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Progression in field infestation is linked with trapping of coffee berry borer, *Hypothenemus hampei* (Col., Scolytidae)

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Abstract: Phenology of the coffee plant and infestation by coffee berry borer *Hypothenemus hampei* Ferrari were studied in relation to trapping of adult females in kairomone-baited traps in a coffee plantation in New Caledonia. In a 0.4 ha coffee field, a group of 27 trees located along a transect beginning at an early infestation point was selected. The number of green, red and dry coffee berries, along with the number of larvae, adult males and females per berry was determined monthly from October 1993 to July 1994. Twelve, red multifunnel traps, each baited with a solution of methanol:ethanol (1:1 ratio, a mean solution release rate of 1 g/day) were placed within the coffee field, along the transect, within the selected trees, grouped in four zones named 1–4. Two additional traps were located outside the plantation.

The proportion of infested berries increased as berry maturity and harvest date approached, while the infestation rate decreased with distance from the epicentre. Over the 10 months of the study, beetle populations increased and spread from the original infestation point across the different zones, according to distance and availability of berries or appropriate physiological status. Traps near the epicentre caught the largest numbers of beetles. Linear relationship between trap catch and infestation level was demonstrated. Traps placed outside the field approached zero catch. Trap catch was highly influenced by rainfall events, and the highest captures coincided with rapidly declining berry numbers on trees. There are good prospects for management of this insect using traps.

1 Introduction

Coffee berry borer (*Hypothenemus hampei* Ferrari is a key pest of coffee in many countries (WATERHOUSE and NORRIS, 1989). Infestations can reach 90–100% of berries, causing total loss unless control measures are applied. The most effective insecticide is endosulfan, which remains an important pest management tool in many countries. Recently, there has been an increasing interest in alternative control measures (MURPHY and MOORE, 1990) following a high level of endosulfan resistance and consequent increases in pest status of coffee berry borer in New Caledonia (BRUN et al., 1989). This situation has led us to consider various aspects of the pest biology in managing infestation. These aspects include population genetics (GINGERICH et al., 1996), dispersal (GINGERICH, 1997; MATHIEU et al., 1997a) and host plant responses (GIORDANENGO et al., 1993; MATHIEU, 1995). Many factors are probably important in the development of pest populations, including frequency of flowering events, berry availability, temperature, humidity, rainfall, and sunlight (BAKER et al., 1992a, b; MATHIEU et al., 1997a).

In New Caledonia, coffee berry phenology varies between locations and varieties. For *Coffea canephora* Pierre var. 'robusta' Linden, harvest occurs from September (east coast) to December (west coast). Harvest of *Coffea arabica* var. catimore is harvested 2 months earlier. From five to 10 flowering events were recorded for the former variety (west coast) by GIORDANENGO (1992), from the end of May to the beginning of October, with harvest about 9 to 10 months later. The physiological induction of flowering requires a significant rainfall of at least 5 mm of rain after a dry period (PORTÈRES, 1946; DUBLIN, 1960; DE ALVIM, 1960). The endosperm of var. 'robusta' berries can be attacked by coffee berry borer at the green berry stage, from 2 months after flowering (without beetle reproduction), or later on, with reproduction, when green berries are over 4 months old, or even at the dry berry stage (more than 10 months after flowering (PENADOS and OCHOA, 1977; BAKER, 1984).

On the basis of analyses of life stages present in berries GIORDANENGO (1992), found between four and five generations per year of *H. hampei*. The brief, initial colonization phase is characterized by movements of mated females from old dry berries, remaining from the previous crop, to the first maturing green berries (MATHIEU, 1995). Three or four generations subsequently occur during the 'multiplication phase' from initial berry colonization to harvest. One to two generations can then occur in the residual unharvested dry berries (MATHIEU, 1995), referred to here as the 'survival phase'. The initial colonization is typically caused by low numbers of beetles, with population expansion occurring from an epicentre, leading to an aggregated distribution (DECAZY et al., 1989). Dispersal occurs over a short distance (GINGERICH, 1997), which is corroborated by the distribution of phenotypes exhibiting

insecticide resistance within fields (BRUN and SUCKLING, 1992). BAKER (1984) however, noted the potential for long distance dispersal of this insect during flight when strong winds and thermal convection occurred.

There is evidence of attraction by host plant odours as well as visual stimuli (TICHELER, 1961; GIORDANENGO et al., 1993). A trapping system is desirable given the economic importance of both the crop and pest. Trapping would permit detection of incipient populations and rapid assessment of population levels, and could provide the basis for pest management decisions. A prototype trapping system has been developed for *H. hampei* using ethanol and solvent extracts (GUITIERREZ-MARTINEZ and ONDARZA, 1996), although no information is available about the relationship between trap catch and beetle populations. Another trapping system has recently been developed (MATHIEU et al., 1997b), using methanol and ethanol as a lure in multiple funnel traps (LINGREN, 1983). The aim of the present study was to develop the basis for a trapping system that could be used to monitor coffee berry borer populations in coffee plantations. Trapping data, as well as an evaluation of fruit maturity and infestation levels are required to provide an understanding of the colonization process.

2 Materials and methods

2.1 Field layout

The study field (located at La Foa on the west coast in New Caledonia (21°44'S, 165°55'E), had been abandoned from cultivation the previous year and comprised *C. canephora* Pierre var. 'robusta' Linden grown at 2 m × 2.5 m spacing in full sunlight. The field was 110 m long × 34 m wide (approx. 0.4 ha). Visual inspection of the field in August 1993 identified a group of three trees near the edge, with a heavy infestation. The rest of the field had little or no evidence of infestation. Twenty-seven trees (including the first three heavily infested trees) were selected in a 20-m wide band across the narrow dimension of the field (34 m). The block of selected trees was then divided into four zones each of six to seven trees, grouped by distance from the initial infestation i.e. zone 1 (epicentre of infestation), zones 2 to 4 (towards the opposite side of the field), plus zone 5 (20 m away from the study field, with vegetation other than coffee plants present).

2.2 Coffee berry phenology

The number of each type of coffee berry (green, red, dry, green infested, red infested and dry infested) was determined monthly from October 1993 to July 1994 (except for May and June), along with the proportion that were infested by *H. hampei*. The same five 'typical' branches were monitored monthly on each of 19 trees. Branches were chosen to reflect average berry numbers and state of maturity for each tree.

2.3 *Hypothenemus hampei* sampling

During the same monthly assessments the number of immatures (larvae plus pupae), adult males and adult females was determined by dissecting berries in the laboratory. This was carried out for each type of berry. Phenology development of the tree resulted in the absence of some types of berries on occasions. During the multiplication phase from October 1993 to January 1994, 40% of the samples had no berries of a certain type. During the survival phase (from February to July 1994), only dry berries were present. Furthermore, to avoid an impact on beetle populations, sampling of certain zones was only carried out when sufficient berries of each type had an infestation rate of more than 5%. In practice, 93% of successful samples consisted of 10 to 53 berries (mean = 33, standard deviation = 14) of each type on each zone on each date.

2.4 Beetle trapping

A total of 12 red multifunnel traps (based on LINGREN, 1983), offering the visually attractive colour (MATHIEU et al., 1997b) were placed in the first four zones. They were baited with a solution of methanol : ethanol (1 : 1 ratio, a mean solution release rate of 1 g/day), previously determined in a field cage study (MATHIEU, 1995), and checked weekly. Two additional traps were placed in zone 5 (20 m from the field) to determine whether beetles were flying outside the field.

2.5 Meteorological data

Daily records of rainfall, temperature, and relative humidity were collected 1 km from the study field at Pocquereux (La Foa). Barometric pressure was obtained from the Tontouta Airport (50 km).

2.6 Statistical analysis

A berry maturity index was developed to characterize the tree phenology in each zone on each sampling occasion. The maturity of green berries was set at 0, red at 1, and dry berries at 2. The mean of these values was then taken over all berries present on each occasion in each zone (i.e. a population comprising entirely green berries would have a mean maturity index of 0). The ratio of the number of infested berries divided by the total number of berries will be called the 'infestation rate'. The number of female beetles in each zone at each date was estimated by multiplying the mean number of females present in each type of berry by the number of each corresponding type of berry. The number of female beetles in each zone at each date will be called the 'infestation level'. The mean maturity index for each zone throughout the multiplication phase was correlated with the logarithm of the infestation level of that zone. This correlation was performed using a General Linear Model so that the effect of differing densities across the zones could be allowed for. The number of beetles per berry of each life stage was compared between berry types by one-way analysis of variance (ANOVA) after transformation (log count + 1), and the means compared by Fisher's protected LSD test (HINTZE, 1989). Means followed by the same letter were not significantly different ($P > 0.05$). The infestation level was correlated with mean catch per zone after transformation (log catch + 1), for each month in the multiplication phase (October to January).

For graphical analysis only (see fig. 3b), the missing infestation level data was estimated. Linear interpolation was used to estimate the number of females per berry and the number of berries per tree for the months of May and June, and for cases where berries of a certain type were not present in a zone (see Sections 2.2, 2.3 above). The development time between generations was estimated from mean monthly temperature and linear regression of published data from BERGAMIN (1943), TICHELER (1961) and BORBON-MARTINEZ (1989).

3 Results

3.1 Berry phenology

Two phases of berry development were evident in the data. The first, or beetle multiplication phase (October

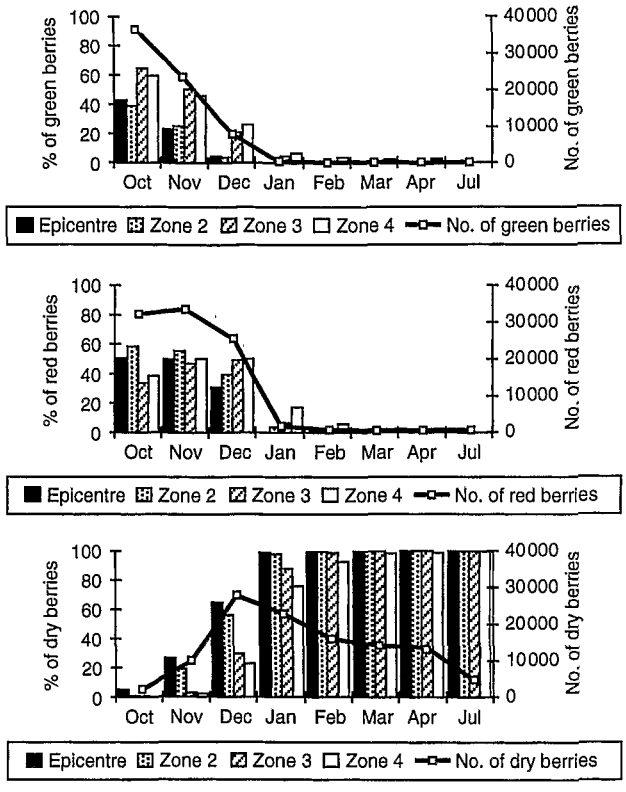

Fig. 1. Coffee berry phenology in relation to zone and sampling date in New Caledonia. Monthly record of berries of each category (green, red or dry), over 19 trees (five 'typical' branches per tree); percentage of green, red or dry berries counted monthly in each zone (from the infestation epicentre to zone 4). For a single month and zone, the sum of the percentage totals of green, red and dry berries equals 100

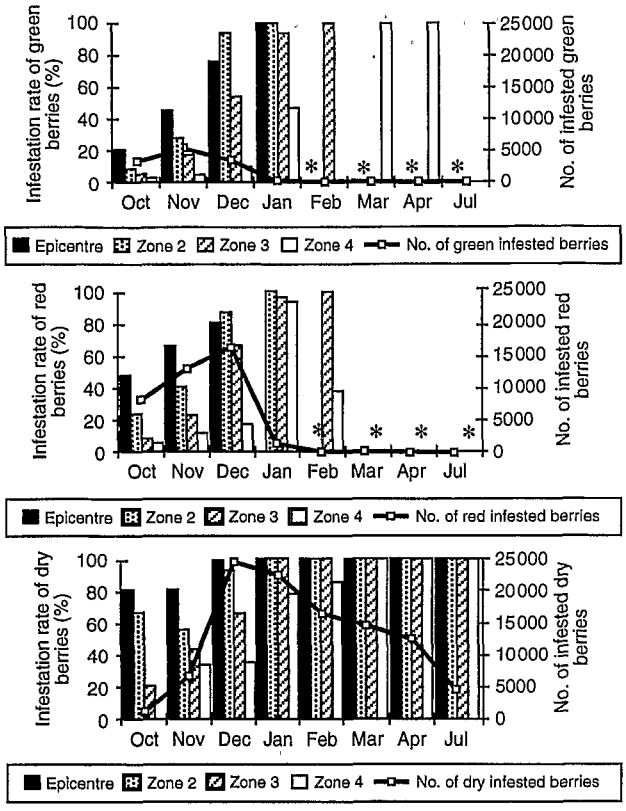

Fig. 2. Monthly H. hampei *infestation rate according to sampling zone. Asterisk indicates a lack of berries of the corresponding category. Monthly record of infested berries of each category (green, red or dry), over 19 trees (five 'typical' branches per tree). Percentage of infested berries from each category (green, red or dry) recorded monthly in each zone (from the infestation epicentre to zone 4). For a single month, zone, and berry category, the sum of percentages of infested and noninfested berries equal 100.*

to January) was characterized by all types of berries being present. There was a shift in distribution from predominantly green to predominantly dry berries during the first phase. The first dry berries were detected in the epicentre (zone 1) during October (fig. 1). Zone 1 continued to have a higher proportion of dry berries than the other zones during November and December (fig. 1). The second, or beetle survival phase (January to July) consisted of dry berries alone being present on the trees (fig. 1). There was a rapid drop in green and red berry numbers on trees between December and January, reflecting the point of transition between the two phases (note line in fig. 1). This field provided results in the absence of harvesting. In a normal situation, the number of berries remaining on the trees would have dropped at harvest. The gradual drop in dry berry numbers from December onwards continued over several months.

3.2 *Hypothenemus hampei* populations

The infestation rates increased for each type of berry, over time, and in each zone, and reached 100% of berries available in all zones (fig. 2). The initial rate of infestation in the epicentre varied between green (20%), red (50%) and dry (80%) berries in October. The infestation rate then increased dramatically during the early part of the study period (multiplication phase) in all zones. In the epicentre, the infestation rate rose from 20% of green berries in October to 100% in January (fig. 2). For red and dry berries, the trend was similar, but started at a higher level than for green berries. The infestation rates of dry berries in zones 2 and 3 reached 100% by January, and by March for zone 4.

The infestation level during the multiplication phase was significantly correlated with the berry maturity index ($n = 8$, $r = 0.82$; $P = 0.013$), when the effect of the changing beetle density across the zones was controlled for. This indicates that the relationship between infestation and maturity was present across a range of densities. A gradient in female beetle numbers between berry types continued to be evident across the zones from October to December. However, there was insufficient replication to examine the relationship further between zone and maturity.

For zone 1, which had the highest population, female beetle density varied significantly between berry types during the multiplication phase with 1.67 beetles per green berry (colonizing female), 3.20 beetles per red berry (first generation progeny females) and 5.60 beetles per dry berry (subsequent generation progeny females) (table). For zone 1, male beetle density per berry also

Table. *Population level of* H. hampei *in accordance with berry types*

	Berry types			
	Green	Red	Dry	ANOVA
Female	1.67a ± 2.18	3.20ab ± 3.52	5.60bc ± 4.62	$F = 30.6$; d.f. = 2, 312; $P < 0.001$
Male	0.14a ± 0.43	0.32ab ± 0.57	0.78bc ± 0.74	$F = 32.00$; d.f. = 2, 312; $P < 0.001$
Immature stages	4.70a ± 4.49	6.34b ± 4.90	4.10a ± 6.08	$F = 9.80$; d.f. = 2, 312; $P < 0.001$

Means followed by the same letter are not significantly different ($P > 0.05$).
See Section 2. 6 for details on data treatments.

varied significantly with berry type during the multiplication phase, with 0.14 beetles per green berry, 0.32 beetles per red berry, 0.78 beetles per dry berry (table). The results from immature stages were also significant for zone 1, with 4.70 beetles per green berry, 6.34 beetles per red berry, 4.10 beetles per dry berry berries (table).

The sex ratio during the multiplication phase varied from 1 male for eight to 14 females ($n = 2850$ females). However, during the survival phase, this ratio varied considerably more, from 1 male for three to 35 females ($n = 2800$ females).

3.3 Beetle trapping

The traps were successful at catching adult females, with 73 168 caught in the 12 traps over the 10-month period. Only 196 beetles were caught in the two traps outside the field. The largest catches were made at the epicentre of infestation (zone 1), and there was excellent spatial agreement between the locations of high beetle populations in berries (estimated by interpolation for May and June) and trap catch in the field (figs 3a, b). There was a highly significant relationship between the infestation level and the log of mean trap catch in each zone, over the four months of the multiplication phase ($n = 12$; $r = 0.92$; $P < 0.001$).

Females caught during the multiplication phase were characterized by a light-brown coloured head and dark brown body, whereas during the survival phase females were all entirely black in colour. This indicates that the females that emerged during the multiplication phase were between 1 and 2 weeks old.

The largest catches occurred in January, although minor flight peaks were also evident in February, June, and at the end of November (fig. 4). Each peak coincided with significant rainfall (30–80 mm), and the associated drop in atmospheric pressure. The largest flight also coincided with a dramatic drop in the number of (dry) berries per tree in January. The amount of time between adjacent flight peaks was sufficient to permit the development of the next generation in each case (BERGAMIN, 1943; TICHELER, 1961; BORBON-MARTINEZ, 1989), at the prevailing temperatures (fig. 4).

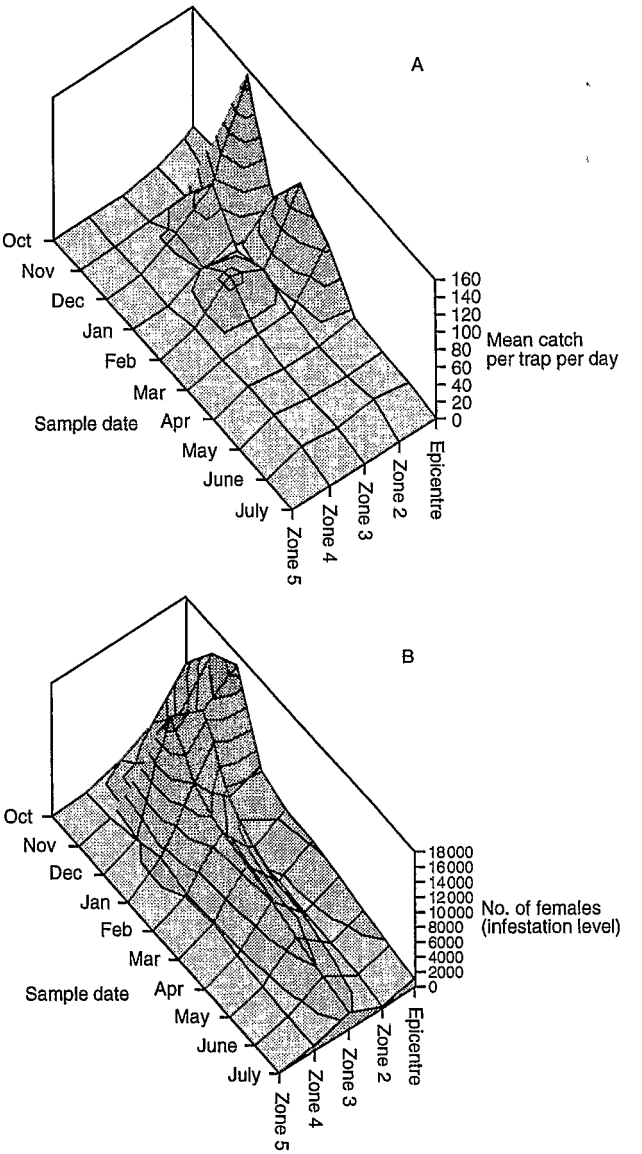

Fig. 3. *Total catch in traps (a) and estimated infestation level in berries (b) over time for each zone. There was missing data for 2 months (May and June). However, the number of berries and females per berry was decreasing at a linear rate from January to April, so linear interpolation was used to estimate the beetle populations during these months*

4 Discussion

For the first time, it is clear that traps for *H. hampei* can provide information of value in relation to coffee infestation levels. The epicentre (zone 1) had 16 530 adult females in berries in December. On the spatial scale, the traps in this zone caught the highest numbers of females, indicating good prospects for mapping

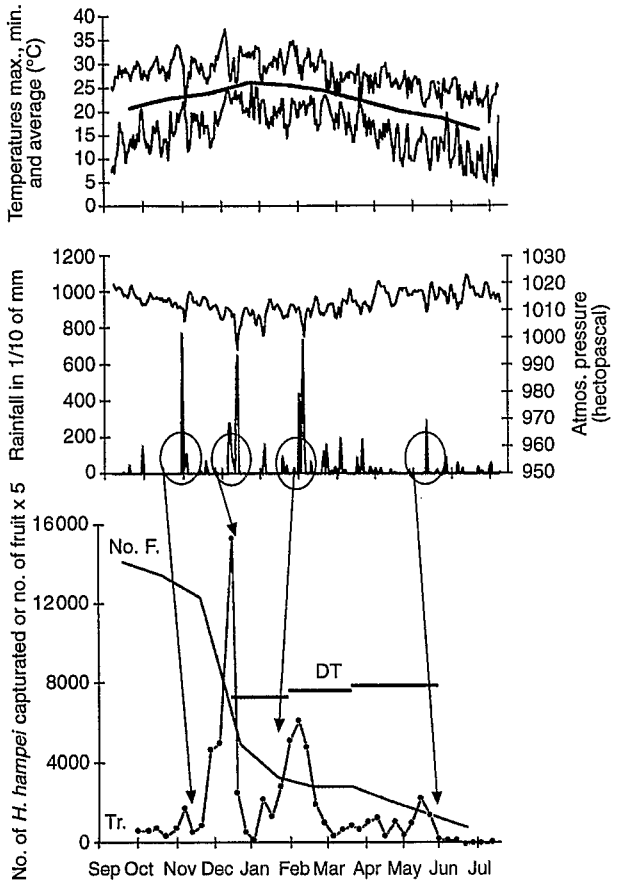

Fig. 4. Catch of adult female H. hampei *over time, in relation to meteorological conditions and changing number of berries in coffee trees. DT: Duration of development from oviposition to adult emergence plus 20 days (5 days for oviposition plus 15 days to obtain female maturity for colonization). It is calculated from the mean temperature over the period (Tm), according to the formula* $DT = (0.347 \times Tm - 5.20)^{-1} \times 100 + 20$ *($R^2 = 0.78$), derived from linear regression of data from* BERGAMIN *(1943),* TICHELER *(1961) and* BORBON-MARTINEZ *(1989).*
Tr. Trapping data, No. F. Total no. of fruit on trees in the field

infestations. At the minimum, traps could be used by coffee farmers for monitoring areas of higher infestation by *H. hampei* within a field, to indicate the need for corrective action such as physical removal of infested berries, or localized insecticide treatment. There is potential for the development of a threshold of trap catch in the early part of the season, to predict infestation at harvest, as well as for detection of incipient attack.

Three generations are present during the multiplication phase, which means that a single female laying 20 to 80 eggs (BERGAMIN, 1943) in October could result in a population of 8000 to 512 000 at harvest. This assumes successful colonization by all females, while the real proportion is likely to be much lower. However, it is clear that populations can increase dramatically during this phase, and control measures at the beginning of this phase would be likely to be of the greatest benefit. Mass trapping could be of interest during the population bottleneck at the end of the survival phase (when populations are low because females are constrained by the supply of dry berries), and shortly afterwards, at the beginning of the initial colonization phase. During this period, catch of the maximum number of females would be desirable in New Caledonia, but improvements to trap efficiency will be needed before this approach can be realistically proposed.

The development of a trapping system combined with the use of biopesticides (i.e. *Beauveria bassiana*) is another avenue worthy of investigation. Such tools would enhance biopesticide distribution if used when population flights are at their highest between January and March.

The relationship of catch in the multiplication phase to subsequent infestation was obscured by the substantial beetle movement between zones, which resulted in 100% infestation. Although individual *H. hampei* females do not appear to disperse far within fields (GINGERICH, 1997), population movement between the zones was evident across several generations. The use of traps to accurately identify population levels will probably be limited by the number of traps which can be used per hectare, in relation to the spatial scale of aggregation. Further work is needed to determine the relationship between these factors. It may be more feasible to use traps to identify the number of infestation epicentres in a field, rather than to estimate the population or infestation rate, because of the aggregated population distribution. An estimate of the number of epicentres in a field could then be used together with the number of generations remaining before harvest to predict the level of damage at harvest.

In addition, it is highly probable that rainfall events, possibly in combination with changes in coffee berry numbers on trees can directly affect the emergence of adult females and their resulting colonization flights. In the early part of the trapping period (October–December), the proportion of infested berries increased dramatically (fig. 2), while the population of female beetles was also increasing rapidly inside the berries (fig. 3b). However, trap catches did not reflect the increase in this population over time until January, when high catches coincided with rainfall and decreasing berry numbers (fig. 4). This phenomenon may be explained by the following reasons.

MATHIEU et al. (1997b) suggested three hypotheses to explain the development of *H. hampei* populations during the survival phase, when only dry berries (usually highly infested) are present. The number of insects present is the result of the balance between females entering and abandoning the berries. At the same time, the decrease in number of suitable berries can lead to accumulation of females of different origin in the remaining dry berries. Finally, it appears that a portion of these females undergo a 'momentary interruption in development', without oviposition or apparent movement. It is common to find highly galleried berries (sometimes resulting in complete disappearance of coffee seed endosperm) with up to 100 mature females per berry at the end of the survival phase (4 to 6 months after normal harvest), both on the trees and to a much

lesser extent on the ground. MATHIEU et al. (1997b) showed that beetle longevity inside such berries was considerably greater than the 12-day longevity of females outside such berries. It is possible that significant rainfall could be the stimulus for females in this phase to emerge and disperse, leading to their capture in traps.

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References

DE ALVIM, P. T., 1960: Moisture stress as a requirement for flowering of coffee. Science. **132,** 3423.

BAKER, P. S., 1984: Some aspects of the behaviour of the coffee berry borer in relation to its control in southern Mexico (Coleoptera, Scolytidae). Fol. Entomol. Mex. **61,** 9–24.

BAKER, P. S.; BARRERA, J. F.; RIVAS, A., 1992a: Life-history studies of the coffee berry borer (*Hypothenemus hampei*, Scolytidae) on coffee trees in southern Mexico. J. Appl. Ecol. **29,** 656–662.

BAKER, P. S.; LEY, C.; BALBUENA, R.; BARRERA, J. F., 1992b: Factors affecting the emergence of *Hypothenemus hampei* (Coleoptera, Scolytidae) from coffee berries. Bull. Entomol. Res. **82,** 145–150.

BERGAMIN, J., 1943: Contribuicao para conhecimento da biologia da broca do cafe "*Hypothenemus hampei* (Ferr. 1867)" (Coleoptera, Ipidae). Arq. Inst. Biol. **14,** 31–72.

BORBON-MARTINEZ, O., 1989: Bioécologie d'un ravageur des baies de caféier, *Hypothenemus hampei* Ferr. (Coleoptera, Scolytidae) et de ses parasitoides au Togo. Thesis, Université Paul-Sabatier de Toulouse.

BRUN, L. O.; SUCKLING, D. M., 1992: Field selection for endosulfan resistance in *Hypothenemus hampei* (Coleoptera. Scolytidae) in New Caledonia. J. Econ. Entomol. **85,** 325–334.

BRUN, L. O.; MARCILLAUD, C.; GAUDICHON, V.; SUCKLING, D. M., 1989: Endosulfan resistance in *Hypothenemus hampei* (Coleoptera. Scolytidae) in New Caledonia. J. Econ. Entomol. **82,** 1311–1316.

DECAZY, B.; OCHOA, H.; LOTODE, R., 1989: Indices de distribution spatiale et méthode d'échantillonnage des populations du scolyte des drupes du caféier, *Hypothenemus hampei* Ferr. Café, Cacao, Thé. **33,** 27–41.

DUBLIN, P., 1960: Biologie florale du *Coffea dewevrei* 3e partie. Floraison, pollinisation, fécondation. L'Agronomie Tropicale **15** (2), 189–212.

GINGERICH, P., 1997: The evolution of insecticide resistance in an inbreeding scolytid *Hypothenemus hampei* (Coffee berry borer). Thesis. Cornell, USA: University of Cornell, p. 89.

GINGERICH, P.; BORSA, P.; SUCKLING, D. M.; BRUN, L. O., 1996: Inbreeding in the coffee berry borer *Hypothenemus hampei* (Coleoptera: Scolytidae) estimated by genotype frequencies showing endosulfan resistance. Bull. Ent. Res. **86,** 667–674.

GIORDANENGO, P., 1992: Biologie, éco-éthologie et dynamique des populations du scolyte des grains de café, *Hypothenemus hampei* Ferr. (Coleoptera, Scolytidae), en Nouvelle-Calédonie. Thesis, Université de Rennes I. p. 109.

GIORDANENGO, P.; BRUN, L. O.; FRÉROT, B., 1993: Evidence for allelochemical attraction of the coffee berry borer, *Hypothenemus hampei*, by coffee berries. J. Chem. Ecol. **19,** 763–769.

GUITIERREZ-MARTINEZ, A.; ONDARZA, R. N., 1996: Kairomone effect of extracts from Coffea canephora over *Hypothenemus hampei* (Coleoptera, Scolytidae). Environ. Entomol. **25,** 96–100.

HINTZE, J. L., 1989: SOLO Statistical System. BMDP Statistical Software Inc.

LINGREN, B. S., 1983: A multiple funnel trap for scolytid beetles (Coleoptera). Can. Entomol. **115,** 299–302.

MATHIEU, F., 1995: Mécanismes de la colonisation de l'hôte chez le scolyte du café *Hypothenemus hampei* (Ferr.) (Coleoptera: Scolytidae). Thesis, Paris, France: Université de Paris VII, p. 134.

MATHIEU, F.; BRUN, L. O.; FRÉROT, B., 1997a: Factors related with native host abandon by the coffee berry borer. J. Appl. Entomol. **121,** 181–186.

MATHIEU, F.; BRUN, L. O.; MARCILLAUD, C.; FRÉROT, B., 1997b: Trapping of the coffee berry borer within a mesh-enclosed environment: interaction of olfactory and visual stimuli. J. Appl. Entomol. **121,** 175–180.

MURPHY, S. T.; MOORE, D., 1990: Biological control of the coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera, Scolytidae): previous programmes and possibilities for the future. Biocontrol. News Information **11,** 107–117.

PENADOS, R.; OCHOA, H., 1977: La consistencia del fruto del cafe y su importancia en el control de broca *Hypothenemus hampei* Ferr. Rev. Cafet. (ANACAFE) **168,** 36–38.

PORTÈRES, R., 1946: Action de l'eau après une période sèche sur le déclanchement de la floraison chez *Coffea arabica* L. L'agronomie Tropicale **1** (3–4), 148–158.

TICHELER, J. H. G., 1961: Etude analytique de l'épidémiologie du scolyte des graines de café, *Stephanoderes hampei* Ferr., en Côte d'Ivoire. Meded Landbouwhogeschool, Wageningen **61,** 1–49.

WATERHOUSE, D. F.; NORRIS, K. R., 1989: Biological Control., Pacific Prospects-Suppl. 1. Canberra: Australian Centre for International Agricultural Research. pp. 56–75.

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