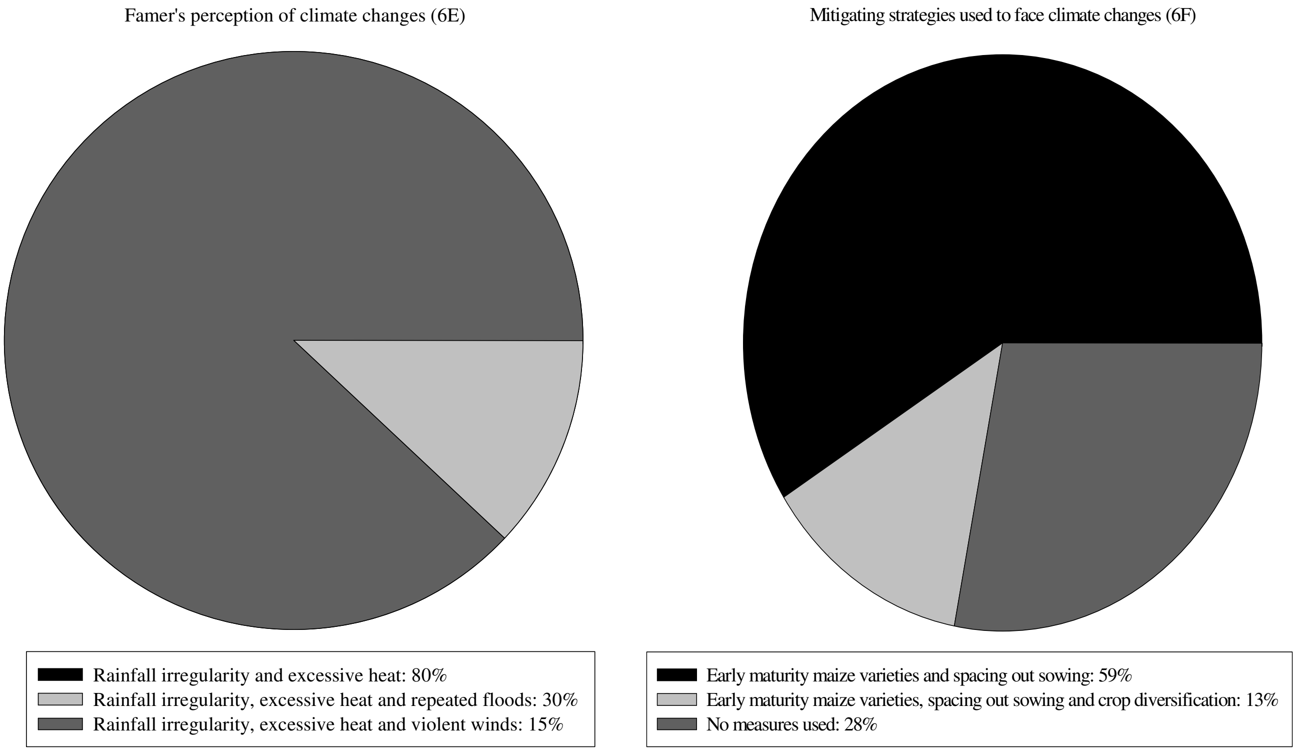


Figure 6: Climate change and maize stem borers: Farmers' perception on climate change (A), maize stem borers identification by farmers (B), farmers knowledge on control measure against maize cob borers (C), farmers knowledge on crop damage estimation (D) and mitigation measures adopted by farmers (E)

DISCUSSION

The present study is the first detailed research conducted on maize stem and ear borers in Togo since the surveys conducted by Silvie (1993) in restricted cereal and cotton-cropping areas. The results showed that stemborer *S. calamistis*, *E. saccharina* and *B. fusca* and the ear borer *M. nigrivenella* cause significant damage and reduce maize yield. Similar results were reported in Benin (Gounou *et al.*, 1994; Schulthess *et al.*, 1997), Ghana (Buadu *et al.*, 2002). This is probably because these countries including Togo share similar agroecological conditions and situated in Dahomey Gap. Moreover results of the countrywide surveys on stem and ear borers in West Africa so far showed that borers oviposited heavily on wild host plants but their relative importance, both on maize and wild grasses varied between regions, eco-zones and within the same eco-zone (Schulthess *et al.*, 1997). Although wild host of stem and ear borers were not included in this study, *S. calamistis* the most frequently reported maize borers in West Africa (Bosque-Pérez and Mareck 1990; Gounou *et al.*, 1994; Schulthess *et al.*, 1997), were found in the three agroecological zones surveyed in Togo. Similarly, Gounou *et al.* (2009) showed that the predominant species in southern Benin were *S. calamistis* and *E. saccharina.* As for *B. fusca* it was found only in Yoto district causing serious damages on maize. In contrast to this, Harris (1962) described *B. fusca* as the most abundant species and major pest of sorghum in the drier parts of the Guinea and Sudan savannah, while Tams and Bowden (1953) stated that in west Africa, *B. fusca* was the most serious in the wetter parts of the Guinea savannas. In Cameroon, *B. fusca* is the most abundant species on maize across all ecological zones (Cardwell *et al.*, 1997; Ndemah *et al.*, 2001a). Matama-Kauma *et al.* (2007) reported that variations in dominance among these species could be a result of specific adaptations in their ecological requirements. Furthermore, given the geographic distribution of stem borers and the role of wild host plants, Schulthess *et al.* (1997) proved that the differences in relative importance of species may be due to differences in human population densities including intensity of cereal cultivation (Harris, 1962). Increasing population pressure and the concomitant expansion of agricultural areas often result in deforestation and displacement of wild habitats of borers, which probably affect the population dynamics of both borers and their natural enemies. Kloto district, which was a very dense forest zone where coffee and cocoa are usually produced is currently subjected to serious deforestation for cereals and yam production. Moreover, in most locations, it is observed that borer's larvae particularly third instars tended to be aggregate in unopened maize inflorescences instead of stem or ear. This could indicate that female moths lay their eggs on all phenological stages of the plant not only on the leaf whorl but also on tassels and on ears. Is this change in oviposition behaviour of maize stem borers related to adaptation to changing of climatic conditions? This should be elucidated in future studies in all agroecological zones in Togo.

In most locations surveyed, the egg parasitoid *T. busseolae*, the larval parasitoids *S. parasitica* and *Cotesia* spp., and entomopathogenic fungus *B. bassiana* are the main biotic mortality factors of the stem borers in Togo. The latter was recorded and tested successfully on *S. calamistis* in Benin (Cherry *et al*., 1999). *Telenomus busseolae* is an important natural biocontrol agent against *S. calamistis* on maize with mean parasitism more than 80%. This corroborates with findings of studies conducted in Benin where mean parasitism was more than 80% (Sétamou and Schulthess, 1995; Schulthess *et al*., 1997). With these relatively high egg parasitism rates on maize, the parasitoid could maintain the noctuid stem borers at low level and as concluded by Schulthess *et al.* (2001), *S. calamistis* is usually not of economic importance in the Dahomey Gap, which includes parts of Benin, Togo and Ghana. According to Ndemah (1999), egg parasitism was the main reason for the relatively low *B. fusca* densities found during the second season in the forest zone. Parasitism of the tachnid *S. parasitica*, although not as high as compared to that by *T. busseolae*, suppresses less than 10% of the larvae. This low parasitism recorded can be explained by the functional response of the parasitoid and its guild. According to Smith *et al.* (1993) and Gounou *et al.* (2009) *S. parasitica* utilizes a planidial-ingress host attack strategy whereby mobile first instar maggots (planidia) are deposited on moist frass at stem borer tunnel entrances. The planidia then have to move through the frass to attack and penetrate the host larva inside the tunnel. Ndemah *et al.* (2002) found that parasitism of *S. calamistis* by the larval parasitoid *S. parasitica* was higher on the thin-stemmed grasses than on the large-stemmed maize. It was concluded that part of the reason for the differences in parasitism rates was due to differences in accessibility of the host inside the stem. *Sturmiopsis parasitica* appeared to be common on *S. calamistis* and *E. saccharina* in West Africa (Gounou *et al*., 2009) as observed in the present study, while in Cameroon it was recovered only once, and from *B. fusca* (Ndemah *et al*., 2001b, 2007). The third parasitoid *Cotesia* spp. recorded sporadically in southern Togo could result from the establishment of *C. sesamiae* in southern Benin (Hailemichael *et al*., 2008). However, further morphological and molecular analysis of the *Cotesia* species recorded in southern Togo is needed to confirm this hypothesis.

The present study indicated that farmers are aware of the changes in climate. Farmers perceived climatic variations through excessive heat, rainfall irregularities, regular floods and violent winds. Similar perceptions were shown in studies conducted by Mertz *et al.* (2009) in the Sahel, Apata *et al.* (2009) in southwestern in Nigeria and Nyanga *et al.* (2011) in Zambia. The variability of rainfall leads to variability in sowing dates and as a consequence, varying phonological stages of maize plant were observed in all agroecological zones resulting in continuous stem and ear borers' infestation. Based on the estimation given by farmers, potential losses were relatively high in low potential areas (Hassan *et al*., 1998; De Groote 2002).

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