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Responses of Coffee Berry Borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae), to Vertical Distribution of Methanol: Ethanol Traps

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ABSTRACT - Captures of the coffee berry borer (CBB) *Hypothenemus hampei* (Ferrari) were assessed in traps in the field. IAPAR designed traps [plastic bottles (2 L) lured with methanol:ethanol (1:1) in a vessel] were placed either at 0.5, 1.0 and 1.5m high from the ground or simultaneously tested in the 2004 fructification season. Traps placed at the three heights trapped 5.5 times more CBB than the others, mostly at the traps placed at 0.5 m (75%). Treatments using the IAPAR designed trap placed at 1.2 m high; IAPAR trap with a white plastic plate above (IAPAR modified I) at 1.2 m high; IAPAR at 0.5 m high and two additional vessels at 1.0 and 1.5m high (IAPAR modified II) and T-163 trap [three red plastic cups (300 ml) and a red plastic plate as a cover] lured with M:E (1:1) at 1.2m height were compared in the vegetative (2005) and fructification (2006) periods. IAPAR modified II (dispenser vessels placed at 0.5, 1.0 and 1.5 m) trapped more beetles than the remaining types (2.72 times more beetles than IAPAR design); and IAPAR modified I traps trapped more beetles than T 163 and IAPAR traps in the vegetative period. In the reproductive period, IAPAR modified II trapped less beetles than IAPAR and IAPAR modified I. In 2007 vegetative season, IAPAR modified II trap were compared with IAPAR trap and trapped 2.8 times more beetles. The positive responses to a vertical distribution of the volatile attractants in the vegetative period of the planting allow the development of more efficient trapping systems for CBB.

KEY WORDS: Semiochemical, capture, attractant

Coffee (*Coffea* spp.) is the principal agricultural product for millions of families of small farmers in several countries in the humid tropics. Its production is threatened by the coffee berry borer (CBB), *Hypothenemus hampei* Ferrari, that may reach 90-100% of infestation and is the most important pest of the crop (Mathieu *et al* 1999). Chemical control has been the ordinary management strategy and can be eventually associated with cultural practices. The highly toxic endosulfan and chlorpyrifos are the active ingredients used in these areas in which growers are generally deprived of adequate equipments and security facilities for spraying coffee plants. Insecticide resistance in *H. hampei* has already been reported, and could be easily spread worldwide due to the low levels of genetic variability among populations of this insect (Brun & Suckling 1992, Brun *et al* 1995). In addition, environmental and health concerns are growing and the search for certificated pesticide free foods are stimulating the development of safe and environmental friendly strategies.

Phenology of coffee plants has implications on CBB population ecology in the field. During the fructification period of the plants, there is an abundant supply of berries that facilitate the rapid growth of CBB (CBB multiplication phase). In the vegetative season, the CBB beetles survive in fruits that were not harvested or were left on the ground (CBB survival phase). The amount of berries remaining in the plants and on the ground is determinant in the initial size of the population in the multiplication phase, and consequently, for the infestation intensities (Mathieu *et al* 1999).

Methanol and ethanol lured traps have been studied for CBB management since the efficiency of the synergistic effects of this mixture in attracting CBB was demonstrated (Mendonza Mora 1991). Several types of traps have been proposed trying to optimize beetle capture (Silva *et al* 2006b, Barrera *et al* 2006). Since insects also respond to visual stimuli and interactions between visual and chemicals responses may occur (Silva *et al* 2006a), the development and evaluation of trapping systems to each particular target species could be an important approach in an integrated strategy for CBB management (Mathieu *et al* 1997). Failures in the massive control of the CBB (Morales - personal observation, Barrera *et al* 2006) have showed the importance of the improvement of trap efficiency and have highlighted the need for more detailed studies on the conditions under which traps could be adequately used in the field.

In 2004, the heights in which traps are set were compared. Experiments also compared different kinds of traps with a new design with vertical distribution of the methanol:ethanol attractant during vegetative (2005) and fructification periods (2006) of coffee plantings. Finally in 2007, the trap with vertical distribution was again compared with the standard trap design in the vegetative period (2006).

Material and Methods

Trap captures were assessed in four field experiments, which were conducted in an unshaded organic coffee plantation in Lerrovile County in Londrina (23°19'S, 51°12'W), Paraná State, Brazil. Plants were about 30 year old and were pruned at the base in 2000. The coffee varieties utilized in the field sites, with specifications of row spacing and distance between plants were: "Catuai" (2.0 x 0.6 m); 'Mundo Novo'. (3.5 x 3.0 m) and'Catuaí' (2.8 x 0.8 m) for the first, second and the remaining experiments, respectively.

Unless otherwise stated, traps consisted of 2.0 L transparent green bottles (recycled from soft drink containers) with a window (13 x 18 cm) at 9 cm above the bottom and hung in a bamboo stake (IAPAR design) (Villacorta *et al* 2001, Silva *et al* 2006a). Water (200 ml) with liquid detergent (2 ml) was added to the bottle bottom to kill and retain CBB beetles. A 10ml amber glass vial with a plastic cover containing the attractants was hung inside the bottle, 20 cm above the bottom of the trap. Unless otherwise stated, a 1.6mm thick wire was used to hold the vial plasticcover and dispense the methanol:ethanol (1:1) attractant mixture (an average of 550 mg/day). Traps were placed in wood stakes between plant rows. Distance between traps was 12 m within a block, and 15 m between blocks. In the assessments, insects were removed to the laboratory to be counted and the vial weighted to determinate mean volatile release rates.

In a first stage, responses to trap height placement were studied. Traps were placed at 0.5, 1.0, and 1.5 m high from the ground or in the three heights simultaneously using four traps per treatment. Traps were placed in the field on March 2nd, 2004 and seven evaluations were carried out (March 5th, 16th, 19th, 23th e 25th and April 2nd and 8th, 2004). The mean obtained for each date was considered a replicate.

A field experiment was carried out during vegetative and fructification periods to assess responses to trap design. The IAPAR trap was hung 1.2 m above the ground as the standard treatment. The same trap design, at the same height, was used adding a plate (0.2 m diameter) above the bottle (IAPAR modified 1). In the third treatment, the same trap was fixed at a height of 0.5 m and two additional amber glass vials (hole of 0.5 mm in the cover) were fixed at 1.0 m and 1.5 m high from the ground (an average of 140 mg/day of the attractant mixture) (IAPAR modified 2). T-163 trap (ChemTica International, Heredia, Costa Rica), which consisted of three red plastic cups (300 ml) placed one above the other and a red plastic plate as a cover, hung at a height of 1.2 m. The vial containing the attractants was placed inside the medium cup of the trap. Ten traps per treatment were used. Traps were placed in the field on September 1st and assessments were conducted on September 9th, October 7th, 13th and 20th of 2005 in the vegetative period, and placed on March 28th and assessments were done during the reproductive period on April 6th, 12th, 20th, and May 3rd of 2006.

In 2007 vegetative season, IAPAR trap was compared against IAPAR modified II trap. Traps were placed in the field in the same heights of anterior experiments on August 8th and assessments were done on August 8th, 15th and 22nd. Ten replicates were used.

The randomized complete block design was used. ANOVA was performed followed by Tukey test ($P < 0.05$) to compare means (Tukey 1949) for the experiments with more than two treatments. In the two treatments experiments, t-paired test was used.

Results and Discussion

Traps placed at heights of 0.5, 1.0 and 1.5 m trapped similar amounts of CBB adults (Table 1). However, when the traps were simultaneously placed at the three heights, the average capture was 5.5 times higher than those found at each height individually. When traps were simultaneously placed at the three heights, the captures at a height of 0.5 m were larger than at 1.0 m and 1.5 m (Table 2).

These results showed that the CBB female beetles respond to a vertical distribution of the volatile attractant obtained when the three traps were used, but captures concentrated in the trap placed at a height of 0.5 m (76%). Another hypothesis to justify these results could be the increase of the amount of attractants per trap. However, increasing transparent green traps release rates from 720 mg/day of the 1:1 mixture of methanol:ethanol decreased captures of the CBB in a previous study using the IAPAR trap (Silva *et al* 2006a). IAPAR modified II trap caught, in average, more beetles than the remaining types in the vegetative period (2.72 times more beetles than IAPAR design) (Table 3). These results corroborate those obtained in the previous experiment, confirming that the presence of the attractant vessels at the three heights of the stake led to higher captures (Table 1).

Table 1 Mean number (± SE) of coffee berry borers daily trapped by IAPAR traps tested either at heights of 0.5, 1.0 and 1.5 m or simultaneously tested during vegetative period in coffee Catuai cv. plantation from March 2nd to April 8th, 2003.

Trap height (m)	Caught beetles
0.5	21.2 ± 10.93 b
1.0	22.1 ± 9.53 b
1.5	18.9 ± 8.70 b
Three heights simultaneously	114.3 ± 45.91 a

Different letters in the same column indicate statistical differences according to Tukey test with $P < 0.05$, $n = 7$.

Table 2 Mean number (± SE) of coffee berry borers daily trapped by IAPAR traps tested either at heights of 0.5, 1.0 and 1.5 m or simultaneously tested during vegetative period in coffee Mundo Novo cv. plantation. Londrina, PR, 2003.

Trap height (m)	Caught beetles
1.5	11.2 ± 5.24 b
1.0	16.2 ± 7.37 b
0.5	87.1 ± 36.25 a

Different letters in the same column indicate statistical differences according to Tukey test with P < 0.05, n = 10, N = 7.

IAPAR modified I traps trapped more beetles than T 163 and IAPAR traps (Table 3). The presence of the plate above the bottle trap may have influenced the release of volatiles from the trap or even changed the visual pattern, enhancing CBB captures.

However, when traps were used in the reproductive period, IAPAR modified II caught less beetles than IAPAR and IAPAR modified I trap (Table 4). Apparently, the vertical distribution of the volatile attractant inhibited CBB captures in this case. These results disagree with those obtained in the first experiment in which captures were higher when simultaneously using traps at the three heights also in the presence of berries (Table 1). However, in this case the three traps were used in the same stake, what may have affected the insect visual response. Additionally, coffee berry yields were significantly different in the areas (higher in the second) and with plants of a different age. During the reproductive period, the attractants released from the traps were probably overwhelmed by natural attractants released from the berries, even though ethanol is an important component of the coffee volatiles (Ortiz *et al* 2004). The height CBB flies in the absence of berries are higher than those in the reproductive period of the coffee planting, which could also affect this insect chemical and/or visual response to the traps (Barrera *et al* 2005). In addition, insects in the survival phase (vegetative period of coffee plants) are older than those in the multiplication phase (Mathieu *et al* 1999), suggesting a different physiological state and different responses as consequence. These results corroborate previous data in which intrinsic factors of the traps interacted among them and with environmental factors, and the performance of the trap was variable according to them (Mathieu *et al* 1997, Silva *et al* 2006a).

Experiments carried out in the 2007 vegetative period confirmed the better performance of IAPAR modified II trap, as it trapped 2.8 times more CBB than IAPAR traps (means 149.0 vs. 52.3 beetles, respectively, t = 2.41, P < 0.039, n = 10).

Recent studies showed that shaded coffee plantings favor CBB captures compared to unshaded ones (Arroyo 2004). Further investigation is required to evaluate the relative efficiency of the IAPAR modified II trap in these conditions, mostly in the vegetative period. The number of traps per area is important information for mass trapping usage. The best density for efficient mass trapping was 22 units per ha (Dufour & Frérot 2008). Higher individual trap performance, as reported in here, might reduce trap costs and improve

Table 3 Mean number (± SE) of coffee berry borers daily trapped by traps during vegetative period in coffee Catuai cv. plantation. Londrina, PR, 2005.

Trap	September 9	October 7	October 13	October 20	Mean
IAPAR	16.5 ± 5.45 b	46.5 ± 10.69 b	18.1 ± 2.43 b	9.5 ± 2.52 b	22.8 ± 3.91 c
IAPAR modified I	25.3 ± 8.43 b	77.6 ± 9.82 ab	40.7 ± 15.11 a	21.5 ± 10.60 ab	36.3 ± 5.89 b
IAPAR modified II	42.3 ± 4.92 a	120.0 ± 14.69 a	47.5 ± 2.55 a	37.8 ± 12.84 a	62.1 ± 7.74 a
T-163	15.6 ± 6.75 b	40.3 ± 8.80 b	29.0 ± 6.56 ab	13.0 ± 7.84 b	24.4 ± 4.09 c

Different letters in the same column indicate statistical differences according to Tukey test with P < 0.05, n = 10.

Table 4 Mean number (± SE) of coffee berry borers daily trapped by traps during reproductive period in coffee Catuai cv. plantation. Londrina, PR, 2006.

Trap	April 6^{ns}	April 12^{ns}	April 20^{ns}	April 27^{ns}	May 3	Mean
IAPAR	142.7 ± 29.63	219.6 ± 43.15	104.5 ± 22.62	100.7 ± 17.93	25.5 ± 4.41 ab	118.6 ± 15.21 ab
IAPAR modified I	166.9 ± 43.81	233.1 ± 46.06	166.0 ± 36.01	133.6 ± 27.79	32.5 ± 9.68 a	146.4 ± 18.24 a
IAPAR modified II	71.2 ± 19.50	153.0 ± 43.84	60.7 ± 13.94	55.4 ± 2.73	8.7 ± 2.73 b	69.8 ± 12.46 c
T-163	115.4 ± 30.59	137.1 ± 35.19	114.7 ± 50.71	85.7 ± 30.29	16.1 ± 4.95 ab	93.8 ± 15.80 bc

Different letters in the same column indicate statistical differences according to Tukey test with P < 0.05, n = 10; ^{ns}não significativo.

CBB field control efficiency. A lower number of traps per area would also decrease costs with labor and the amount of attractants used.

The knowledge that CBB responds to a vertical distribution of the volatiles in the vegetative period of the coffee plants allows for an important approach in designing new traps to collect CBB. The lack of efficiency of this kind of trap in the 2006 reproductive period of the crop (Table 4) does not represent a limitation because the use of traps for mass capture is proposed for the vegetative period (Barrera *et al* 2006, Silva *et al* 2006b).

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