Natural enemies of the coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae) in Togo and Côte d'Ivoire, and other insects associated with coffee beans

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A search for natural enemies of the coffee berry borer, *Hypothenemus hampei* (Ferrari), was conducted in Togo and Côte d'Ivoire. Several strains of the fungal entomopathogens *Paecilomyces farinosus* (Holm ex SF Gray) Brown & Smith and *Beauveria bassiana* (Balsamo) Vuillemin were found in each country. This is the first report of *P. farinosus* infecting coffee berry borer. *Leptophloeus* sp. near *punctatus* (Coleoptera: Laemophloeidae) was observed preying on coffee berry borer larvae for the first time. *Cephalonomia stephanoderis* Betrem (Hymenoptera: Bethylidae) was the most abundant coffee berry borer parasitoid found in Côte d'Ivoire followed by *Phymastichus coffea* LaSalle (Hymenoptera: Eulophidae). Both species also occur in Togo, although in very low numbers, together with another parasitoid, *Prorops nasuta* Waterston (Hymenoptera: Bethylidae). Other insects emerging from coffee beans are also reported.

Key words: Scolytidae, *Hypothenemus hampei*, coffee berry borer, pathogens, coffee, parasitoids, biological control.

INTRODUCTION

The coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae) is a major pest of coffee throughout the world. Adult females bore into the fruit and feed on the endosperm while laying eggs in extensive excavated galleries. The damage caused by the adult, together with larval feeding, reduces the quality of the beans and sometimes also causes abscission of the fruit (Le Pelley 1968). The insect is endemic to Central Africa (Waterhouse & Norris 1989) but was first reported in the Neotropical Region in Brazil in 1926 (Le Pelley 1968), and has since spread to most coffee-growing areas in the world.

Insecticides have been used to manage the pest, but the insects have acquired resistance to endosulphan (Brun *et al.* 1990), the most efficient product to date. Insecticides are generally too expensive for use by small-scale growers who, in many areas, account for most of the of production (Nyambo *et al.* 1996). Because of escalating global concerns about pesticides, increasing interest is being shown in the use of biological control for coffee berry borer. Attempts have been made to curb the pest with mitosporic fungi such as *Beauveria bassiana* (Balsamo) Vuillemin (Hawksworth *et al.* 1996) and parasitoids including *Cephalonomia stephanoderis* Betrem (Hymenoptera: Bethylidae), particularly in southern México, Central America and Colombia (Barrera *et al.* 1990; Bustillo *et al.* 1991). To a lesser extent, work has been done on another mitosporic fungus, *Metarhizium anisopliae* (Metschn.) Sorokin (de la Rosa-Reyes *et al.* 1995), the parasitoids *Prorops nasuta* Waterston (Hymenoptera: Bethylidae) (Barrera *et al.* 1990) and *Phymastichus coffea* LaSalle (Hymenoptera: Eulophidae) (Feldhedge 1992). A fourth parasitoid, *Heterospilus coffeicola* (Hargreaves) (Hymenoptera: Braconidae) has potential as a biocontrol agent but is difficult to rear (Toledo-Piza & Pinto-da-Fonseca 1935).

The European Biological Control Laboratory (EBCL) in Montpellier, France, initiated a foreign exploration programme in Togo and Côte d'Ivoire in an attempt to discover new coffee berry borer pathogens with potential for use in biological control programmes in coffee-growing regions in America. Here we report on the pathogens and

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parasitoids found during this exploration, and on the associated entomofauna that emerged from coffee beans.

MATERIAL AND METHODS

Coffea canephora Pierre ex Fröhner (Robusta coffee) is the most widespread variety of cultivated coffee in West Africa. Small quantities of *Coffea arabica* L. is also grown, usually at higher altitudes. Exploration for natural enemies was conducted in January and February 1997. This is the inter-harvest period, which is less pronounced in the case of Robusta than Arabica coffee Nonetheless, extensive material was available because, for economic reasons, many producers had not harvested their coffee or had done so incompletely. All coffee plantations sampled in both countries were growing Robusta coffee, with the exception of one site in Togo (Danyi-Monastere) where Arabica was grown.

The identification and collection of coffee berries infested by the coffee berry borer was based on the characteristic hole bored by females near the terminal pore area. Some beans also revealed symptoms of attack from other insects. Beans in all stages of development that were attacked by coffee berry borer were collected, but most of them were black. Beans from each locality were placed in plastic containers covered with gauze for the duration of the trip and any moisture build-up within the container was dried with tissue paper. During the initial stages of the exploration, the beans that were collected each day were dissected the same night to assess for the presence of fungal entomopathogens. This technique was discontinued after two weeks owing to the lack of visible signs of pathogens and the intensive labour required. To assess for the presence of fungal entomopathogens, coffee berry borers that emerged from the beans were screened. Emergence took place in EBCL's quarantine facility, where beans were sealed in light-proof boxes with an illuminated vial to attract emerging insects. Insects were removed from the vial every second day and other than coffee berry borer were placed in gelatine capsules pending identification. To assess for fungal presence, Petri dishes with water agar (3.5 g/litre; Agar-agar powder, Labosi, Oulchy-le-Chateau, France) mixed with chloramphenicol (0.4 g/litre) were prepared. The dorsum of coffee berry borer's emerging from the beans was placed against the agar surface, and the plate was sealed with parafilm to maintain high humidity. Petri dishes were maintained at room temperature in the laboratory and examined at intervals for the presence of fungal entomopathogens.

Experiments also were conducted at the Institut de Recherches du Café et Cacao (IRRC), Kpalime, Togo, where insect emergence from large samples of infested coffee berries, from various locations, were monitored daily. All the additional insects were sent to EBCL for identification at the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), France.

RESULTS AND DISCUSSION

Of approximately 3000 coffee berry borers from several different localities placed in water agar, only 55 developed symptoms of fungal entomopathogen infection (<0.02 %). Levels below 1 % have been reported for *Beauveria bassiana* (Balsamo) Vuillemin infecting coffee berry borer in the field in México (Méndez-López 1990) and for *Fusarium avenaceum* (Fr.) Sacc., *Paecilomyces fumosoroseus* (Wize) Brown & Smith, and *Verticillium lecanii* (Zimmerman) Viegas in India (Balakrishnan *et al.* 1995). Nineteen coffee berry borers from Côte d'Ivoire developed *B. bassiana* symptoms of infection. These insects were collected from four localities: Ayenoua (90 m above sea level), Abengourou (205 m), Tombokro (130 m), and Bozi (150 m). One location in Togo (Gbadi-Gaodo; 520 m) yielded 23 insects with *B. bassiana* infection. *Beauveria bassiana* has been widely reported throughout the world infecting coffee berry borer (*e.g.* Brazil (Averna-Saccá 1930; Villacorta 1984), Cameroon (Pascalet 1939), Colombia (Bustillo *et al.* 1991; Varela & Morales 1996), Ecuador (Klein *et al.* 1988), India (Balakrishnan *et al.* 1995), Côte d'Ivoire (Ticheler 1961) and Thailand (Varela & Morales 1996)).

Eleven insects from Côte d'Ivoire (Abengourou) were infected with the mitosporic fungus *Paecilomyces farinosus* (Holm. ex S. F. Gray) Brown & Smith, whereas only two insects from Togo (Gbadi-Gaodo) were infected. This is the first report for this fungal entomopathogen infecting coffee berry borer. Other *Paecilomyces* species have been reported from coffee berry borer, *e.g.* *P. javanicus* (Friederichs & Bally) Brown & Smith in

Table 1. Insects that emerged from coffee beans in Togo.

Order	Family	Genus	Locality[1]
Hymenoptera	Bethylidae	*Prorops nasuta*	Gbadi-Gaodo (4)
	Bethylidae	*Cephalonomia stephanoderis*	Agotimékopé (2) Danyi-Asséssénini (2) Gbadi-Gaodo (5)
	Bethylidae	*Goniozus* sp.	Agotimékopé; Benali
	Braconidae	*Chelonus* sp.	Gbalivé
	Braconidae	*Bracon* sp.	Gbadi-Gaodo
	Braconidae	*Euvipio* sp.	Amon Obla; Elé
	Bethylidae	Not determined	Danyi-Elavagnon
	Elasmidae	*Elasmus* sp.	Danyi-Monastere
	Encyrtidae	*Coccidoctonus* sp.	Danyi-Koudzravi
	Eulophidae	*Phymastichus coffea*	Agotimékopé (6) Gbadi-Gaodo (5) Gbadi-N'Kougna (2) Zoumenu (1)
	Eulophidae	Not determined	Danyi-Koudzravi
	Eupelmidae	Not determined	Danyi-Elavagnon
	Eupelmidae	*Tineobius* sp.	Gbadi-N'Kougna
	Eurytomidae	*Eurytoma* sp.	Amon Obla; Danyi-Dzogibegan
	Mymaridae	*Polynema* sp.	Danyi-Koudzravi
	Pteromalidae	*Oxysychus* sp.	Danyi
Coleoptera	Apionidae	*Piezotrachelus* sp.	Gbalivé
	Cerambycidae	*Sophronica calceata*	Danyi-Asséssénini
	Corylophidae	*Clypeaster* sp.	Danyi-Koudzravi
	Cucujidae	*Cathartus quadricollis*	Agotimékopé Danyi-Asséssénini Gbadi-Gaodo Gbadi-N'Kougna
	Laemophloeidae	*Leptophloeus* sp. near *punctatus*	Benali (1) Danyi-Asséssénini (3)
	Nitidulidae	*Carpophilus dimidatus*	Amon Obla
Hemiptera	Anthocoridae	*Anthocoris* sp.	Gbalivé
	Lygaeidae	*Geocoris* sp.	Danyi-Koudzravi
Diptera	Tephritidae	*Trirhithrum coffeae*	Gbadi-N'Kougna

1: figures in brackets indicate the number of insects from each locality.

Indonesia (Friederichs & Bally 1923; Samson 1974), and *P. fumosoroseus* and *P. amoenoroseus* (Hennings) Samson in India (Balakrishnan *et al.* 1995). All fungal entomopathogen strains from Togo and Côte d'Ivoire have been deposited in the EBCL Fungal Entomopathogens Collection and in the U.S. Department of Agriculture Collection of Entomopathogenic Fungal Cultures in Ithaca, New York.

A marked characteristic of many of the coffee-growing areas in both Togo and Côte d'Ivoire is the infrequent cloud cover during the dry season. In most plantations in both countries, coffee is grown with little or no shade, but the cloud cover reduces excessive dehydration, scorching and premature exhaustion of the coffee trees. However, at the time of the study in Togo, the misty Harmatton wind was blowing, creating a secondary drying effect. Lower humidity levels (down to 27 % RH on the exposed Danyi Plateau) were recorded in Togo than in Côte d'Ivoire, where humidity measurements fell within the range of 72–92 %. These differences in relative humidity could explain the higher number of sites in Côte

Table 2. Insects that emerged from coffee beans collected in Côte d'Ivoire.

Order	Family	Genus	Locality
Hymenoptera	Braconidae	*Bracon* sp.	Man
	Bethylidae	*Cephalonomia stephanoderis*	Abengourou (92) Ayenoua (65) Broukro (97) Bilekro (21) Bozi (96) ORSTOM Stn at Man (10) Tombokro(19) Yakkasé-Mé (277)
	Ceraphronidae	*Aphanogmus reticulatus*	Yakkasé-Mé
	Encyrtidae	*Comperia alfierii*	Bilekro
	Encyrtidae	*Anagyrini* sp.	Bozi
	Eulophidae	*Phymastichus coffea*	Abengourou (30) Bozi (90) Tombokro(27) Yakkasé-Mé (1)
	Eulophidae	Not determined	Yakkasé-Mé
	Eulophidae	*Pediobius* sp.	Bozi
	Eupelmidae	*Eupelmus* sp.	Agotimékopé; Abengourou
	Pteromalidae	*Oxysychus* sp.	Broukro; Ayenoua
	Scelionidae	*Telenomus sechellensis*	Tombokro
Coleoptera	Anthribidae	*Araecerus coffeae*	Tombokro
	Cucujidae	*Cathartus quadricollis*	Abengourou Tombokro
	Laemophloeidae	*Leptophloeus* sp. near *punctatus*	Ayenoua (9) Abengourou (3) Bilekro (1), Bozi (11) ORSTOM Station (1) Tombokro (8) Yakkasé-Me (4)
	Laemophloeidae	*Planolestes* sp. near *brunneus*	ORSTOM Stn.
Hemiptera	Anthocoridae	Not determined	Abengourou
	Lygaeidae	*Geocoris* sp.	Tombokro

1: figures in brackets indicate the number of insects from each locality.

d'Ivoire with infected insects (ranging in elevation from 90–205 m) in contrast to only one site in Togo (at 520 m).

Even though we did not record the total numbers of beans collected at each site, the numbers of specimens of the known coffee berry borer parasitoids emerging from the collected beans is given in Tables 1 and 2 as an indication of their relative abundance. Sixteen different species of parasitic Hymenoptera emerged from beans collected in Togo (Table 1). Of these *P. nasuta*, *C. stephanoderis* and *P. coffea* are known to attack coffee berry borers and were found at very low levels (Table 1). *Cephalonomia stephanoderis* was discovered by Ticheler (1961) in Côte d'Ivoire whereas *P. coffea* was first collected in Togo in 1987 (Borbón 1989; LaSalle 1990). *Prorops nasuta* has already been recorded in Togo (Klein *et al.* 1988; Gálvez 1992). Eleven species of parasitic Hymenoptera emerged from beans collected in Côte d'Ivoire, including *P. coffea* and *C. stephanoderis*, of which the latter was far more abundant (Table 2). Because some beans had been attacked by other insects, we were not able to ascertain which (if any) of the remaining parasitic Hymenoptera originated from coffee berry borers.

In addition to the coffee berry borer, several other Coleoptera emerged from the beans, including *Carpophilus dimidiatus (Nitidulidae)*. Members of this genus are known to serve as vectors of phytopathogenic fungi in other crops (Dowd 1991). *Leptophloeus* sp. near *punctatus* Lefkovich (Coleoptera: Laemophloeidae) was collected in both countries (Tables 1, 2): this insect was observed during on-site dissection of coffee beans (G. Mercadier, unpubl.) to prey upon coffee berry borer larvae. This is the first report of this insect as a coffee berry borer predator. A relative of this insect, a European species, *L. clematidis* (Erichson), has been reported to prey on the scolytid *Xylocleptes bispinus* (Duftschmid), a *Clematis* stemborer (R.G. Booth, pers. comm.). Very few Hemiptera, mainly Anthocoridae and Lygaeidae, and only one fly, *Trirhithrum coffeae* Bezzi (Diptera: Tephritidae), emerged from the beans.

The entomopathogenic fungi from Togo and Côte d'Ivoire will be tested in laboratory bioassays against coffee berry borers. In addition, spore yields in liquid medium are currently being assessed in an attempt to identify a high-yielding strain that might be suitable for commercial formulations. Additional explorations will be conducted in several African countries; these might yield other natural enemies, including fungal entomopathogens, that could be useful in biological control programs.

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