J. Appl. Entomol. **131(9–10)**, 658–668 (2007) doi: 10.1111/j.1439-0418.2007.01219.x

Lepidopteran cereal stemborers and associated natural enemies on maize and wild grass hosts in Cameroon

R. Ndemah[1], F. Schulthess[1], B. Le Rü[2] and I. Bame[3]
[1]International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya; [2]Institut de Recherche pour le Développement (IRD-ICIPE), Nairobi, Kenya; [3]Institut de Recherche Agricole pour le Développement, Bambui, Bamenda, Cameroon

Ms. received: May 18, 2007; accepted: June 12, 2007

Abstract: In Cameroon, the noctuid *Busseola fusca* is the most important pest of maize. The braconid *Cotesia sesamiae*, which is the most common larval parasitoid of noctuid stemborers in eastern Africa, was absent on *B. fusca* attacking maize. Thus, it is planned to introduce several strains of the parasitoid from Kenya. Pre-release surveys were undertaken in major maize growing areas to catalogue stemborer species, and larval and pupal parasitoids on maize and four wild host plant species. On maize, *B. fusca* was the predominant borer in all ecozones except for the lowland coastal forest, usually accounting for 60–99%, followed by the pyralid *Eldana saccharina* in the forest zone and the crambid *Chilo* sp. in the mid-altitudes. Contrary to what was reported before, the noctuid *Poeonoma serrata* – and not *B. fusca* – was the predominant borer on elephant grass, constituting 70–96% of all borers. On wild sorghum in the forest zone, the noctuid *Sesamia poephaga* was the most abundant species, while on *Panicum* sp., *Chilo* sp. predominated. On *Setaria megaphylla* in the forest zone, *Chilo* sp. was the most abundant species followed by *Busseola quadrata*. *Busseola fusca* was scarce on all wild grass species, indicating that previous reports on the predominance of this pest species on wild host plants were the result of misidentifications. Three tachinid and 16 hymenopteran parasitoids were obtained, most of them from *B. fusca* and *P. serrata*, on maize and *Pennisetum purpureum* respectively. *C. sesamiae* was scarce and never recovered from *B. fusca* on maize. In view of the new findings, acceptability and suitability studies involving the different stemborer species identified from wild plant hosts are required to determine if they will form a reproductive sink or perennate *C. sesamiae* populations during the off-season when maize is scarce and *B. fusca* is diapausing.

Key words: maize and wild grass hosts, parasitoids, stemborers

1 Introduction

Busseola fusca (Fuller) (Lep.: Noctuidae) is the most important maize pest across all agroecological zones of Cameroon with yield losses ranging between 25% and 55% (Cardwell et al. 1997; Ndemah and Schulthess 2002; Chabi-Olaye et al. 2005a). Several control techniques have been researched and are being tested, mostly in the humid forest zone. Among them are insecticides (Ndemah and Schulthess 2002), intercropping of maize with non-hosts of stemborers (Chabi-Olaye et al. 2005a), planting of border rows with grasses serving as trap plants and/or refugia for pests and natural enemies (Ndemah et al. 2002), crop rotation with leguminous cover and grain crops (Chabi-Olaye et al. 2005b) and the use of nitrogen fertilizer (Chabi-Olaye et al. 2006; accepted), both improving soil fertility and thereby enhancing the plant's tolerance to stemborer attacks.

Schulthess et al. (1997) proposed the exchange of natural enemy species and strains between African regions to control cereal stemborers. During country-wide surveys and on-station trials in the 1990s, Ndemah et al. (2000, 2001a) found that several parasitoid species, common in other regions in Africa, were very scarce or absent in Cameroon. For example the braconid *Cotesia sesamiae* (Cameron) was found only 10 times. In East and Southern Africa, however, this is the most common larval parasitoid recovered from *B. fusca* and the noctuid *Sesamia calamistis* Hampson (Kfir 1992). In East Africa, parasitism can attain regional means of 30% but are mostly below 7% (Jiang et al. 2006). However, in Western Kenya particularly in the Kitale area, parasitism of *B. fusca* is over 70% (Catherine Gitau, ICIPE, unpublished data). Similarly in South Africa, parasitism of *B. fusca* on sorghum was as high as 75% and *C. sesamiae* is thought to keep *S. calamistis* under control (Kfir 1995). Furthermore, the tachinid *Sturmiopsis parasitica* Curran was never recovered in Cameroon, while in West Africa it is the most common larval parasitoid of *S. calamistis* and the pyralid *Eldana saccharina* Walker (Conlong 2001). In Zimbabwe, it was commonly obtained from *B. fusca* larvae and it was the second most common parasitoid after *C. sesamiae* (Chinwada and Overholt 2001). Thus, releases of several highland strains of *C. sesamiae* from Kenya and a West African strain of *S. parasitica*, both reared at the International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya, are planned in the humid forest zone and the western highlands (WH) of Cameroon.

Schulthess et al. (1997) postulated that wild hosts (grasses mainly and some *Cyperus* species (Cyperaceae) of stemborers are harbouring the pest and natural enemies during the off-season, when the crop is not present, thereby stabilizing the pest-parasitoid system. Le Rü et al. (2006) in East and Southern Africa obtained and identified dozens of noctuid species from wild grasses. However, with exception of *Sorghum* spp. in East Africa and the grass *Arundo donax* L. in Eritrea, Ethiopia and South Africa, *B. fusca* was rarely found on those wild hosts, and it was suggested that earlier reports of common occurrence of *B. fusca* on these host plants was due to misidentification of the species (Le Rü et al. 2006). The stemborer species adapted to wild host plants could be either suitable or unsuitable as hosts to introduced natural enemies, thereby either perennate the parasitoids during the off-season or form a reproductive sink. Therefore, the present study aims at re-analysing the stemborer and parasitoid species composition on maize and wild host plants in the humid forest zone and the WH of Cameroon relying on the taxonomic expertise of specialists at the Institut de Recherche pour le Développment (IRD, France). An IRD team is working on the systematics and diversity of African noctuid stemborers since 2002, using both classical morphological and molecular tools (Le Rü et al. 2006 Moyal 2006; Moyal and Le Rü 2006).

2 Materials and Methods

2.1 Data collection

Three surveys of lepidopteran stemborers on maize and four grass species were undertaken during the first and second maize cropping season of 2005 and the second season of 2006, in the WH and humid forest zone. Elephant grass, *Pennisetum purpureum* (Moench), wild sorghum, *Sorghum arundinaceum* (Desv.) Stapf, *Panicum* sp. and *Setaria megaphylla* (Steud) Dur. and Schinz were selected because in previous surveys (Rose Ndemah, unpublished data) they have shown to be relatively frequently attacked by stemborers. Moreover, *P. purpureum* is the most common grass species across all ecozones surveyed in the past (Cardwell et al. 1997). The WH comprises three ecozones: the lowland grassy savannah (below 800 m a.s.l.), the mid-altitude (between 800 and 1200 m a.s.l.) and the highlands (above 1200 m a.s.l.). The forest zone was subdivided into lowland coastal forest (seaside localities with dense or degraded forest and altitude < 200 m a.s.l.), lowland hinterland forest with secondary forest and elevation below 200 m a.s.l., and lowland interior forest between 200 and 800 m a.s.l. The latter two will herewith referred to as humid forest-1 and forest-2 zone respectively (fig. 1).

2.1.1 Western highlands

The first season surveys on both maize and grasses took place from 23 June to 7 July, 2005, and the second season surveys from 29 September to 10 October on wild grass hosts, and from 25 to 29 November on maize. In the first season, 93 maize fields and 46 grass patches were surveyed along the ring road loop (Bamenda – Kumbo – Nkambe – Wum-Bamenda) as well as the major roads from Bamenda to Batibo via Bali and from Bambui to Njinikom (fig. 1). In the WH, *Panicum* sp. was found in the mid-altitude only. Because the maize in the highlands during the June–July surveys was barely tasseling (maize takes 6 months to maturity), the same fields were re-visited at harvest from 31 August to 2 September. During the second season of 2005, 42 elephant grass and *Panicum* sp. patches were sampled from 29 September to 10 October, and 28 maize fields from 25 to 29 November.

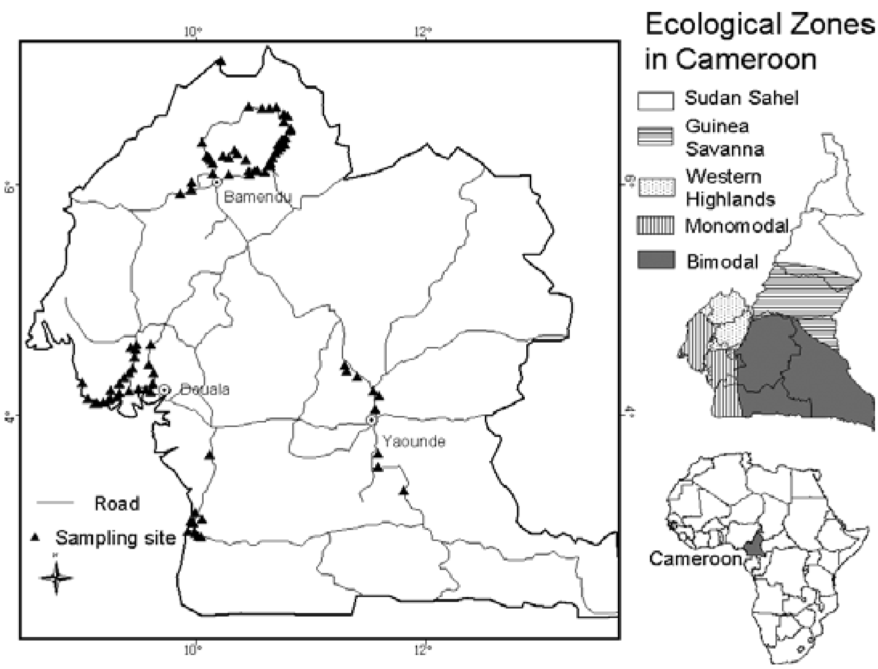

Fig. 1. *Survey routes and agro-climatic zones in Cameroon*

2.1.2 Forest zone

The first season 2005 samplings in the humid forest-2 zone were carried out from 20 July to 2 August. In total, 23 patches of elephant grass, *Panicum* sp. and wild sorghum as well as 14 maize fields were visited along the Yaoundé – Ebebda highway, and at Nkometou. In the second season, 49 patches of the four grass species were sampled between 12 and 18 October, and 46 maize fields and grass patches from 9 November to 17 December.

During the second season 2006 surveys, 43 maize fields were visited in coastal forest localities and the humid forest-1 and forest-2 zones, at the foot of Mt Cameroon from 24 to 29 November (fig. 1).

2.1.3 Sampling procedures

During the 2005 surveys, roadside maize fields in the tasseling to harvest stages, or grass patches visible and accessible from the main roads were selected every 10–15 km in the WH and every 20 km in the forest zone. In 2006, roadside fields were sampled every 5 km. In some representative villages away from the major roadsides, maize fields in the right growth stage or grass patches were selected at random in different parts of the locality. For each maize or grass patch, the coordinates and altitude were recorded. Each maize field was divided into four quadrants and 24 randomly selected plants, six per quadrant, were purchased from the farmer. Each plant was dissected and searched for lepidopteran stemborer larvae and pupae. The total grass abundance at about 50 m in the vicinity of a maize field was scored (0 = no grasses, 3 = 100% grasses). Similarly, each grass patch was divided into four quadrants and 25 tillers (together with lateral shoots) were randomly sampled per quadrant and dissected to determine the number of stemborer larvae or pupae. All the stemborer larvae per host plant type and field were placed in labelled plastic 1 l jars with ventilated lids. They were brought to the laboratory and reared on maize or grass stem pieces until pupation or parasitoid emergence. The pupae or dead larvae obtained from the field or lab were placed individually in small round plastic Petri dishes, labelled according to host plant and field and kept until adult moth or parasitoid emergence. The adult moths were sent to the French IRD and the parasitoids to the ICIPE to taxonomists for identification. All noctuid stemborer species belonging to *Sesamia sensu lato* group, to which the genera collected belong, appear to be closely related and the adults can be easily confused (Holloway 1998). They are most reliably distinguished on genitalia characters; therefore dissection is necessary in most cases. Adult moth genitalia were dissected after a short stay in a boiling potash 10% bath and then slide mounted in Euparal. Identification to species level was made according to Tams and Bowden (1953) and Bowden (1956) revision of the African species of noctuid stemborers. Voucher specimens were deposited in the Muséum National d'Histoire Naturelle (Paris, France) and in ICIPE Museum (Nairobi, Kenya)

2.2 Statistical analyses

Least square and arithmetic means as well as percentages were computed for counts of the different pests and parasitoid species, according to host plant, borer host, season and ecozone, using the SAS statistical analyses package (SAS 1997). The mixed model was applied with ecozone as fixed, and fields, quadrants and plants as random effects. Significance was set at $P \leq 0.05$. Correlation analyses were performed to elucidate the relationships between the relative importance of a pest species and altitude, and between grass abundance and pest incidence in a field.

3 Results

3.1 Species composition and densities of borers on maize

Four stemborers (*B. fusca*, *S. calamistis*, *E. saccharina* and *Chilo* sp.) and two earborers [*Mussidia nigrivenella* Ragonot (Lep.: Phyticinae), *Cryptophlebia leucotreta* Meyrick (Lep.: Torticidae)] species were recovered from maize (in the savanna, only *C. leucotreta* was obtained and the results are not further discussed here). While stemborers were found in both stems and ears, earborers only fed inside ears; their parasitoids were not included in this study because they were very scarce; most of them belong to the *Tetrastichus atriclavus* Waterston (Hym.: Eulophidae) complex which are facultative hyperparasitoids, and, moreover, stem and earborers very rarely share the same parasitoid species (Ndemah et al. 2001a).

During the first season of 2005, *B. fusca* was the predominant species of stemborer on maize in all ecozones, accounting for 64–99% of all stemborers collected (tables 1 and 2). *Eldana saccharina* was the second most important species in the humid forest-2 zone, and *Chilo* sp. in the mid-altitudes. During the second season of 2005, *B. fusca* was again the most important species in the forest zone, though *E. saccharina* increased in importance accounting for 29% of all stemborers. In the mid-altitude and highlands, the percentage of *B. fusca* dropped below 50% with a concomitant increase in *Chilo* spp. densities (table 2). During both seasons, *E. saccharina* was limited to the lower altitudes and it was not recovered at all from the highlands, while the reverse was true for *Chilo* spp. *Sesamia calamistis* was of minor importance across all ecozones. During the second season of 2006, surveys concentrated on ecozones below 600 m consisting of humid forest. In the forest adjacent to the mid-altitude (humid forest-2 zone), *E. saccharina* predominated over *B. fusca*, while the reverse was true for the humid forest-1 zone. In the coastal forest, *S. calamistis* was the most common species while *B. fusca* and *E. saccharina* were of similar importance (table 2).

During both seasons of 2005, *B. fusca* and *E. saccharina* densities were highest in the humid forest zone while *Chilo* sp. was more important in the higher altitudes (table 1). However, during the first season of 2005, the relative importance of *B. fusca* (percentage on total numbers) increased ($r = 0.30$; $P = 0.01$) and that of *E. saccharina* decreased with altitude ($r = -0.44$; $P < 0.0001$). During the second season, the percentage of both *B. fusca* and *E. saccharina* decreased ($r = -0.26$, $P = 0.003$; $r = -0.55$, $P < 0.0001$ respectively) while that of *S. calamistis* and *Chilo* sp. increased with altitude ($r = 0.35$, $P = 0.002$; $r = 0.68$, $P < 0.0001$ respectively). In the second season of 2006, the relative importance of *S. calamistis* decreased with altitude ($r = -0.34$, $P = 0.04$).

Table 1. *Least square means of counts of lepidopteran stemborers according to altitude, during surveys at tasseling to harvest of maize in farmers' fields, in various ecozones of Cameroon in the first and second rainy seasons of 2005 and second season of 2006*

Season	Altitude (m a.s.l.)	Ecozone	*Busseola fusca*	*Sesamia calamistis*	*Eldana saccharina*	*Mussidia nigrivenella*	*Cryptophlebia leucotreta*	*Chilo* sp.	Others
First 2005	597	Humid forest 2	1.01 c	0.004 a	0.15 b	0.07 b	0.07 b	0.00 a	0.00 a
	1165	Mid-altitude	0.13 a	0.01 a	0.00 a	0.001 a	0.002 a	0.03 b	0.01 a
	1902	Highlands	0.75 b	0.002 a	0.00 a	0.002 a	0.001 a	0.01 a	0.00 a
	590	Savanna	0.00 a	0.00 a	0.00 a	0.00 a	0.04 a	0.00 a	0.04 a
		d.f.	3, 2133	3, 87	3, 87	3, 87	3, 86	3, 87	3, 87
		F-value	32.55	0.55	9.38	13.51	30.11	3.59	1.88
		P > *F*	< 0.0001	0.65	< 0.0001	< 0.0001	< 0.0001	0.03	0.14
Second 2005	650	Humid forest 2	0.65 b	0.03 a	0.34 b	0.05 a	0.03 a	0.04 a	0.01 a
	1159	Mid-altitude	0.15a	0.06 a	0.01 a	0.07 ab	0.05 a	0.11 b	0.04 a
	1417	Highlands	0.28 a	0.03 a	0.00 a	0.11 b	0.04 a	0.21 c	0.06 b
		d.f.	2, 1480	2, 71	2, 71	2, 71	2, 71	2, 71	2, 71
		F-value	11.87	1.13	13.67	2.69	0.66	9.66	3.69
		P > *F*	< 0.0001	0.33	< 0.0001	0.07	0.52	0.0002	0.03
Second 2006	65	Humid coastal forest	0.07 a	0.26 a	0.13 a	0.08 a	0.08 a	0.01 a	0.01 a
	66	Humid forest 1	0.24 b	0.16 a	0.17 a	0.07 a	0.08 a	0.01 a	0.00 a
	475	Humid forest 2	0.16 ab	0.01 a	0.19 a	0.01 a	0.03 a	0.00 a	0.00 a
		d.f.	2, 800	2, 799	2, 37	2, 37	2, 37	2, 37	2, 37
		F-value	5.33	1.25	0.14	0.17	0.57	0.16	1.32
		P > *F*	0.005	0.30	0.87	0.84	0.57	0.85	0.28

Within column and season, the means per season followed by the same letter were not significantly different from each other at P ≤ 0.05 following pair wise comparisons.

Table 2. *Relative importance (percentages) of lepidopteran stem boring species in various ecozones during surveys of maize, at tasseling to harvest, in the first and second rainy season of 2005 and second rainy season of 2006*

Season	Ecozone	*Busseola fusca*	*Sesamia calamistis*	*Eldana saccharina*	*Chilo* spp.
First 2005	Humid forest 2	87.1 b	0.96	12.5 b	0.00 a
	Mid-altitude	64.3 a	3.62	0.00 a	32.1 b
	Highlands	99.4 c	0.67	0.00 a	0.00 a
	d.f.	2, 72	2, 72	2, 72	2, 72
	F-value	29.73	1.74	19.45	20.19
	P > *F*	< 0.0001	0.18	< 0.0001	< 0.0001
Second 2005	Humid forest 2	64.7 b	2.19 a	28.7 b	4.48
	Mid-altitude	47.2 a	11.3 b	4.22 a	37.0
	Highlands	49.3 ab	9.1 ab	0.00 a	43.3
	d.f.	2, 71	2, 71	2, 71	2, 71
	F-value	3.68	7.57	13.12	70.79
	P > *F*	0.03	0.001	< 0.0001	< 0.0001
Second 2006	Humid coastal forest	26.4a	46.2 b	22.6	4.00
	Humid forest 1	44.7 b	20.8 a	31.3	3.09
	Humid forest 2	36.8 ab	11.8 a	54.3	0.00
	d.f.	2, 36	2, 36	2, 36	2, 36
	F-value	1.73	4.82	1.39	0.20
	P > *F*	0.19	0.01	0.26	0.83

Within column and season, least square of percentages after ANOVA using the mixed procedure followed by the same letter were not significantly different from each other at P ≤ 0.05.

3.1.1 Relationships between grass abundance and stemborers infestations on maize

During both the first and second season of 2005, grass abundance around a field and *B. fusca* densities on maize were significantly negatively correlated (r = −0.32, P = 0.002 and −0.34, P = 0.0004 respectively). During both seasons, abundance of *P. purpureum* was also negatively related with *B. fusca* (r = −0.32, P = 0.002 and −0.33, P = 0.005 respectively), while during the first season *Panicum* sp. abundance was positively related (r = 0.21, P = 0.05). During the second season, total grass and *P. purpureum* abundance was negatively correlated with *E. saccharina* on maize (r = −0.31, P = 0.01).

3.2 Species composition and densities of stemborers on wild grasses

Five species were recovered from *P. purpureum* (i.e. the noctuids *Poeonoma serrata* Hampson, *B. fusca*, *S. calamistis*, *Busseola phaia* Bowden, *Sesamia*

Table 3. *Relative importance (percentages) of lepidopteran stem boring species on four grasses in various ecozones during the first and second rainy season of 2005*

Grass species	Season	Ecozone	*Poeonoma serrata*	*Busseola fusca*	*Sesamia calamistis*	*Busseola phaia*	*Sesamia penniseti*	Others
Pennisetum purpureum	First	Humid forest 2	98.47	0.75	0.00	0.00	0.00	0.84
		Mid-altitude	96.93	1.11	0.00	1.43	0.00	1.44
		Highlands	98.47	0.65	0.00	0.06	0.43	0.39
		Savanna	100	0.00	0.00	0.00	0.00	0.00
		d.f.	3, 46	3, 46		3, 46	3, 46	3, 46
		F-value	0.72	0.23		0.39	0.57	0.93
		P > *F*	0.55	0.87		0.76	0.64	0.43
	Second	Humid forest 2	87.32 b	1.05	0.00 a	1.01 a	0.00	10.90
		Mid-altitude	70.81 a	0.83	5.13 b	8.70 b	0.56	16.45
		Highlands	70.99 a	1.70	4.14 ab	1.42 a	0.00	21.30
		Savanna	100 b	0.00	0.00 a	0.00 a	0.00	
		d.f.	3, 49	3, 49	3, 49	3, 49	3, 49	3, 49
		F-value	3.68	0.24	1.69	5.13	0.78	1.50
		P > *F*	0.02	0.87	0.18	0.004	0.51	0.23
Panicum sp.			*P. serrata*	*B. fusca*	*S. calamistis*	*Chilo* sp.		Others
	First	Humid forest 2	5.56	0.00	0.00	50.00		44.44
		Mid-altitude	0.00	0.00	0.00	0.00		0.00
	Second	Humid forest 2	2.18	4.42	7.14	88.44 b		0.00
		Mid-altitude	0.00	0.00	0.00	0.00 a		0.00
		d.f.	8	8	8	8		
		t-value	2.91	1.02	1.03	3.13		
		P > *t*	0.02	0.34	0.33	0.01		
Sorghum arundinaceum			*Sesamia poephaga*	*B. fusca*	*S. calamistis*	*Eldana saccharina*	*S. penniseti*	Others
	First	Humid forest 2	91.66 b	2.09	2.61	0.00	0.77	1.16 a
	Second		0.35 a	7.95	16.61	14.79	2.47	64.59 b
	d.f.		1, 10	1, 10	1, 10	1, 10	1, 10	1, 10
	t-value		291.66	0.78	0.83	0.81	0.34	12.18
	P > *t*		< 0.0001	0.40	0.38	0.39	0.57	0.006
Setaria megaphylla		Humid forest 2	*Busseola quadrata*	*Busseola* sp.	*Chilo* sp.			Others
			9.31	0.69	83.79			5.52

Within column and season, least squre of percentages after ANOVA using the mixed procedure followed by the same letter were not significantly different from each other at P ≤ 0.05.

penniseti Tams and Bowden), three from *Panicum* sp. (i.e. *B. fusca*, *S. calamistis*, *Chilo* sp.), five from *S. arundinaceum* (*Sesamia poephaga* Tams and Bowden, *B. fusca*, *S. calamistis*, *E. saccharina and S. penniseti*) and three from *S. megaphylla* (*Busseola quadrata* Bowden, *Busseola* sp. and *Chilo* sp.).

On *P. purpureum*, *P. serrata* was the predominant species in all ecozones and both seasons, while other species were very rare (table 3). In the forest zone and savanna, *P. serrata* densities increased from the first to the second season, and during the second season they were higher in the forest zone and savanna than the higher altitudes (table 4). For the other species, densities did not vary significantly with ecozone. On *Panicum*, wild sorghum and *S. megaphylla*, borer densities were exceedingly low except for *S. poephaga* in the humid forest during the first season, and *Chilo* sp. in the humid forest during the second season of 2005.

3.3 Species composition of parasitoids on maize and wild grasses

Three tachinids (Diptera), seven braconids, four ichneumonids and one species of each the Ceraphronidae, Chalcididae, Chloropidae, Bethylidae and Eulophidae (all Hymenoptera) families were recovered, among them 15 larval, four pupal and one hyperparasitoid. The vast majority was collected on maize and *P. purpureum* from *B. fusca* and *P. serrata* respectively (table 5). The number of parasitoids recovered from a given host plant and stemborer species corresponded with host density (table 6). Noctuid stemborers often shared the same parasitoid species, while *Actia* sp. was found on both noctuids and pyralids. In general, parasitization rates of an individual species were exceedingly low (i.e. < 1%) except for *Actia* sp., which produced relatively high parasitism on *E. saccharina*. *Cotesia sesamiae* was only obtained from noctuid species on wild grasses and never from *B. fusca,* while *S. parasitica* (Curran) was recovered for the first time from *B. fusca* on maize in the forest zone (table 5).

4 Discussion

With the exception of the coastal forest, *B. fusca* was the predominant stemborer species in all ecozones corroborating results by Cardwell et al. (1997) and Ndemah et al. (2001b). This is in stark contrast to

Table 4. *Least square means following* anova *of lepidopteran stemborer counts on grasses in four ecozones during surveys in the first (June–August) and second (October–December) rainy seasons of 2005 in Cameroon*

Grass species	Season	Ecozone	Altitude (m a.s.l.)	*Poeonoma serrata*	*Busseola fusca*	*Sesamia calamistis*	*Busseola phaia*	*Sesamia penniseti*	Others
Pennisetum purpureum	First	Humid forest 2	601	0.26 ab	0.002	0.00	0.00	0.00 a	0.003
		Mid-altitude	1188	0.19 a	0.002	0.00	0.0004	0.00 a	0.002
		Highlands	1915	0.48 b	0.003	0.00	0.002	0.003 b	0.001
		Savanna	584	0.14 a	0.00	0.00	0.00	0.00 a	0.00
		d.f.		3, 47	3, 47		3, 47	3, 47	3, 47
		F-value		3.14	0.19		0.62	2.35	0.38
		P > *F*		0.03	0.90		0.61	0.08	0.77
	Second	Humid forest 2	642	0.74 b	0.01 ab	0.00 a	0.003	0.00	0.04
		Mid-altitude	1145	0.07 a	0.001 a	0.004 b	0.01	0.00	0.01
		Highlands	1808	0.14 a	0.002 a	0.004 b	0.002	0.001	0.05
		Savanna	688	1.36 b	0.00 a	0.00 a	0.00	0.00	0.00
		d.f.		3, 49	3, 49	3, 49	3, 49	3, 49	3, 49
		F-value		10.19	1.54	1.72	1.17	0.58	1.35
		P > *F*		< 0.0001	0.22	0.17	0.33	0.63	0.27
				P. serrata	*B. fusca*	*S. calamistis*	*Chilo* sp.		Others
Panicum sp.	First	Humid forest 2	599	0.001	0.00	0.003	0.04		0.01
		Mid-altitude	1147	0.00	0.00	0.00	0.00		0.00
		d.f.		1, 11		1, 20	1, 11		1, 11
		F-value		0.42		0.29	0.42		1.34
		P > *F*		0.53		0.60	0.53		0.27
	Second	Humid forest 2	648	0.00	0.004	0.01	0.18		0.00
		Mid-altitude	1206	0.00	0.00	0.00	0.00		0.00
		d.f.			1, 9	1, 9	1, 9		
		F-value			0.35	0.20	0.31		
		P > *F*			0.57	0.66	0.59		
Sorghum arundinaceum				*Sesamia poephaga*	*B. fusca*	*S. calamistis*	*E. saccharina*	*S. penniseti*	Others
	First	Humid forest 2	629	0.41	0.002	0.02	0.00	0.002	0.002
	Second	Humid forest 2	659	0.003	0.004	0.01	0.01	0.01	0.37
		d.f.		1, 1248	1, 1248	1, 1248	1, 1248	1, 1248	1, 1248
		F-value		10.11	0.20	0.50	1.68	0.27	0.95
		P > *F*		0.002	0.65	0.48	0.20	0.60	0.33
Setaria megaphylla	Second			*B. quadrata*	*Busseola* sp.	*Sesamia* sp.	*Chilo* sp.		Others
			642	0.02	0.001	0.001	0.10		0.02 ± 0.010

Within column and season, means per host plant and/or per season followed by the same letter were not significantly different from each other at P ≤ 0.05 following pair-wise comparisons.

West Africa, where *B. fusca* is common in the Guinea savannas and on sorghum mainly while in the humid forest and forest-savanna transition zone, where *E. saccharina* and *S. calamistis* predominate, it is a minor species (Schulthess et al. 1997). In East and Southern Africa, *B. fusca* is a mid-altitude and highland species and only of importance above 1000 m a.s.l. (Smithers 1960; Phiri 1995; Zhou et al. 2001; Ong'amo et al. 2006). A phylogenetic analyses by Sezonlin et al. (2006) separated *B. fusca* populations on maize in Africa into three mitochondrial clades: one from West Africa, and two from East, Southern and Central Africa, which includes Cameroon. In addition, a recent nuclear marker analysis made with eight microsatellites clearly indicated distinct *B. fusca* populations in western and central Cameroon (Michel Sezonlin, Gif sur Yvette, France, unpublished results).

Furthermore, in the coastal forest in Cameroon only, the relative importance of the three major stemborers species was similar to that of the neighbouring Nigeria (Schulthess et al. 1997) and coastal forest in French Congo (Bruno Le Rü, unpublished data) where *S. calamistis* was the major noctuid species. Schulthess et al. (1997) hypothesized that as a result of the destruction of forests and a concomitant increase of grassy habitats, the relative importance of the different borer species may have changed. As shown by the present study and work by Le Rü et al. (2006) the host plant range of *B. fusca* is very narrow. Thus, forest habitats, where grass abundance is generally very low (Ndemah et al. 2003), should favour stemborer species such as *B. fusca*, which do not depend on alternative host plants during the off-season, when maize is scarce, because they diapause in the larval stage inside dry maize stems. By contrast, non-diapausing species such as *S. calamistis* and *E. saccharina* should predominate in grassy habitats, because they are forced to switch to wild grasses during the off-season. This is corroborated by results from surveys by Ndemah et al. (2001b), which showed that during the second cropping season, *E. saccharina* was the predominant pest species on maize in roadside fields in degraded forest habitats while inside the forest at a distance from grassy habitats it was of minor importance. Furthermore, during the off-season in the forest zone of Cameroon, some maize is grown in

Table 5. *Parasitoids of lepidopteran stemborer larvae and pupae in three ecological zones of Cameroon*

	Species	Month	Locality	Host plant	Host	Host stage
Dip.: Tachinidae	*Actia* sp.	6, 10, 11, 12	Ak, Aw, Mv, Nkom, Bali, Kikai	Zm, Pp, Sa	Es, Bf, Sc, Ps	L
Dip.: Ceraphronidae	*Aphanogmus fijiensis* (Ferrière)	6, 7, 11, 12,	Nkom, Bali, Ak, Babungo	Zm, Sm, Pp	Bf, *Chilo* sp, Borer?	L, P
Hym.: Braconidae	*Bracon sesamiae* Cameron	7, 10, 12,	Mv, Nkom, Kakar, Ki	Zm, Pp	Bf, Ps, Borer?	L
Hym.: Chalcididae	*Chalcidid* sp.	12,	Mv	Zm	Borer? dam	
Hym.: Chloropidae	*Chloropid* sp.	10, 11,	Ak, Babungo	Zm, Pp	Bf, Ps	L
Hym.: Braconidae	*Cotesia sesamiae*	6, 7, 10, 11, 12	Ak, Mv, Nkol, Nkom, Manta'a, Bambuiy	Pp, Sm	Ps, Bq	L
Hym.: Ichneumonidae	*Dentichasmias busseolae* Heinrich	7, 12,	Mv, Obang	Zm	Borer?	L
Hym.: Braconidae	*Dolichogenidea fuscivora* Walker	7, 10	Bali, Nkom, Bam, Manta'a, Kishong, Ki	Zm, Pp	Borer? Ps	L
Hym.: Braconidae	*Dolichogenidea polaszeki* Walker	7, 10, 11	Nji, Nkom, Bali, Bamunka	Zm, Pp	Sc, Ps	L
Hym.: Braconidae	*Dolichogenidea* sp.	7	Bali	Zm	Borer?	L
Hym.: Ichneumonidae	*Enicospilus ruscus*	7	Nkom	Sa	Bf	L
Hym.: Bethylidae	*Goniozus indicus*	6	Babungo	Pp	Ps	L
Dip.: Tachinidae	*Linnaemyia longirostris*? (Meigen)	10, 12,	Nkom, Bam	Zm, Pp	Bf	L
Hym.: Braconidae	*Macrocentrus* sp.	6, 10	Bambuiy, Binka	Pp	Ps	P
Hym.: Braconidae	*Microgastrinae*	7, 10, 12,	Mv, Bali, Nji, Nkom, Babessi, Manta'a, Ki	Zm, Pp	Borer? Ps	L
Hym.: Eulophidae	*Pediobus furvus* Gahan	10	Nkom	Pp	Ps	P
Hym.: Ichneumonidae	*Procerochasmias nigromaculatus* (Cameron)	6, 7, 8, 9, 10, 12	Ak, Mv, Nkom, Nko, Ba, Ki, Manta'a, Lower Mbot	Zm	Bf, Ps	P
Dip.: Tachinidae	*Prosenina* ?	7	Nkambe	Pp	From borer tunnel	P
Dip.: Sarcophagidae	*Sarcophagid* sp.	11,	Ak	Zm	Bf	L
Dip.: Tachinidae	*Siphona murina*	10, 11, 12,	Ak, Aw, Mv, Nji, Binka, Lower Mbot	Zm, Pp	Es, Bf, Ps	L
Dip.: Tachinidae	*Sturmiopsis parasitica* (Curran)	12	Nkom	Zm	Bf	L
Hym.: Ichneumonidae	*Venturia* sp.	7	Lower Mbot	Pp	Ps	L

Ak, Akometam; Aw, Awae; Mv, Mvoutessi; Nkom, Nkometou; Nko, Nkozoa; Nkol, Nkolbisson; Bam, Bamessing; Nji, Njinikom; Ki, Kitiwum; Kikai, Kikaikilaiki; Zm, *Zea mays*; Sm, *Setaria megaphylla*; Sa, Wild sorghum; Pp, *Pennisetum purpureum*; Pm, *Panicum* sp; Bf, *Busseola fusca*; Bq, *Busseola quadrata*; Sc, *Sesamia calamistis*; Es, *Eldana saccharina*; Ps, *Poeonoma serrata*; L, Larvae; P, Pupae.

inland valleys, which are inundated during the cropping season and where wild host plants abundance and diversity is higher than in the surrounding forest. Chabi-Olaye et al. (2006) showed that during the off-season, the proportion of *Sesamia* sp. in the inland valleys was much higher than on upland maize during the cropping season. Again, this suggests that in the humid lowland tropics of Central Africa, *Sesamia* spp. are adapted to grass-rich habitats while *B. fusca* is a forest species.

Stemborer pests were rarely found on the four grass species sampled. On wild hosts, the most common stemborer species were *P. serrata* on *P. purpureum* and *S. poephaga* on *S. arundinaceum*. Likewise, Gounou and Schulthess (2004) reported only two plant species as hosts of *B. fusca* in West Africa. Similar stemborer species compositions on wild grasses were reported by Le Rü et al. (2006) from East and Southern Africa. The present findings support the suggestion by Le Rü et al. (2006) that the wide range of host plants reported for *B. fusca* or/and its common occurrence on *P. purpureum* in the past (e.g. Polaszek 1998; Ndemah et al. 2000) was the result of misidentification of the stemborer species.

Grass abundance around a field was negatively correlated with stemborer infestations in the field corroborating results by Cardwell et al. (1997), Ndemah et al. (2003) and Gounou and Schulthess (2006).

Table 6. *Percent larval and pupal parasitism (number of parasitized larvae or pupae in parentheses) of lepidopteran stemborers species on maize and wild host plants in the first (June/July) and second (October–December) rainy season of 2005 in Cameroon*

Season	Ecozone	Host plant	Host species	Parasitoid species	% Parasitism
First	Forest	*Zea mays*	*Busseola fusca*	*Procerochasmias nigromaculatus*	1.47 (5)
				Bracon sesamiae	0.29 (1)
			Total		1.76
	Mid-altitude		*B. fusca*	*P. nigromaculatus*	0.73 (1)
				Microgastrinae	0.73 (1)
			Total		1.46
	High altitude		*B. fusca*	*Actia* sp.	0.15 (1)
				P. nigromaculatus	0.15 (1)
			Total		0.30
	Forest	*P. purpureum*	*P. serrata*	*Cotesia. sesamiae*	0.43 (1)
				B. sesamiae	0.86 (2)
			Total		1.29
		Sorghum arundinaceum	*Sesamia poephaga*	*Enicospilus ruscus*	0.97 (2)
	Mid-altitude	*P. purpureum*	*P. serrata*	*D. polaszeki*	0.22 (1)
				Goniozus indicus	0.22 (1)
			Total		0.44
	High altitude		*P. serrata*	*C. sesamiae*	0.15 (1)
				P. nigromaculatus	0.15 (1)
				Venturia sp.	0.15 (1)
			Total		0.45
Second	Forest	*Z. mays*	*B. fusca*	*Actia* sp.	1.57 (12)
				A. fijiensis	0.13 (1)
				B. sesamiae	0.13 (1)
				Chloropid sp	0.13 (1)
				L. longirostris?	0.13 (1)
				P. nigromaculatus	1.05 (8)
				Sarcophagid sp.	0.13 (1)
				S. parasitica	0.39 (3)
			Total		3.66
			E. saccharina	*Actia* sp.	4.8 (18)
				S. murina	0.53 (2)
			Total		5.33
	Mid-altitude		*B. fusca*	*Actia* sp.	1.65 (2)
				Sarcophagid sp.	0.83 (1)
				S. murina	0.83 (1)
			Total		3.31
			S. calamistis	*Actia* sp.	2.94 (1)
				D. polaszeki	2.94 (1)
			Total		5.88
	Forest	*P. purpureum*	*P. serrata*	*Actia* sp.	0.25 (3)
				C. sesamiae	0.17 (2)
				D. polaszeki	0.08 (1)
				D. fuscivora	0.08 (1)
				Microgastrinae	0.17 (2)
				P. furvus	0.08 (1)
			Total		0.83
		S. arundinaceum	*E. saccharina*	*Actia* sp.	16.67 (1)
		S. megaphylla	*B. quadrata*	*C. sesamiae*	6.45 (2)
			Chilo sp.	*A. fijiensis*	0.60 (1)
	Mid-altitude	*P. purpureum*	*P. serrata*	*C. sesamiae*	0.83 (1)
				Chloropid sp.	0.83 (1)
				D. fuscivora	1.65 (2)
				D. polaszeki	0.83 (1)
				Microgastrinae	1.65 (2)
				P. nigromaculatus	0.83 (1)
			Total		6.62
			B. fusca	*L. longirostris*?	0.83 (1)
	High altitude		*P. serrata*	*B. sesamiae*	0.76 (2)
				D. fuscivora	1.14 (3)
				S. murina	1.52 (4)
			Total		3.42

As also shown by Cardwell et al. (1997), *P. purpureum* was the only species that was negatively related to *B. fusca* densities. Alternative host of stemborers planted as border rows have been promoted as a means to control stemborers by various authors (Khan et al. 1997; Van den Berg et al. 2001; Ndemah et al. 2002). However, recent studies (Matama-Kauma et al. 2006; Ndemah et al. 2006) showed that the efficiency of this technology in reducing stemborer densities in crop fields is highly variable. Very likely, the amount of grasses planted around the field may not always be sufficient to have an effect and, as proposed by Ndemah et al. (2002), leaving wild habitats in the vicinity of crop fields intact rather than burning them every dry season might have more effect on pest populations in crops than planting grass border rows.

In the present study, larval and pupal parasitoid diversity was much higher than in the study by Ndemah et al. (2001a). However, they sampled maize and some *P. purpureum* patches only, while in the present study four grass species were included, though no parasitoids were obtained from stemborers in *Panicum* sp. Stemborers were very scarce on this grass species and, in general, parasitoid diversity tended to increase with host density.

In West Africa in areas with bimodal rainfall distribution, stemborer densities increase from the first to the second cropping season (Schulthess et al. 1997). By contrast, in the forest zone and highlands of Cameroon, *B. fusca* densities were lower in the second compared with the first season, while in the mid-altitude pest densities remained on a similar level. This corroborates results by Ndemah et al. (2001b) from surveys in the forest zone and mid-altitudes in the 1990s. In the forest zone, this decline was shown to be due to a rapid increase in egg parasitism at onset of the second season (Ndemah et al. 2003). In the mid-altitude and highlands, egg parasitism was not assessed in those nor the present surveys. However, in view of the low larval and pupal parasitism rates found on maize and wild grasses, it is speculated that they also play a role in the higher altitudes. Field studies are underway to assess the importance of egg parasitoids in those ecologies.

As also shown by Ndemah et al. (2001a) larval and pupal parasitization rates were generally very low except for the tachinid *Actia* sp. This tachinid was the most common parasitoid in field trials in the forest zone by Chabi-Olaye et al. (2005a) and surveys by Conlong (2001). By contrast in West and eastern Africa, *Actia* spp. are exceedingly rare. Jordan (1966 in Polaszek 1998) recorded *A. cuthbertsoni* Curran (Dipt.: Tachinidae) from *Chilo* '*zaleukos*' [= *Chilo zacconius* Bleszynski (Lep.: Crambidae)] in Sierra Leone while in East Africa it was reared from two *B. fusca* larvae only (Polaszek 1998). In many countrywide surveys of maize and sorghum fields in West Africa by Fritz Schulthess (unpublished data), *Actia* spp. were never recovered. By contrast, *S. parasitica*, which is common in West Africa and was the most common larval parasitoid of *S. calamistis* and *E. saccharina* in an 18-month field study in Benin (Saka Gounou, unpublished data) , was exceedingly rare and only obtained from three *B. fusca* larvae in the forest zone. Thus the parasitoid strain present in Cameroon may be avirulent and/or incompatible with local stemborer species. In contrast to the West African strain, which successfully parasitizes *S. calamistis*, *E. saccharina* and *B. fusca* (Obadiah Mucheru, ICIPE, Kenya, unpublished data) , *S. parasitica* from Zimbabwe successfully develops in *B. fusca* only (Chinwada et al. 2004). For those reasons, the West African strain was introduced into South Africa and released against *E. saccharina* on sugar cane (Conlong 2001). It would, therefore, be interesting to assess the performance of both the West African and Zimbabwean strains of *S. parasitica* on the stemborer species of this region. Similarly, *C. sesamiae*, which is the most common indigenous larval parasitoid of several noctuid and pyralid stemborers in East and Southern Africa (Walker 1994), was only obtained from *P. serrata* and *B. quadrata* feeding on *P. purpureum* and *S. megaphylla* respectively, and never from maize and *B. fusca*. Ndemah et al. (2003) obtained *C. sesamiae* from *P. purpureum* mostly, but only from eight larvae. The reasons for the general scarcity of *C. sesamiae* in western as compared with eastern Africa are not yet understood. In Kenya, *C. sesamiae* exists as two biotypes that differ in their ability to parasitize *B. fusca*. *Cotesia sesamiae* from western Kenya completes development in *B. fusca* larvae, hence it is virulent (Gitau et al. 2006), while in the coastal *C. sesamiae* biotype the eggs that are oviposited are encapsulated by haemocytes in *B. fusca* larvae, and hence it is avirulent. *Cotesia* sp. females inject polyDNA viruses (PDV) together with the egg at oviposition. The PDV genes are expressed in the host larvae, causing the destruction of haemocytes, thus preventing encapsulation of the eggs (Beckage and Gelman 2004). Recent studies revealed two types of PDVs that are distinguishable by CrV1 gene sequences (Dupas et al. 2006). One allele is found in viruses from coastal Kenya and the other one in viruses form inland Kenya with differences by seven nucleotide substitutions in the partial CrV1 gene sequences. Whether these differences cause a functional change from virulent to avirulent in *C. sesamiae* biotypes remain to be investigated. Furthermore, several mitochondrial clades of *B. fusca* have been described (Sezonlin et al. 2006) and it is not clearly understood whether or not the host contributes to variation in *C. sesamiae* parasitism. Lastly, *Cotesia* spp. are known to have a high genetic plasticity in terms of insect host suitability or preference for host plants (Mohyuddin et al. 1981; Carl 1982). Therefore, several virulent *C. sesamiae* strains from Kenya, which have been shown to be virulent to *B. fusca* (Gitau 2007), will be released in the humid forest zone of Cameroon and in the WH.

The results from the present surveys in Cameroon show that the stemborer species diversity in wild habitats is much higher than reported. Furthermore, there are at least two *B. fusca* populations in the country. Thus, there is a need for acceptability and suitability studies involving several virulent Kenyan *C. sesamiae* strains and the different host species and populations. It is hypothesized that the chances of establishment depend on the abundance of suitable hosts in a given locality. Thus, the findings may give some indications on the probability of a given parasitoid strain to establish in the different ecozones.

Acknowledgements

The authors thank Dr Nanqing Jiang for critically reviewing the manuscript and for producing the map. This study was funded by the German Federal Ministry for Economic Co-operation (BMZ).

References

Beckage NE, Gelman DB, 2004. Wasp parasitoid disruption of host development: implications for new biologically based strategies for insect control. Ann. Rev. Entomol. **49,** 299–330.

Bowden J, 1956. New species of African stem-boring Agrotidae (Lepidoptera). Bull. Ent. Res. **47,** 415–428.

Cardwell K, Schulthess F, Ndemah R, Ngoko Z, 1997. A systems approach to assess crop health and maize yield losses due to pests and diseases in Cameroon. Agric. Ecosyst. Environ. **65,** 33–47.

Carl KP, 1982. Biological control of native pests by introduced natural enemies. Biocontrol News Inf. **3,** 191–200.

Chabi-Olaye A, Nolte C, Schulthess F, Borgemeister C, 2005a. Relationships of intercropped maize, stem borer damage to maize yield and land-use efficiency in the humid forest of Cameroon. Bull. Ent. Res. **95,** 417–427.

Chabi-Olaye A, Nolte C, Schulthess F, Borgemeister C., 2005b. Effects of grain legumes and cover crops on maize yield and plant damage by *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) in the humid forest of southern Cameroon. Agric. Ecosyst. Environ. **108,** 17–28.

Chabi-Olaye A, Nolte C, Schulthess F, Borgemeister C, 2006. Relationships of soil fertility and stem borers damage to yield in maize-based cropping system in Cameroon. Ann. Soc. Entomol. France **42,** 471–479.

Chinwada P, Overholt WA, 2001. Natural enemies of maize stem borers on the highveld of Zimbabwe. Afr. Entomol. **9,** 67–75.

Chinwada P, Overholt WA, Omwega CO, Mueke JM, 2004. Biology of *Sturmiopsis parasitica* (Diptera: Tachinidae) and suitability of three cereal stem borers (Lepidoptera: Crambidae, Noctuidae) for its development. Ann. Entomol. Soc. Am. **97,** 153–160.

Conlong DE, 2001. Indigenous African parasitoids of *Eldana saccharina* (Lepidoptera: Pyralidae). Proc. SA Sug. Techn. Ass. **74,** 201–211.

Dupas S, Gitau CW, Le Rü B, Silvain JF, 2006. Single-step PCR differentiation of *Cotesia sesamiae* (Cameron 1891) and *Cotesia flavipes* Cameron 1891 (Hymenoptera: Braconidae) using polydnavirus markers. Ann. Soc. Entomol. France **42,** 319–323.

Gitau ACW, 2007. Geographic variation in development of *Cotesia sesamiae* (Hymenoptera: Braconidae) on Busseola fusca (Lepidoptera: Noctuidae) in Kenya: polydnaviruses and co-evolutionary dynamics. PhD Thesis. Kenyatta University, Nairobi.

Gitau CW., Dupas S, Ngi-Song AJ, Mbugi PJ, Schulthess F, 2006. Calyx fluid proteins of two *Cotesia sesamiae* (Hymenoptera: Braconidae) biotypes in Kenya. Implications to biological control of the stem borer *Busseola fusca* (Lepidoptera: Noctuidae). Ann. Soc. Entomol. France **42,** 433–441.

Gounou S, Schulthess F, 2004. Spatial distribution of lepidopterous stemborers on wild host plants in West Africa and its implications for sampling schemes. Afr. Entomol. **12,** 172–177.

Gounou S, Schulthess F., 2006. Effect of traditional rice/maize intercropping on population densities, crop damage and parasitism of stem-borers in Côte d'Ivoire. Afr. Plant Prot. **12,** 93–102.

Holloway JD, 1998. Noctuidae. In: African cereal stem borers: economic importance, taxonomy, natural enemies and control. Ed. by Polaszek A, CAB International, Wallingford, 79–86.

Jiang N, Zhou G, Overholt WA, Schulthess F, 2006. The synchrony of the stemborer and parasitoid populations of coastal Kenya. Ann. Soc. Entomol. France **42,** 381–388.

Kfir R, 1992. Selecting parasites for biological control of lepidopterous stalk borers in summer grain crops in South Africa. Redia **74,** 231–236.

Kfir R, 1995. Parasitoids of the African stemborer, *Busseola fusca* (Lepidoptera: Noctuidae) in South Africa. Bull. Ent. Res. **85,** 369–377.

Khan ZR, Chiliswa K, Ampong-Nyarko K, Smart LE, Polaszek A, Wandera J, Mulaa MA, 1997. Utilization of wild gramineous plants for the management of cereal stem borers in Africa. Insect Sci. Appl. **17,** 143–150.

Le Rü BP, Ong'amo GO, Moyal P, Muchugu E, Ngala L, Musyoka B, Abdullah Z, Kauma-Matama T, Lada VY, Pallangyo B, Omwega , CO , Schulthess F, Calatayud PA, Silvain JF, 2006. Diversity of lepidopteran stem borers on monocotyledonous plants in eastern Africa and the islands of Madagascar and Zanzibar revisited. Bull. Ent. Res. **96,** 555–563.

Matama-Kauma T, Schulthess F, Mueke JM, Omwega CO, Ogwang JA, 2006. Effect of wild grasses planted as border rows on stem borer infestations in maize in Uganda. Ann. Soc. Entomol. France **42,** 455–460.

Mohyuddin AI, Inayatullah C, King EG, 1981. Host selection and strain occurrence in *Apanteles flavipes* (Cameron) (Hymenoptera: Braconidae) and its bearing on biological control of graminaceous stem borers (Lepidoptera: Pyralidae). Bull. Ent. Res. **71,** 575–581.

Moyal P, 2006. History of the systematics of *Sesamia sensu lato* group of African noctuid stemborers of monocotyledonous plants. Ann. Soc. Entomol. France **42,** 285–292.

Moyal P, Le Rü B, 2006. From population to species: morphological and molecular diversity in east African stemborer species of the genus Manga Bowden 1956 (Lepidoptera: Noctuidae). Ann. Soc. Entomol. France **42,** 293–308.

Ndemah R, Schulthess F, 2002. Yield of maize in relation to natural field infestations and damage by lepidopterous borers in the forest and forest/savannah transition zones of Cameroon. Insect Sci. Appl. **22,** 183–193.

Ndemah R, Schulthess F, Poehling M, Borgemeister C, 2000. Species composition and seasonal dynamics of lepidopterous stemborers on maize and the elephant grass, *Pennisetum purpureum* (Moench) (Poaceae), at two forest margin sites in Cameroon. Afr. Entomol. **8,** 265–272.

Ndemah R, Schulthess F, Poehling HM, Borgemeister C, 2001a. Natural enemies of lepidopterous borers on maize and elephant grass in the forest zone of Cameroon with special reference to *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae). Bull. Ent. Res. **91,** 205–212.

Ndemah R, Schulthess F, Korie S, Borgemeister C, Cardwell KF, 2001b. Distribution, relative importance and effect of lepidopterous borers on maize yields in the forest zone and mid-altitude of Cameroon. J. Econ. Entomol. **94,** 1434–1444.

Ndemah R, Gounou S, Schulthess F, 2002. The role of wild grasses in the management of lepidopterous cereal stemborers on maize in western Africa. Bull. Ent. Res. **92,** 507–519.

Ndemah R, Schulthess F, Korie S, Borgemeister C, Poehling HM, Cardwell KF, 2003. Factors affecting infestations of the stalk borer *Busseola fusca* (Fuller) on maize in the forest Zone of Cameroon with special reference to scelionid egg parasitoids. Environ. Entomol. **32,** 51–60.

Ndemah R, Schulthess F, Nolte C, 2006. The effect of grassy field margins and fertilizer on soil water, plant nutrient levels, stemborer attacks and yield of maize in the humid forest of Cameroon. Ann. Soc. Entomol. France **42,** 461–470.

Ong'amo GO, Le Rü B, Dupas S, Moyal P, Calatayud PA, Silvain JF, 2006. Distribution, pest status and agroclimatic preferences of lepidopteran stemborers of maize and sorghum in Kenya. Ann. Soc. Ent. France **42,** 171–177.

Phiri GSN, 1995. Interaction of the spotted stem borer Chilo partellus (Swinhoe) with some alternative hosts and its larval parasitoid *Cotesia sesamiae* (Cameron) in Malawi. PhD thesis, Reading, UK.

Polaszek A, 1998. African cereal stem borers, economic importance, taxonomy, natural enemies and control. CAB International in association with the ACP-EU Technical Centre for Agricultural and Rural Co-operation (CTA). CABI, Wallingford, UK, 530.

SAS 1997. SAS Institute Inc., SAS/STAT Software: Changes and Enhancements through Release 6.12. SAS Institute Inc., Cary, NC, 1167.

Schulthess F, Bosque-Pérez NA, Chabi-Olaye A, Gounou S, Ndemah R, Goergen G, 1997. Exchange of natural enemies of lepidopteran cereal stem borers between African regions. Insect Sci. Appl. **17,** 97–108.

Sezonlin M, Dupas S, Le Rü B, Le Gall P, Moyal , P , Calatayud , PA , Giffard I, Silvain JF, 2006. Phylogeography and population genetics of the maize stalk borer *Busseola fusca* (Lepidoptera, Noctuidae) in sub-Saharan Africa. Mol. Ecol. **15,** 407–420.

Smithers CN, 1960. Some recent observations on *Busseola fusca* (Fuller) Lep.: Noctuidae) in southern Rhodesia. Bull. Ent. Res. **50,** 809–819.

Tams WHT, Bowden J, 1953. A revision of the African species of *Sesamia* Guenée and related genera (Agrotidae-Lepidoptera). Bull. Ent. Res. **43,** 645–678.

Van den Berg J, Rebe M, De Bruyn J, Van Hamburg H, 2001. Developing habitat management systems for gramineous stem borers in South Africa. Insect Sci. Appl. **21,** 381–384.

Walker AK, 1994. Species of Microgasterinae (Hymenoptera: Braconidae) parasitizing lepidopterous cereal stemborers in Africa. Bull. Ent. Res. **84,** 421–434.

Zhou G, Overholt WA, Mochiah MB, 2001. Changes in the distribution of lepidopteran maize stemborers in Kenya from the 1950s to 1990s. Insect Sci. Appl. **21,** 395–402.

Author's address: F. Schulthess (corresponding author), International Center of Insect Physiology and Ecology, PO Box 30772-00100 Nairobi, Kenya. E-mail: fschulthess@icipe.org