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Evidence of the establishment of *Cotesia flavipes* (Hymenoptera: Braconidae), a parasitoid of cereal stemborers, and its host range expansion in Ethiopia

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Abstract

Three lepidopteran cereal stemborers, *Chilo partellus* (Swinhoe) (Crambidae), *Busseola fusca* Fuller, and *Sesamia calamistis* Hampson (Noctuidae) were collected from maize and sorghum in Ethiopia. The noctuid stemborers are indigenous to Africa while *C. partellus* is an introduced species from Asia. In 1999, the Asian stemborer parasitoid, *Cotesia flavipes* Cameron (Braconidae) was found to be widespread in Ethiopia, even though it had never been released in the country. In addition to attacking *Chilo partellus*, *Cotesia flavipes* was reared from *B. fusca* and *S. calamistis*. The origin of *C. flavipes* in Ethiopia may have been Somalia where it was released in 1997 near the border with eastern Ethiopia. Percent parasitism of borers by *C. flavipes* was higher in eastern Ethiopia than other surveyed regions, and parasitism was higher in 2000 than 1999. Parasitism was higher when cereals were intercropped with other plants and when wild grass hosts of stemborers were present.

Introduction

Maize and sorghum are important food crops in Ethiopia ranking second and third in terms of acreage after teff, and first and second in terms of yield per hectare, respectively (CSA, 1997). One of the constraints to maize and sorghum production is herbivory by lepidopteran stemborers. Four stemborers are reported to attack these crops in Ethiopia; the noctuids *Busseola fusca* Fuller, *Sesamia calamistis* Hampson, and *Sesamia nonagrioides botanephaga* Lefebvre and the crambid, *Chilo partellus* (Swinhoe) (Getu *et al.*, 2001). These stemborers are indigenous to Africa with the exception of *C. partellus*, which is of Asian origin and invaded Africa sometime before 1930, when it was first recorded in Malawi (Tams, 1932).

A high diversity of natural enemies attack lepidopteran stemborers in Ethiopia, including 20 parasitoids, 14 predators and seven pathogens (Getu *et al.*, 2001). Several of these natural enemies were reared from *C. partellus*, and yet the exotic borer still causes extensive damage to maize and sorghum. One of the parasitoids found attacking stemborers in Ethiopia was *Cotesia flavipes* Cameron (Hymenoptera: Braconidae), an exotic species introduced into Kenya in 1993 from Pakistan and India, and later into other countries in

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eastern and southern Africa, for biological control of *Chilo partellus* (Overholt, 1998). However, *Cotesia flavipes* was never released in Ethiopia. This paper reports on the establishment, geographical distribution, and parasitism caused by *C. flavipes* in Ethiopia.

Materials and methods

Surveys were conducted at 130 sites in 1999 and 2000 (fig. 1) in major maize and sorghum growing regions of northern, eastern, southern and western Ethiopia. The survey sites were the same in both years. Surveys were conducted at the vegetative and mature growth stages of the crops in 1999, while only at the mature growth stage in 2000. From each region, districts where maize and sorghum were grown were identified (CSA, 1997), and then two or three districts were randomly selected from the lists. Sorghum was not sampled in the western region as it is not grown there, and only sampled in the southern region in 2000. Ten plants were randomly selected from each field and cut at ground level. Plants were dissected, insects removed, tentatively identified and counted. The cropping system (monocropping and/or intercropping) of each field was recorded, as well as the presence or absence of grasses reported to be wild hosts elsewhere (*Pennisetum purpureum* (Schumach), *Sorghum verticilliflorum* (Steud), *Hyparrenia* spp. and *Sorghum vulgare* var. Sudanese Hitche (all Poaceae) (Khan *et al.*, 1997) in the field and within 100 m of the edges of the field.

Eggs, larvae and pupae of stemborers and parasitoid cocoons found in plants were taken to a laboratory and reared. Larvae were reared on either maize or sorghum stems, whereas eggs, pupae and parasitoid cocoons were kept in Petri dishes. Percent parasitism by *C. flavipes* was calculated in relation to the susceptible stages of the host (third and older instar larvae, Ngi-Song *et al.*, 1995) for each species of stemborer. Other parasitoids reared during the survey are reported elsewhere (Getu *et al.*, 2001). Proportional data were transformed to arcsine square root of the proportion, while count data were transformed to $\log_{10}$ prior to analyses. Coordinates were recorded using a Global Positioning System (GPS) and used in a Geographic Information System (GIS) for mapping the survey sites and distribution of *C. flavipes*. The Almanac Characterization Tool (ACT) (Corbett *et al.*, 2001) and ArcView (ESRI, 1992) were used for mapping.

Insect identifications were confirmed at the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya. The presence of *C. flavipes* in the collections was surprising, as the insect has never been released in Ethiopia. Thus, insect collections in Ethiopia at Melkasa Research Centre, Ambo Research Centre, Alemaya University of Agriculture and Bahidar Ministry of Agriculture were searched, and CAB International staff were requested to search The Natural History Museum collections in London to determine whether *C. flavipes* had previously been collected in Ethiopia. Voucher specimens from our collection were deposited at ICIPE, Melkasa Agricultural Research Centre and The Natural History Museum, London.

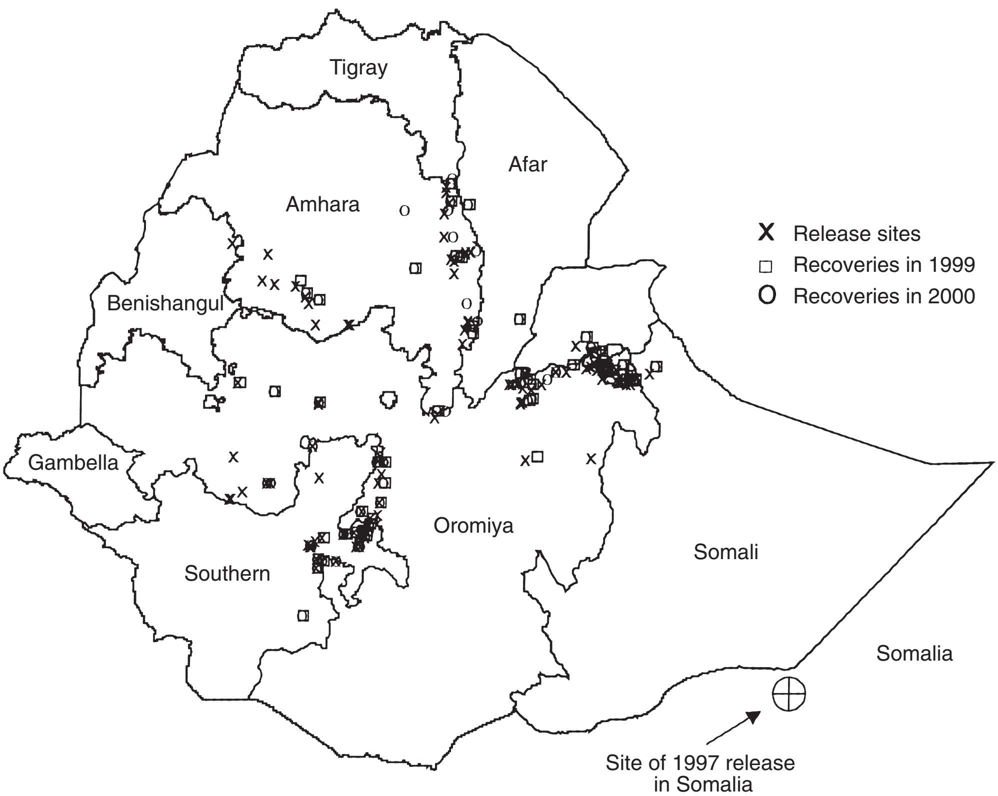

Fig. 1. Sampling sites and recoveries of *Cotesia flavipes* in Ethiopia in 1999 and 2000.

Results

Maize

Busseola fusca was found in maize in all surveyed regions in Ethiopia in both years, while *Chilo partellus* and *S. calamistis* were not found in western Ethiopia (table 1). Density of *B. fusca* was higher in eastern and western Ethiopia in maize than in other regions in 1999 ($F_{3, 126}$ = 59.76; $P < 0.006$), while it was highest in southern and western Ethiopia in 2000 ($F_{3, 126}$ = 115.38; $P < 0.01$). Density of *C. partellus* was not different in eastern, northern and southern regions in maize in 1999 ($F_{3, 126}$ = 56.04; $P < 0.009$) or in 2000 ($F_{3, 126}$ = 46.25; $P < 0.003$). Density of *S. calamistis* was higher in eastern Ethiopia in 1999 than in other regions ($F_{3, 126}$ = 14.58; $P < 0.009$), and equally high in maize in eastern and southern Ethiopia in 2000, but not present in the other regions ($F_{3, 126}$ = 39.20; $P < 0.01$).

Percent parasitism of *B. fusca* by *Cotesia flavipes* was higher in western and southern Ethiopia than in other regions in 1999 ($F_{3, 126}$ = 23.94; $P < 0.001$), and highest in maize in eastern and southern Ethiopia in 2000. In both years, percent parasitism of *Chilo partellus* in maize was higher in eastern and northern Ethiopia than other regions ($F_{3, 126}$ = 40.26; $P < 0.01$; $F_{3, 126}$ = 31.70; $P < 0.005$ for 1999 and 2000, respectively). Percent parasitism of *S. calamistis* in maize was higher in eastern Ethiopia in 1999 ($F_{3, 126}$ = 13.5; $P < 0.01$) and 2000 ($F_{3, 126}$ = 18.24; $P < 0.001$) than in other regions. Parasitism of the total stemborer complex in maize was significantly higher in eastern Ethiopia in 1999 ($F_{3, 126}$ = 88.27; $P < 0.01$) and 2000 ($F_{3, 126}$ = 117.68; $P < 0.0001$).

Sorghum

In sorghum, there was no difference in the density of *B. fusca* in eastern and northern Ethiopia in 1999 ($F_{1, 128}$ = 53.12; $P < 0.06$) or 2000 ($F_{2, 127}$ = 65.84; $P = 0.09$). The density of *C. partellus* was highest in northern Ethiopia compared to other regions in 1999 ($F_{1,128}$ = 58.87; $P < 0.04$) and highest in the southern region in 2000 ($F_{2, 127}$ = 73.32; $P < 0.002$). *Sesamia calamistis* density was higher in eastern Ethiopia than in other regions both in 1999 ($F_{1, 128}$ = 20.88; $P < 0.001$) and 2000 ($F_{2, 127}$ = 49.38; $P < 0.007$) (table 1).

Percent parasitism of *B. fusca, C. partellus* and *S. calamistis* in sorghum was higher in eastern Ethiopia than other regions in 1999 ($F_{1, 128}$ = 28; $P < 0.004$, $F_{2, 127}$ = 38.36; $P < 0.002$, $F_{1, 128}$ = 12.88; $P < 0.01$, respectively) and in 2000 ($F_{2, 127}$ = 31.28; $P < 0.001$, $F_{2, 127}$ = 38.36; $P < 0.001$, $F_{2, 127}$ = 8.88; $P < 0.002$, respectively) (table 1).

Cropping system, wild host, regional and temporal effects

Percent parasitism of the stemborer complex by *Cotesia flavipes* was higher in sorghum than in maize ($P < 0.05$). Parasitism was also higher in maize intercropped with other crops, such as haricot bean (*Phaseolus vulgaris* L.) and cowpea (*Vigna unguiculata* (L.), than in maize monocultures ($F_{1, 129}$ = 135; $P < 0.01$) and in the presence of the wild grasses (*Pennisetum purpureum*, *Sorghum verticilliflorum*, *Hyparrenia* spp. and *S. vulgare* var. Sudanese) than when no wild hosts were found ($F_{1,128}$ = 76.56; $P < 0.001$). Percent parasitism was higher ($F_{3, 126}$ = 97.73; $P < 0.01$) in eastern Ethiopia than in other regions (fig. 2) and increased three-fold (6% to 18%)

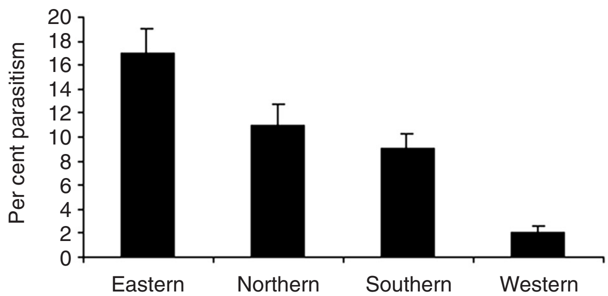

Fig. 2. Percent parasitism of the stemborer complex by *Cotesia flavipes* in different regions of Ethiopia.

Table 1. Mean density of stemborer per 10 plants (± SE) and mean percent parasitism (± SE) of stemborers by *Cotesia flavipes* in maize in Ethiopia (1999/2000).

Crop	Year	Region	*Busseola fusca*	*Chilo partellus*	*Sesamia calamistis*	% parasitism of *B. fusca*	% parasitism of *C. partellus*	% parasitism of *S. calamistis*	% total parasitism
Maize	1999	East	5.6±0.4b	9.2±0.4b	6.0±0.1c	1.0±0.02b	5.2±0.2b	1.0±0.02c	7.2±0.4c
		West	4.5±0.3b	0±0a	0±0a	2.3±0.1c	–	–	2.3±0.1a
		North	2.3±0.06a	11.0±0.4b	0.1±0.01a	0.4±0.01a	8.0±0.4b	0.0±0a	8.4±0.4c
		South	2.0±0.7a	8.0±0.1b	0.6±0.02b	2.0±0.09c	2.0±0.09a	0.1±0.002b	4.1±0.11b
	2000	East	13.0±0.6b	7.2±0.1b	3.7±0.01b	3.0±0.09c	10.6±0.5c	3.0±0.09c	16.4±1.3c
		West	26.4±1c	0±0a	0±0a	1.6±0.04b	0.0±0a	0.0±0a	1.6±0.04a
		North	0.7±0.02a	9.5±0.5b	0±0a	0.7±0.01a	11.0±0.02c	0.0±0a	11.0±0.04c
		South	25.7±1c	9.9±0.2b	4.6±0.1b	3.0±0.09c	5.0±0.2b	1.2±0.04b	9.2±0.5b
Sorghum	1999	East	12.6±0.4a	12.3±0.4a	2.8±0.1b	3.0±0.09b	7.1±0.04b	2.5±0.1b	12.1±0.7b
		West	–	–	–	–	–	–	–
		North	12.2±0.4a	23.0±1b	0.3±0.1a	0.50±0.01a	4.0±0.11a	1.0±0.04a	5.5±0.20a
		South	–	–	–	–	–	–	–
	2000	East	12.7±0.4b	13.9±0.4a	29.0±1b	5.6±0.20c	17.0±1.5c	4.0±0.11b	26.6±2.5c
		West	–	–	–	–	–	–	–
		North	8.6±0.2b	33.6±1b	0.0±0a	2.0±0.01b	12.8±0.7b	0±0a	14.8±1.2b
		South	0±0a	70.0±0.4c	0.0±0a	0±0a	8.1±0.2a	0±0a	8.1±0.02a

Means followed by the same letter in the same column, year and crop are not significantly different at 5% (HSD).

from 1999 to 2000 ($F_{1, 128}$ = 49.64 ; P = 0.006). Parasitism of *Chilo partellus* was significantly higher ($F_{2, 127}$ = 149; P = 0.009) than parasitism of *B. fusca* and *Sesamia calamistis* (fig. 3).

Cotesia flavipes was distributed in all surveyed regions of Ethiopia (fig. 1). In 1999, *C. flavipes* was found at 56 sites out of 130 sites surveyed, and in 2000 it was found at 75 sites out of 130 sites.

Discussion

Cotesia flavipes has never been purposely released in Ethiopia. The intention was to release the parasitoid in 2000 at selected sites based on surveys in 1999. However, in the survey conducted in 1999, *C. flavipes* was discovered at many sites (Getu *et al*., 2001). Surveys of stemborer natural enemies made in 1996, 1997 and 1998 in eastern, southern and western maize and sorghum growing areas of Ethiopia did not find *C. flavipes* (T. Abate, personal communication; Mullugetta, 2001). Moreover, *C. flavipes* was not found in museum collections in Ethiopia or the United Kingdom (A. Polaszek, personnal communication). The origin of *C. flavipes* in Ethiopia may have been Somalia, were releases where made in 1997 near Beledweyne on the Shebele river (Overholt, 1998), which is an area bordering eastern Ethiopia. This hypothesis is supported by higher parasitism by *C. flavipes* in eastern Ethiopia than in other regions. The other evidence for its recent invasion was the three-fold increase in percent parasitism from 1999 to 2000. This information, coupled with the absence of *C. flavipes* in the earlier collections, gives credence to the speculation that the parasitoid entered Ethiopia from Somalia. Alternatively, the parasitoid could have moved into Ethiopia from Kenya or Uganda in the south where it was also released (Overholt, 1998).

In the current study, it was found that *Chilo partellus* was the most heavily parasitized host, although 20% and 5% of *Cotesia flavipes* emerged from *B. fusca* and *S. calamistis*, respectively. The emergence of *C. flavipes* from *B. fusca* indicates the presence of a suitable biotype of *B. fusca* in Ethiopia. Earlier studies in Kenya (Ngi-Song *et al*., 1995) and West Africa (Hailemichael *et al*., 1997) indicated that *B. fusca* was not a suitable host of *C. flavipes*. In contrast, there are reports of *C. flavipes* parasitizing *B. fusca* in South Africa (Skoroszewski & van Hamburg, 1987), Uganda (Matama-Kauma *et al*., 2001) and Mozambique (Cugala *et al*., 1999).

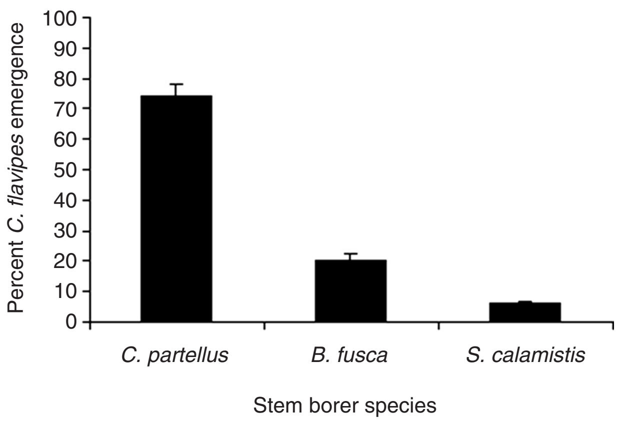

Fig. 3. Proportion of *Cotesia flavipes* emerged from *Chilo partellus*, *Busseola fusca* and *Sesamia calamistis*.

A higher percent parasitism of *C. flavipes* in sorghum than in maize could be explained by a density-dependent response to the higher abundance of *Chilo partellus* in sorghum as compared to maize. Interestingly, Ngi-Song *et al*. (1996) found that *Cotesia flavipes* was more attracted to maize than sorghum in host-finding experiments in the laboratory.

Root (1973) proposed the natural enemy hypothesis to explain differences in abundance of natural enemy populations in simple (monocrop) and diverse (intercrop) habitats, and postulated a greater functional and numerical response by parasitoids in diverse habitats due to a supply of alternative hosts, food and refuges. In the current study, the enemy hypothesis may explain the higher parasitism by *C. flavipes* in intercropping systems than in monocropped maize or sorghum. In Ethiopia, over 50% of the farmers grow maize or sorghum in an intercropped system with pulses and other crops (Getu *et al*., 2001). The fact that *C. flavipes* performed better in an intercropped system compared to monocultures could favour population growth of the parasitoid in Ethiopia.

Rische *et al*. (1983) found that vegetation in the proximity of crops significantly affected the abundance of natural enemies and the pest. In the current study, there was higher parasitism by *C. flavipes* when stemborer wild hosts were present in the vicinity of maize or sorghum, than where there were no wild hosts, implying that wild host plants sustain stemborers, which *C. flavipes* can exploit, especially when susceptible stemborer stages are not found in a crop stand (Overholt *et al*., 1997). In Ethiopia, over 60% of maize or sorghum fields were either surrounded by wild hosts or mixed with wild hosts as weeds (Getu *et al*., 2001).

In conclusion, *C. flavipes* was the most abundant natural enemy of stemborers and was distributed in eastern, northern, southern and western Ethiopia. It was reared from *Chilo partellus*, *B. fusca* and *S. calamistis*. The association of *Cotesia flavipes* and *Chilo partellus* is old, while its associations with *B. fusca* and *S. calamistis* are new. *Cotesia flavipes* is suppressing stemborer populations in some areas of Kenya where it has established (Zhou *et al*., 2001). It is expected that this will also happen in Ethiopia, and will be evaluated in the future. Additional work on physiological and ecological interactions between *C. flavipes*, its hosts and host plants may be useful for explaining the differential levels of parasitism reported here.

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Biological Control in the Tropics

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Biological control has been central to many recent successful integrated pest management programmes. It is also the natural choice where protection of the environment is particularly important. This book reviews current knowledge of biocontrol programmes in the tropics, particularly in developing countries. It is based on papers presented at a symposium held in Malaysia in March 1999. Contributors include authorities from Europe, North America and Australia, as well as from South-East Asia.