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Natural enemies of lepidopterous borers on maize and elephant grass in the forest zone of Cameroon

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Abstract

The importance, geographical and temporal distributions of parasitoids of lepidopterous borers on maize and elephant grass, *Pennisetum purpureum*, were assessed during surveys in farmers' fields in six villages and two on-station trials in the forest zone of Cameroon between 1995 and 1996. The borer species encountered were *Busseola fusca* (Fuller), *Sesamia calamistis* Hampson, *Eldana saccharina* Walker on both host plants, and *Mussidia nigrivenella* Ragonot on maize only. *Busseola fusca* was the predominant host accounting for 44–57% and 96% on maize and elephant grass, respectively, followed by *E. saccharina* on maize with 27–39%. Fifteen hymenopterous, two dipterous and one fungal species were found on these stem and cob-borers. Among those were six pupal, six larval, four egg, one larval–pupal parasitoid and four hyperparasitoids. The scelionid parasitoids *Telenomus busseolae* Gahan and *T. isis* Polaszek were found on *B. fusca* eggs in all locations. During the first season, mean egg parasitism was low and ranged between 3.1% and 27% versus 54–87% during the second season. Species belonging to the *Tetrastichus atriclavus* Waterston complex were recovered from all four borer species. The majority and most common larval and pupal parasitoid species belonged to the ingress-and-sting guild. Larval and pupal parasitism were very erratic and on more than 50% of the sampling occasions no parasitoids were recovered. Parasitoid diversity was higher on elephant grass than maize.

Introduction

Across Africa, the most important field pests of maize are lepidopterous stem and cob-borers belonging to the families of Noctuidae, Crambidae and Pyralidae. Reported yield losses range from 10 to 100% (see overview in Polaszek, 1998). The exchange or 'redistribution' of natural enemies between major geographical regions of Africa to control cereal stem-borers has been proposed by several authors (Rao, 1965; Mohyuddin & Greathead, 1970; Mohyuddin *et al*., 1981; Mohyuddin, 1991; Schulthess *et al*., 1997). Several candidates have been proposed including the tachinids *Sturmiopsis parasitica* Curran and *Descampsina sesamiae* Mesnil against *Eldana saccharina* Walker (Lepidoptera: Pyralidae) on sugarcane in South Africa, *Psilochalcis soudanensis* (Steffan) (Hymenoptera: Chalcididae) against *Chilo* spp. (Lepidoptera: Pyralidae) within eastern Africa, and the scelionid *Telenomus isis* Polaszek against the noctuid *Busseola fusca* (Fuller) in East and southern Africa. More recently, a coastal strain of the

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braconid larval parasitoid *Cotesia sesamiae* (Cameron) from Kenya was released and established on the noctuid *Sesamia calamistis* Hampson in southern Benin (Schulthess *et al.*, 1997) and *Sturmiopsis parasitica* was introduced from West into South Africa and released against *E. saccharina* on sugarcane in 1999 (Conlong, 2000).

Lists of natural enemies of stem-borers and their relative importance exist for various countries and cereal crops in West, East and southern Africa (Jerath, 1968; Mohyuddin & Greathead, 1970; Ingram, 1983; Conlong, 1990; Bosque-Pérez *et al.*, 1994; Kfir, 1995; Phiri, 1995) and the findings have been summarized by Polaszek (1998). For Central Africa, however, little is known about either the stem-borer species predominant in the different countries and ecozones or the role natural enemies play in controlling these pests. The present work presents data on the seasonal fluctuation of natural enemies of cereal stem-borers on maize and the wild host *Pennisetum purpureum* (Moench) (Poaceae) in the forest zone of Cameroon.

Materials and methods

Two 144 m^2 maize plots were planted at Minkomeyos and Nkolbisson in the forest zone close to Yaoundé (4°3′N, 11°36′E; fig. 1), during the first cropping season of 1995. At Minkomeyos, the maize field was planted next to a natural *P. purpureum* grass field during the last week in March, while at Nkolbisson, the maize plot was surrounded by *P. purpureum* and planted during the first week in May in a farmer's field. In the second cropping season, new maize was planted on the same plots during the third week of August at Minkomeyos, and during the first week of September at Nkolbisson respectively. The maize variety used was Cameroon Maize Series (CMS) 8704. Maize pockets were spaced at 75 cm between rows and 50 cm within rows, with two plants per pocket. Ten elephant grass tillers including lateral shoots or five maize plants were randomly taken per quadrant at each sampling date. The sample included dry maize stalks in the off-season during

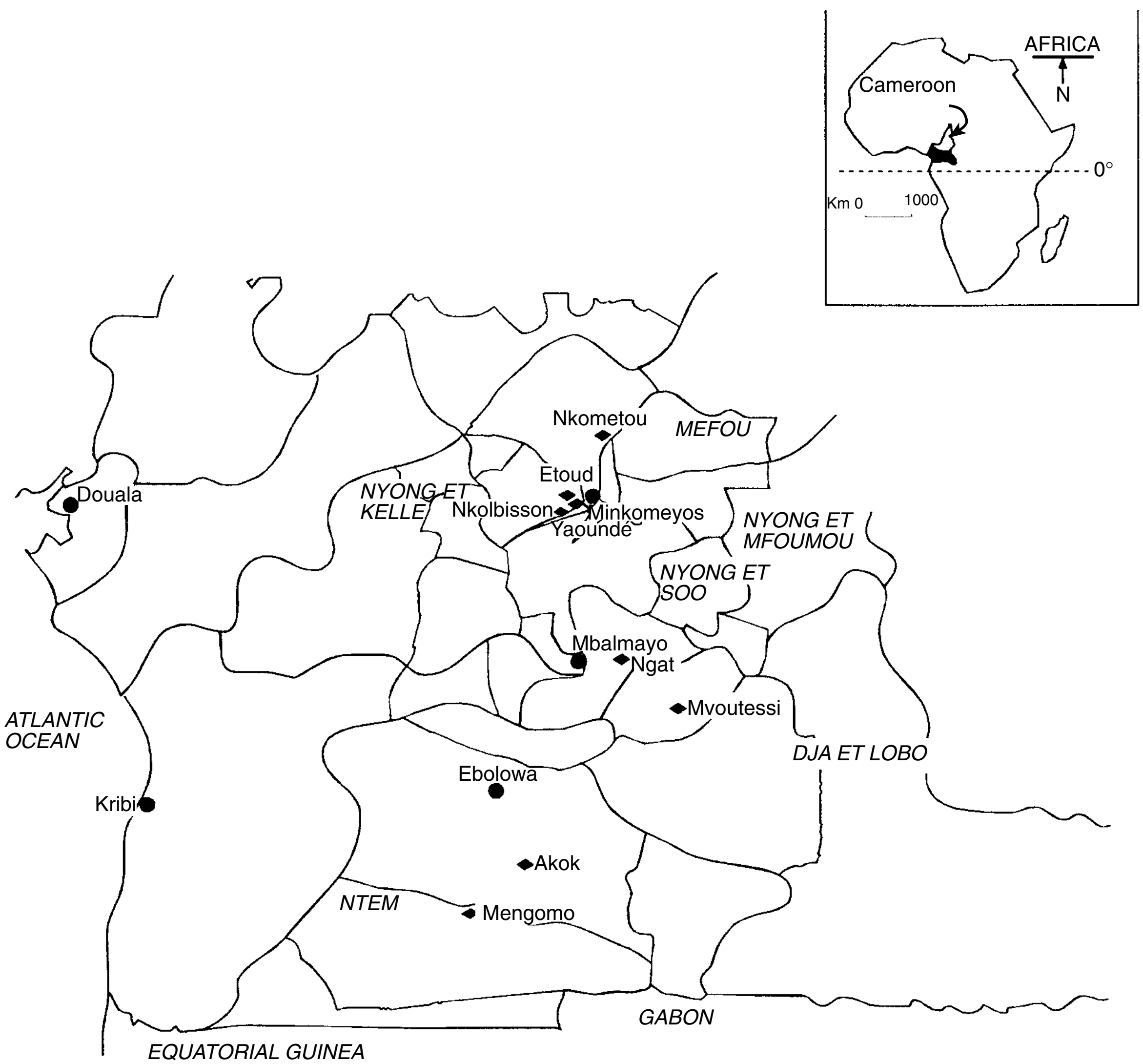

Fig. 1. Research villages (◆) and major urban centres (●) in the humid forest zone of Cameroon.

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the August dry spell and the main dry season lasting from the end of October 1995 to the end of March 1996. In addition, 148 farmers' fields from six villages in the forest zone (fig. 1) were visited once in the vegetative stage of maize during May/June, 1995 (first season crop), and October/November, 1995 (second season crop). In contrast to the Minkomeyos and Nkolbisson trials, these fields were situated inside the forest, i.e. 20–60 min walking distance from the next road, and wild host plants of stem-borers were scarce. Fifty maize plants per field were randomly sampled for *B. fusca* egg masses. Each egg batch was placed individually in a round plastic container and kept in the laboratory for six weeks during which either larvae or parasitoids had emerged and died (Sétamou & Schulthess, 1995). The numbers of eggs and of emerged parasitoids per egg batch were counted. The percentage parasitism was assessed from the total number of parasitized eggs including non-emerged parasitoids. All parasitoids collected were preserved in 70% alcohol. *Telenomus* spp. (Hymenoptera: Scelionidae) were sexed and identified using the keys by Polaszek *et al*. (1993). For assessment of larval and pupal parasitoids, 15 plants per field were randomly selected at the time of maize harvest during both seasons, as well as once after harvest during the August dry spell in 1995 and the dry season in February 1996. All borer larvae and pupae were identified according to species. At each sampling date the larvae of the same species from the same quadrant or field per location were counted and placed together in wide-mouthed jars. Larvae were maintained on a diet of young succulent stem and ear pieces of maize. They were reared until pupation or parasitoid emergence. When the diet was replaced, dead larvae were placed individually in small round plastic containers and kept in the laboratory for parasitoid emergence. Pupae and natural enemies' cocoons or pupae were kept individually in small round plastic containers for parasitoid or adult moth emergence. Parasitoids emerging from borer larvae and pupae were counted according to species and preserved in 70% alcohol for identification at the Insect Museum of the International Institute of Tropical Agriculture, Cotonou, Benin. For each sampling occasion, parasitism is presented according to parasitoid, borer and host plant species.

Results

Stem-borer and natural enemy species and guilds

The lepidopterous borer species encountered were, in order of predominance, *B. fusca*, *E. saccharina*, the ear boring pyralid *Mussidia nigrivenella* (Ragonot), and *S. calamistis*. In the Minkomeyos and Nkolbisson experiments, *B. fusca* accounted for 96.1% of all stem borer species on *P. purpureum* across sampling dates. On maize the species composition was 43.7% *B. fusca*, 27.2% *E. saccharina* and 16.5% *S. calamistis*. Similarly, in farmers' maize fields, *B. fusca* accounted for 57.3% of the borer population followed by 30.9% for *E. saccharina* and 1% for *S. calamistis*.

Fifteen hymenopterous and two tachinid parasitoids were found comprising six pupal, six larval and four egg parasitoids and one ichneumonid, *Enicospilus sesamiae* Delobel, obtained from both larvae and pupae (table 1). Two of the wasps, the eurytomid *Eurytoma braconidis* Ferrière and the ceraphronid *Aphanogmus reticulatus* (Fouts), were hyper-parasitoids. They emerged from one unidentified parasitoid host and from *Bracon sesamiae* Cameron (Hymenoptera: Braconidae) obtained from *Busseola fusca*. The species belonging to the *Tetrastichus atriclavus* Waterston complex (Hymenoptera: Eulophidae) were both parasitoids and hyperparasitoids and were not specific to one host (see Polaszek, 1998). The fact that so many parasitoid species were recovered from *B. fusca* reflects the predominance of this borer species in the forest zone of Cameroon (Cardwell *et al*., 1997). The only species found in all eight sites were the scelionid egg parasitoids *Telenomus busseolae* Gahan and *T. isis*. Species belonging to the *Tetrastichus atriclavus* complex were found at six sites and were the only parasitoids recovered from all four borer species.

The majority, as well as the most common larval and pupal parasitoid species belong to the ingress-and-sting guild (table 1; Smith *et al*., 1993). In this parasitoid guild, the parasitoid is attracted to the tunnel entrance by odour from hosts or frass, whereafter it enters the tunnel and attacks the host. As stem-borers are usually hidden deep inside the maize stem, the two tachinids *Actia* sp. and *Nemoraea* ? *discoidalis* Villeneuve probably belong to the planidial ingress guild, i.e. the female larviposits mobile, planidial, first-instar maggots at the tunnel entrance which search for the borer in the tunnel. The only parasitoid belonging to the drill-and-sting guild was *Bracon sesamiae*. In addition, two trichogrammatid parasitoids, *Lathromeris ovicida* (Risbec) and *Paracentrobia* sp. were collected in 1993 from *Busseola fusca* eggs on *P. purpureum* and maize, respectively (identified by Dr A. Polaszek, CAB International, Ascot, UK).

Temporal distribution of natural enemies of B. fusca *on elephant grass and maize in degraded forest*

During December to March both egg batches and *Telenomus* spp. egg parasitoids were scarce (table 2). Egg parasitism tended to increase from the first to the second growing season. There was no clear pattern according to host plant. *Pennisetum purpureum* had more egg batches and parasitoids during the second season at Minkomeyos, whereas at Nkolbisson, maize was the more important host plant during the first season.

Parasitoids were virtually absent during the dry season, when most *B. fusca* individuals diapause in the larval stage, and early parts of the first cropping season until June. During July and December larval and pupal parasitoids were more common, although during more than 50% of the sampling occasions no parasitoids were recovered. Parasitism was usually less than 15% and high rates were often based on one specimen per sampling date only. Seven parasitoid and one fungus species were obtained from *P. purpureum* vs. two species only from maize (table 2). With the exception of specimens of the *T. atriclavus* complex, all species were larval parasitoids. Eight *C. sesamiae* cocoon masses were recovered from *P. purpureum* and one from maize (table 2). Three *B. fusca* larvae infected with *Cordyceps* sp. (Sphaeriales: Clavicipitaceae) were obtained from *P. purpureum*. The remaining species were the tachinids *N.* ? *discoidalis* and *Actia* sp., the ichneumonids *Enicospilus sesamiae* Delobel and *Procerochasmias nigromaculatus* (Cameron), and the braconid *Bracon sesamiae*. The only other borer species yielding parasitoids was *S. calamistis* on maize, with one *B. sesamiae* and one *Actia* ? *antiqua* Mesnil (Diptera: Tachinidae in August 1995 (not shown in table 2).

Table 1. Parasitoid species of lepidopterous borers on two host plants in the forest zone of Cameroon.

Species	Order: Family	Month	Location	Host plant	Host	Guild	Host stage
Actia ? antiqua	Dip.: Tachinidae	2, 8, 12	Ng, Mv, Nk	*Zm*	*Es, Sc*	PI?	L
Antrocephalus crassipes	Hym.: Chalcididae	2	Mv	*Zm*	*Mn*	IS?	P
Aphanogmus reticulatus	Dip.: Ceraphronidae	12	Ng	*Zm*	*Bf, Bracon*		
Bracon sesamiae	Hym.: Braconidae	2, 9, 12	Ak, Et, Nk, Ng	*Pp, Zm*	*Mn, Bf, Sc*	DS	L
Cordyceps sp.	Sphaeriales: Clavicipitaceae	8, 10	Mi	*Pp*	*Bf*		L
Cotesia sesamiae	Hym.: Braconidae	7, 8, 11	Mi, Nk	*Pp, Zm*	*Bf*	IS	L
Enicospilus sesamiae	Hym.: Ichneumonidae	7, 10	Mi, Nko	*Zm*	*Bf*	IS?	L, P
Eurytoma braconidis	Hym.: Eurytomidae	12	Ng	*Zm*	*Bf, host?*		L
*Lathromeris ovicida**	Hym.: Trichogrammatidae	11	Mi	*Pp*	*Bf*	DA	E
Nemoraea? discoidalis	Hym.: Tachinidae	12	Mi	*Pp*	*Bf*	PI	P
Paracentrobia sp.*	Hym.: Trichogrammatidae	9	Mi	*Zm*	*Bf*	DA	E
Procerochasmias nigromaculatus	Hym.: Ichneumonidae	7, 9, 12	Mi, Nk, Ak, Et, Me	*Pp, Zm*	*Bf, Sc*	IS	P
Telenomus busseolae	Hym.: Scelionidae	1, 3, 5, 9, 10	Mi, Nk, Mv, Et, Ng, Me, Ak, Nko	*Pp, Zm*	*Bf*	DA	E
Telenomus isis	Hym.: Scelionidae	1, 3, 5, 9, 10	Mi, Nk, Mv, Et, Ng, Me, Ak, Nko	*Pp, Zm*	*Bf*	DA	E
Tetrastichus atriclavus	Hym.: Eulophidae	2, 7, 9, 12	Ak, Et, Nk, Nko, Ng, Mv	*Pp, Zm*	*Mn, Bf, Es, Sc*	IS	L, P
Tetrastichus sp.	Hym.: Eulophidae	7	Ak	*Zm*	*Bf, Sc*	IS	P
Trichospilus sp.	Hym.: Eulophidae	12	Ak	*Zm*	*Es*	IS	P

*Collected in 1993 and identified by A. Polaszek, CABI, Ascot, UK.
Ak, Akok; Ng, Ngat; Mi, Minkomeyos; Mv, Mvoutessi II; Nk, Nkolbisson; Et, Etoud; Me, Mengomo; Nkom, Nkometou III; *Pp, Pennisetum purpureum*; *Zm, Zea mays*; *Bf, Busseola fusca*; *Es, Eldana saccharina*; *Sc, Sesamia calamistis*; *Mn, Mussidia nigrivenella*; E, eggs; L, larvae; P, pupae; IS, ingress-and-sting; DA, direct attack; PI, planidial ingress; DS, drill-and-sting.

Table 2. Parasitism of *Busseola fusca* immature stages on two host plant species at two forest margin locations between April 1995 and March 1996.

Location	Host plant	Host and parasitoid species	% of *B. fusca* eggs, % and number ( ) of borer larvae and pupae parasitized											
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
		***B. fusca* eggs**												
Minkomeyos	*Pennisetum purpureum*	*Telenomus* spp.	–	–	–	–	0	27.2	74.9	57.1	0	46.2	–	–
	Zea mays	*Telenomus* spp.	–	100.0	–	–	–	–	43.9	0	–	–	–	–
Nkolbisson	*P. purpureum*	*Telenomus* spp.	–	–	0	–	0	11.5	100.0	66.7	–	–	–	–
	Z. mays	*Telenomus* spp.	–	13.0	33.3	24.2	92.6	–	30.0	100.0	–	–	–	–
		***B. fusca* larvae and pupae**												
Minkomeyos	*P. purpureum*	*Cordyceps* sp.	0	0	0	0	5.9 (2)	0	0.4 (1)	0	0	0	0	0
		Cotesia sesamiae	0	0	0	4.6 (1)	2.9 (1)	0	0	3.3 (4)	0	0	0	0
		Nemoraea discoidalis	0	0	0	0	0	0	0	0	3.5 (2)	0	0	0
		Procerochasmias nigromaculatus	0	25.0 (1)	0	0	0	0	0	0	0	0	0	0
		Total parasitism	**0**	**25.0 (1)**	**0**	**0**	**8.8 (3)**	**0**	**0.4 (1)**	**3.3 (4)**	**3.5 (2)**	**0**	**0**	**0**
	Z. mays	*Enicospilus sesamiae*	0	0	0	0	0	0	1.6 (1)	0	0	0	0	0
		C. sesamiae	0	0	0	4.4 (1)	0	0	0	0	0	0	0	0
		Total parasitism	**0**	**0**	**0**	**4.4 (1)**	**0**	**0**	**1.5 (1)**	**0**	**0**	**0**	**0**	**0**
Nkolbisson	*P. purpureum*	*Tetrastictius atriclavus* complex	–	0	0	0	0	12.5 (1)	0	0	0	0	0	0
		C. sesamiae	–	0	0	3.5 (1)	16.7 (1)	0	0	0	0	0	0	0
		Bracon sesamiae	–	0	0	0	0	0	0	0	25.0 (1)	0	0	0
		Total parasitism	**–**	**0**	**0**	**3.5 (1)**	**16.7**	**12.5 (1)**	**0**	**0**	**25.0 (1)**	**0**	**0**	**0**
	Z. mays	*C. sesamiae*	–	0	0	0	50.0 (1)	0	0	0	0	0	0	0
		Total parasitism	**–**	**0**	**0**	**0**	**50.0 (1)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Number of parasitized larve or pupae in parentheses. –, No host found.

Seasonality of stem-borer parasitoids in forest fields

Busseola fusca *egg parasitism*

Egg parasitoids were the most common natural enemies of *B. fusca* and found in all locations, although during the first season they did not occur in all fields (table 3). During the first season, mean parasitism was low ranging from 3.1% at Nkometou III and 26.6% at Etoud (table 3). *Telenomus busseolae* was the dominant species in all the locations except Etoud. Only two locations had both *Telenomus* species. During the second season, parasitism increased considerably in all the locations with means ranging from 54% at Etoud to 87% at Mengomo. Egg parasitoids were found in all fields (table 3) and *T. busseolae* was always the predominant species accounting for 66–88%. The percentage of fields with both *Telenomus* species was again very low, i.e. less than 5%.

Larval and pupal parasitism

In Ngat no parasitoids were recovered until the second cropping season and the dry season, whereas in Mvoutessi II they were found only during the dry season (table 4). In contrast, in the other locations, they were virtually absent during the dry season. Most species found in forest fields were pupal parasitoids. During the August dry spell and the dry seasons, most parasitoids were collected from *Eldana saccharina* and *M. nigrivenella* whereas during the cropping season most were obtained from *B. fusca* followed by *E. saccharina* and *M. nigrivenella* which reflects the predominance of the individual borer species. The most common species on *B. fusca* were of the *Tetrastichus atriclavus* complex and *P. nigromaculatus*. The former was also recovered from *E. saccharina, M. nigrivenella* and *S. calamistis*, and the latter from *S. calamistis* (table 4). *Actia* sp. was obtained from *E. saccharina* and *Bracon sesamiae* from *Busseola fusca* mainly and from one *M. nigrivenella* larva, and the chalcidid *Antrocephalus crassipes* Masi from a *M. nigrivenella* pupa. Generally, larval and pupal parasitism was <5%, irrespective of borer species.

Discussion

The natural enemy fauna of *B. fusca* was richer on *P. purpureum* than on maize. Because of its non-determinant growth pattern and, thereby, continuous availability of plant parts suitable for oviposition and growth and development of immatures, *P. purpureum* is a much more stable habitat for both pests and natural enemies than maize. Also, the accessibility of the insect hosts may vary with plant species. On *P. purpureum*, *B. fusca* was the most common species and was found mainly in the whorl leaves and inside the stem below the whorl (Ndemah, 1999); only a few older instar larvae were found deeply embedded in older stems. By contrast, on maize the larvae were mostly found in the whorl leaves during the vegetative stage and well-protected in the stem or ear during the crop maturation phase. Thus, it is possible that because of the higher accessibility of the host, larval parasitoids were more common on *P. purpureum*. By contrast, on maize in the forest mainly, where grasses are scarce, pupal parasitoids predominated. Stem-borers pupate close to the tunnel exit or even partly outside the stem (Smith *et al*., 1993), which increases their accessibility to parasitoids.

In south Benin, where derived savanna predominates, *Telenomus busseolae* and *T. isis* are important natural control factors of *S. calamistis* on maize (Sétamou & Schulthess, 1995). At the onset of the second season, mean parasitism was more than 90% (Schulthess *et al*., 1997). In the present work, parasitism of *B. fusca* eggs was considerably lower. *Sesamia calamistis*, however, produces eggs throughout the year and therefore availability of host eggs during the off-season is assured. Bosque-Pérez *et al*. (1994) and Schulthess *et al*. (1997) commonly found both *T. busseolae* and *T. isis* on *S. calamistis* during the dry season in Nigeria and Benin, respectively. By contrast, most *B. fusca* individuals diapause as larvae during the dry season (Adeyemi, 1969) and hosts for the parasitoids become scarce. This may explain the low and erratic egg parasitism in farmers' fields during the first cropping season. During the second season, however, the rates increased to more than 60% in most locations and, 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. Cameroon is the only country outside West Africa from which *T. isis* has been reported (Polaszek, 1998). The present study and results by Schulthess *et al*. (1997) and Ndemah (1999) suggest that both species are needed to have an impact on noctuid

Table 3. Percentage egg parasitism of *Busseola fusca*, sex ratio and species composition of emerged parasitoids at six locations in the forest zone of Cameroon, during first and second cropping seasons of 1995.

Season	Location	Parasitism		Relative importance		
		Mean	Range	*Telenomus busseolae*	Mixed	*T. isis*
First	Ngat	24.1	1.4–57.1	100.0	0.0	0.0
	Mvoutessi II	12.9	0–60.7	86.7	0.0	13.3
	Nkometou III	3.1	0–22.8	100.0	0.0	0.0
	Etoud	26.6	0–57.1	37.2	10.0	52.8
	Mengomo	14.3	0–61.9	100.0	0.0	0.0
	Akok	22.7	0–100.0	62.9	8.8	28.2
Second	Ngat	63.6	33.6–89.8	65.6	3.2	31.2
	Mvoutessi II	65.4	42.9–92.5	66.6	1.2	32.2
	Nkometou III	61.3	24.4–85.2	76.6	4.8	18.6
	Etoud	54.4	32.1–82.3	72.2	3.1	24.7
	Mengomo	87.4	58.0–100.0	74.5	0.0	25.5
	Akok	55.6	26.3–82.4	88.3	0.0	11.7

'Mixed' refers to the percentage of fields having both parasitoids.

Table 4. Percentage and number of lepidopterous borer larvae and pupae parasitized on maize in six locations at harvest during the first and second cropping seasons of 1995, and the August dry spell and dry season of 1995.

Location	Borer	Parasitoid species	1st Season	Dry spell	2nd Season	Dry season
Ngat	*Bf*	*Eurytoma braconidis*			1.1 (1)	0
		Bracon sesamiae			1.1 (1)	4.4 (1)
	Es	*Tetrastichus atriclavus* complex			0.8 (1)	0
		Actia ? antiqua			0.8 (1)	0.5 (1)
	Mn	*T. atriclavus* complex				0.9 (3)
Mvoutessi II	*Es*	*A. ? antiqua*				1.1 (2)
	Mn	*T. atriclavus* complex				3.9 (4)
		Antrocephalus crassipes				1.0 (1)
Nkometou III	*Bf*	*Procerochasmias nigromaculatus*			3.0 (2)	
		Enicospilus sesamiae	0.2 (1)		0	
	Mn	*T. atriclavus* complex				2.4 (1)
Etoud	*Bf*	*B. sesamiae*		3.6 (4)		
		T. atriclavus complex	0.7 (2)			
		P. nigromaculatus			1.6 (1)	
	Es	*T. atriclavus* complex	6.3 (1)			
	Sc	*T. atriclavus* complex			100.0 (1)	
	Mn	*T. atriclavus* complex		9.1 (2)	25.0 (1)	
Mengomo	*Bf*	*P. nigromaculatus*		2.4 (1)	8.3 (1)	
Akok	*Bf*	*Tetrastichus* sp.	1.8 (3)			
		B. sesamiae		2.3 (1)	3.1 (1)	
		P. nigromaculatus	0.6 (1)			
	Es	*Trichospilus* sp.			1.3 (1)	
	Sc	*Tetrastichus* sp.	25.0 (1)			
		P. nigromaculatus				100.0 (1)
	Mn	*T. atriclavus* complex		6.8 (6)	66.7 (2)	
		B. sesamiae		1.1 (1)		

Number of parasitized larvae or pupae in parentheses. *Bf, Busseola fusca; Es, Eldana saccharina; Mn, Mussidia nigrivenella; Sc, Sesamia calamistis.*

stem-borers, emphasizing the suitability of *T. isis* as a potential biocontrol candidate against *B. fusca* in eastern Africa, where it does not exist.

The most common parasitoids in farmers' fields, besides *Telenomus* spp., belong to the *Tetrastichus atriclavus* complex, which attack both larval and pupal stages (Boucek, 1988). They can be both primary and hyperparasitoids and were recovered from all borer species. The predominance of this species complex is not surprising. Given the insular character of forest fields and the scarcity of alternative host plants, the most successful strategy would be facultative hyperparasitism, combined with low specificity for life stage and host. A species specific to *B. fusca* would have little chance of establishing itself, since cues needed for host finding such as frass or synomones emitted by the damaged plant (Kajita & Drake, 1969; Mohyuddin, 1971; van Leerdam *et al.*, 1985; Potting *et al.*, 1995) are not produced during the off season when the borer diapauses in the larval stage. This could explain why hardly any parasitoids were obtained from *B. fusca* during the dry seasons (tables 2 and 4). By contrast, the other species common in the forest area do not diapause and *E. saccharina* was found feeding in dry maize stems long into the dry season (Conlong, 2000). *Tetrastichus atriclavus* was not found in collections from Nigeria, Benin or Ghana (Shanower *et al.*, 1991; Bosque-Pérez *et al.*, 1994; Gounou *et al.*, 1994; M. Botchey, Cape Coast, Ghana and D. Conlong, SASEX, South Africa, unpublished data), but was the predominant parasitoid of *B. fusca* in forest localities in Côte d'Ivoire (Moyal, 1998).

In East and southern Africa, *C. sesamiae* is the most commonly recovered larval parasitoid of *B. fusca*, *Chilo* spp. and *S. calamistis* (Ingram, 1958; Mohyuddin & Greathead, 1970; Kfir, 1992; Kfir & Bell, 1993). Overholt *et al*. (1997) reported that in Kenya, parasitism was typically less than 0.5% whereas in South Africa parasitism of *B. fusca* on sorghum was found to be as high as 75%, and *Cotesia sesamiae* is thought to keep *S. calamistis* under control (Kfir & Bell, 1993; Kfir, 1995). In the 1995/96 field trials, only eight *Cotesia sesamiae* cocoon masses were recovered from *P. purpureum* and one from maize (table 2) while the parasitoid was not recovered from any of the maize fields in forest villages (table 4). Similarly, in 1993, the parasitoid was found only on *P. purpureum* (R. Ndemah, unpublished data). This corroborates results from country-wide surveys on maize carried out in several West African countries which showed that *C. sesamiae* was exceedingly rare in all wet and humid ecozones (Bosque-Perez *et al.*, 1994; Gounou *et al.*, 1994; Moyal, 1998; Conlong, 2000). *Cotesia* spp. are known to have a high genetic plasticity in terms of host suitability or host plant preference (Mohyuddin *et al*. 1981; Carl, 1982; Hailemichael *et al.*, 1997). In Benin and Nigeria, the International Institute of Tropical Agriculture (IITA) is investigating the feasibility of using East African strains of *C. sesamiae* against *S. calamistis* and *B. fusca*, and a coastal strain from Kenya is being recovered in southern Benin since its release in 1994 (see Schulthess *et al.*, 1997).

Actia spp. are relatively rare larval parasitoids of stem-borer species mainly in East Africa (Polaszek, 1998). In West Africa, none has ever been recorded in the various surveys carried out by IITA scientists, although Jordan (1966 in Polaszek, 1998) recorded *Actia cuthbertsoni* Curran (Diptera: Tachinidae) from *Chilo* 'zaleukos' (=*Chilo zacconius* Bleszynski (Lepidoptera: Crambidae)) in Sierra Leone. Nonveiller (1984) reported *A.* ? *antiqua* from

B. fusca, *S. calamistis* and *E. saccharina* on maize at Nkolbisson, Cameroon. More recently, around 150 *Actia* sp. specimens were collected from *E. saccharina* in the same locations during the dry season of 1998 (D. Conlong, unpublished. data) with mean parasitism per location of 12–28%. *Actia* sp. has never been reported in South Africa and could be a redistribution candidate for *E. saccharina* on sugarcane.

In West Africa, no parasitoids were ever obtained from *M. nigrivenella* on annual crops such as maize, cotton, jackbean (*Canavalia ensiformis*), velvet bean (*Mucuna pruriens*) and *Phaseolus* (Moyal, 1988; Gounou *et al*., 1994) but *A. crassipes* was commonly found on *Gardenia* spp. (Rubiaceae) (Sétamou, 1999). In addition to the three parasitoid species found in the present study, Nonveiller (1984) collected *Syzeuctus* sp. (Hymenoptera: Ichneumonidae) from *M. nigrivenella*-infested maize ears at Nkolbisson, Cameroon. The most common species found in the present study belonged to the *T. atriclavus* complex, which, according to Polaszek (1998), comprises six species. Further studies are required to clarify the taxonomy of the species belonging to the *T. atriclavus* complex before any conclusions about their status as redistribution candidates can be drawn. Although several authors have shown the possible benefits of facultative hyperparasitoids as biological control agents (Ehler, 1979; May & Hassel, 1981; Cock, 1986) their introduction and use in biological control is a controversial practice (Ehler, 1979; Wesloh *et al*., 1979). However, as pointed out by Kfir & Bell (1993) a facultative hyperparasitoid should be evaluated according to whether its hyperparasitic behaviour is predominant or only occasional. Little information exists about the age class preferences of species of the *T. atriclavus* complex but in the present study most were obtained from borer pupae.

Most larval and/or pupal parasitoids found belong to the ingress-and-sting and in the case of tachinids probably to the planidial ingress guild (Smith *et al*., 1993). This is not surprising. In the large-stemmed maize plant the larvae and pupae are probably beyond the reach of the parasitoid ovipositor. Successful parasitization is only possible if a larva is close to the stem surface, about to migrate or pupate. Drill-and-sting parasitoids would be more successful on thin-stemmed grasses.

Earlier surveys in the forest zone of Cameroon, Côte d'Ivoire and Ghana showed a strong negative relationship between abundance of grasses in the vicinity of maize fields and borer incidence in the field (Cardwell *et al*., 1997; Schulthess *et al*., 1997; S. Gounou, IITA, Republic of Benin, unpublished data). Subsequent studies in the laboratory and greenhouse showed that some grass species were highly attractive to ovipositing female moths, although survival of immatures stages and adult moth fecundity were considerably lower than on maize (Shanower *et al*., 1993; Sekloka, 1996; Schulthess *et al*., 1997). It was concluded that some wild host species could act as trap plants. In addition and as indicated by Schulthess *et al*. (1997), because of the relative short duration of the maize crop in the field and its susceptibility to borer attacks (maize cannot compensate for stem damage by tillering), biological control of stem-borers most probably has to take place in the wild habitat, which serves as a reservoir for both pest and natural enemies during the off-season, as shown by Schulthess *et al*. (1997) for *Telenomus* spp. in Benin. The present findings also suggest that an increase in grass abundance may also increase the activity of larval parasitoids such as *C. sesamiae* and other species belonging to the drill-and-sting guild in the system. Thus it is theorized that the ever increasing deforestation and concomitant changes in the plant communities will change the pest status of stemborers in the humid forest zone of Cameroon.

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References

Adeyemi, S.A.O. (1969) The survival of stem borer population in maize stubble. *Bulletin of the Entomological Society of Nigeria* **2**, 16–22.

Bosque-Pérez, N.A., Ubeku, J.A. & Polaszek, A. (1994) Survey for parasites of *Sesamia calamistis* (Lep.: Noctuidae) and *Eldana saccharina* (Lep.: Pyralidae) in southwestern Nigeria. *Entomophaga* **39**, 367–376.

Boucek, Z. (1988) *Australasian Chalcidoidea (Hymenoptera). A biosystematic revision of genera of 14 families, with a reclassification of species*. 832 pp. Wallingford, UK, CAB International.

Cardwell, K.F., 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. *Agriculture, Ecosystems and Environment* **65**, 33–47.

Carl, K.P. (1982) Biological control of native pests by introduced natural enemies. *Biocontrol News and Information* **3**, 191–100.

Cock, M.J.W. (1986) Requirements for biological control: an ecological perspective. *Biocontrol News and Information* **7**, 7–16.

Conlong, D.E. (1990) A study of pest-parasitoid relationships in natural habitats: an aid towards the biological control of *Eldana saccharina* (Lepidoptera: Pyralidae) in sugarcane. *Proceedings of the South African Sugar Technologists' Association* **64,** 111–115.

Conlong, D.E. (2000) Indigenous African parasitoids of *Eldana saccharina* (Lepidoptera: Pyralidae). *Proceedings of the South African Sugar Technology Association* **74**, in press.

Ehler, L.E. (1979) Utility of facultative secondary parasites in biological control. *Environmental Entomology* **8**, 829–832.

Gounou S., Schulthess, F., Shanower, T., Hammond, W.N.O., Braima, H., Cudjoe, A.R., Adjakloe, R., Antwi, K.K. & Olaleye, I. (1994) *Stem and ear borers of maize in Ghana*. *Plant Health Management Research Monograph* No. 4. 23 pp. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Hailemichael, Y., Schulthess, F., Smith, J.W. Jr & Overholt, W.A. (1997) Suitability of West African gramineous stemborers for the development of *Cotesia* species. *Insect Science and its Application* **17**, 89–95.

Ingram, W.R. (1958) The lepidopterous stalk borers associated with Graminae in Uganda. *Bulletin of Entomological Research* **49**, 367–383.

Ingram, W.R. (1983) Biological control of graminaceous stemborers and legume pod-borers. *Insect Science and its Application* **4**, 205–209.

Jerath, M.L. (1968) Parasites of sugarcane stemborers in Nigeria. *Journal of Economic Entomology* **61**, 435–436.

Jordan, F.J. (1966) *Report on an investigation into the presence and prevalence of rice stem-borers and their parasites in Sierra Leone, 1964–1965*. 47 pp. West African Rice Research Institute, Los Baños, Philippines.

Kajita, H. & Drake, E.F. (1969) Biology of *Apanteles chilonis* and *A. flavipes* (Hymenoptera: Braconidae), parasites of *Chilo suppressalis*. *Mushi* **42**, 163–179.

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. *Bulletin of Entomological Research* **85**, 369–377.

Kfir, R. & Bell, R. (1993) Intraseasonal changes in populations of the African maize stem borer, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae), in Natal, South Africa. *Revue de Zoologie Africaine* **107**, 543–553.

May, R.M. & Hassell, M.P. (1981) The dynamics of multiparasitoid–host interactions. *American Naturalist* **117**, 234–261.

Mohyuddin, A.I. (1971) Comparative biology and ecology of *Apanteles flavipes* (Cam.) and *A. sesamiae* Cam. as parasites of graminaceous borers. *Bulletin of Entomological Research* **61**, 33–39.

Mohyuddin, A.I. (1991) Utilization of natural enemies for the control of insect pests of sugar-cane. *Insect Science and its Application* **12**, 19–26.

Mohyuddin, A.I. & Greathead, D.J. (1970) An annotated list of the parasites of graminaceous stemborers in east Africa, with a discussion of their potential in biological control. *Entomophaga* **15**, 241–274.

Mohyuddin, A.I., Inayatullah, C. & King, E.G. (1981) Host selection and strain occurrence in *Apanteles flavipes* (Cameron) (Hymenoptera: Braconidae) and its bearing on biological control of graminaceous stem borers (Lepidoptera: Pyralidae). *Bulletin of Entomological Research* **71**, 575–581.

Moyal, P. (1988) *Les foreurs du maïs en zone des savanes de Côte-d'Ivoire. Données morphologiques, biologiques, écologiques. Essais de lutte et relation plante-insecte*. 368 pp. ORSTOM, collection 'Etudes et Thèses' , Paris.

Moyal, P. (1998). Infestation patterns and parasitism of the maize stalk borer, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae), in the Ivory Coast. *African Entomology* **6**, 289–296.

Ndemah, R. (1999) *Towards developing an integrated crop pest management strategy for the African stalk borer,* Busseola fusca *(Fuller) (Lepidoptera: Noctuidae) in maize systems in Cameroon*. 136 pp. PhD thesis, Hannover University, Faculty of Horticulture, Institute of Plant Diseases and Plant Protection, Germany.

Nonveiller, G. (1984) *Catalogue des insectes au Cameroun d'intérêt agricole*. 210 pp. Institut pour la Protection des Plantes, Mémoires XV, Beograd.

Overholt, W.A., Ngi-Song, A.J., Omwega, C.O., Kimani-Njogu, S.W., Mbapila, J., Sallam, M.N. & Ofomata, V. (1997) A review of the introduction and establishment of *Cotesia flavipes* Cameron in East Africa biological control of cereal stemborers. *Insect Science and its Application* **17**, 79–88.

Phiri, G.S.N. (1995) *Interaction of the spotted stem borer* Chilo partellus *(Swinhoe) with some alternative hosts and its larval parasitoid* Cotesia sesamiae *(Cameron) in Malawi*. 347 pp. PhD thesis, University of Reading, UK.

Polaszek, A. (1998) *African cereal stemborers; economic importance, taxonomy, natural enemies and control*. 530 pp. CAB International in association with the ACP-EU Technical Centre for Agricultural and Rural Co-operation (CTA).

Polaszek, A., Ubeku, J.A. & Bosque-Pérez, N.A. (1993) Taxonomy of the *Telenomus busseolae* species complex (Hymenoptera: Scelionidae) egg parasitoids of cereal stemborers (Lepidoptera: Noctuidae, Pyralidae). *Bulletin of Entomological Research* **83**, 221–226.

Potting, R.P.J., Vet, L.E.M. & Dicke, M. (1995) Host microhabitat location by the stemborer parasitoid *Cotesia flavipes*: the role of locally and systemically induced plant volatiles. *Journal of Chemical Ecology* **21**, 525–539.

Rao, V.P. (1965) Natural enemies of rice stem-borers and allied species in various parts of the world and possibilities of their use in biological control of rice stem-borers in Asia. *Commonwealth Institute of Biological Control and Technology Bulletin* **6**, 1–68.

Schulthess, F., Bosque-Pérez, N.A., Chabi-Olaye, A. Gounou, S., Ndemah, R. & Goergen, G. (1997) Exchange of natural enemies of lepidopteran cereal stemborers between African regions. *Insect Science and its Application* **17**, 97–108.

Sekloka, S. (1996) *Contribution a l'étude bioécologique de* Eldana saccharina *Walker (Lepidoptera: Pyralidae) sur* Zea mays *L. et les plantes hôtes alternatives*. Mémoires Ingenieur Agronom, Université National du Benin, Benin.

Sétamou, M. & Schulthess, F. (1995) The influence of egg parasitoids belonging to the *Telenomus busseolae* (Hymenoptera: Scelionidae) species complex on *Sesamia calamistis* (Lepidoptera: Noctuidae) populations in maize fields in southern Benin. *Biocontrol Science and Technology* **5**, 69–81.

Sétamou, M. (1999) *Ecology and management of* Mussidia nigrivenella *Ragonot (Lepidoptera: Pyralidae), a cob borer of maize in West Africa*. 131 pp. PhD thesis, University of Hanover, Germany.

Shanower, T., Schulthess, F. & Gounou, S. (1991) *Distribution and abundance of some stem and cob borers in Benin*. 18 pp. Plant Health Management Research Monograph No. 4. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Shanower, T.G., Schulthess, F. & Bosque-Pérez, N.A. (1993) The effect of larval diet on the growth and development of *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) and *Eldana saccharina* Walker (Lepidoptera: Pyralidae). *Insect Science and its Application* **14**, 681–685.

Smith, J.W. Jr., Wiedenmann, R.N. & Overholt, W.A. (1993) *Parasites of lepidopteran stemborers of tropical gramineous plants*. 89 pp. Nairobi, Kenya, ICIPE Science Press.

Van Leerdam, M.B., Smith, J.W. Jr & Fuchs, T.W. (1985) Frass-mediated, host finding behaviour of *Cotesia flavipes*, a braconid parasite of *Diatraea saccharalis* (Lepidoptera: Pyralidae*). Annuals of the Entomological Society of America* **78**, 647–650.

Weseloh, R.M., Wallner, W.E. & Hoy, M.A. (1979) Possible deleterious effects of releasing *Anastatus kashmirensis*, a facultative hyperparasite of the gypsy moth. *Environmental Entomology* **8**, 174–177.

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