



Effectiveness of Using Attractants to Control *Hypothenemus hampei* in *Coffea arabica* Crop in the Ecuadorian Amazon

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ARTICLE INFO

Keywords:

Amazon clones

Biodiversity

Coffee

Coffee bit

Productivity

Article History:

Received: May 20, 2020

Accepted: August 1, 2021

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ABSTRACT

The present research was aimed to evaluate the effectiveness of attractants placed in craft traps to reduce the bit population (*Hypothenemus hampei*). Three different mixtures of attractants and control were used in craft traps (4 treatments, which represent the mixtures frequently used by Amazonian coffee growers), arranged in a completely random blocks design. The variable number adult coffee drill was analyzed, as well as the most economical and effective treatment in the capture of adult coffee bit. The data were processed by means of a variance analysis to determine the differences between treatments, and the Tukey media multiple comparison test, at the statistical significance of $p < 0.05$. The results have confirmed that the use of craft traps is a good alternative for adult coffee bit control. The treatment that allowed a greater capture of the coffee bits was T1 (mixture of 2 liters of boiled water + 200 grams of ground coffee), this was also the treatment that had the lowest cost for the elaboration of the artisan trap (\$ 14.30). Finally, T1 turned out to be the most effective treatment for adult coffee drill capture in Amazonian conditions of Ecuador.

INTRODUCTION

In the current context of climate change, the conservation of diversity and the combination of production crops to support the family economy in Amazonian secondary forests is conceived with agroecological foundations. Within this framework, Ecuador in its Amazonian region produces *Coffea arabica* (arábiga), a variety present in the world's coffee production (Piato et al., 2021). This species of vital importance for the quality and aroma of its grain, as well as, because of the characteristics of the plant, because in optimal conditions it can be tolerant to drought, to different agronomic management and adapts to different climatic and edaphic conditions

(Duicela-Guambi, Martínez-Soto, Loo-Solórzano, & Rodríguez-Monroy, 2019). However, it is vulnerable to be attacked by *Hypothenemus hampei* (coffee bit), which infects the green developed fruits, red (mature) and dry ones (Abate, 2021; de los Santos Pinargote Chóez, Lino-García, & Palma-Ponce, 2019; Palma Ponce & de los Santos Pinargote Chóez, 2019), and causes production decrease and large economic losses (Alarcón et al., 2017; Donato-Ortiz & Lucio-Quintana, 2018; Leiva-Espinoza, Oliva-Cruz, Rubio-Rojas, Maicelo-Quintana, & Milla-Pino, 2019).

Coffee growers as a control measure use different combinations and doses of chemicals offered by commercial agrochemical units, however, agrochemicals use has negative effects on living

ISSN: 0126-0537 Accredited First Grade by Ministry of Research, Technology and Higher Education of The Republic of Indonesia, Decree No: 30/E/KPT/2018

Cite this as: Muñoz-Rengifo, J. C., Rojas, J. A., Villamar-Torres, R. O., Reyes-Pérez, J. J., & Jazayeri, S. M. (2021). Effectiveness of using attractants to control *Hypothenemus hampei* in *Coffea arabica* crop in the Ecuadorian Amazon. *AGRIVITA Journal of Agricultural Science*, 43(3), 581–588. <https://doi.org/10.17503/agrivita.v43i3.2680>

beings and the environment in which they develop, especially in regions with greater biodiversity (Ganchozo-Mendoza *et al.*, 2018). This is why in recent years with an organic approach natural enemies and mostly manual techniques are used, aimed at reducing herbivorous insect populations (Mendoza-Cervantes, Guzmán-López, & Salinas-Castro, 2021; Villamar-Torres, Mehdi Jazayeri, Liuba-Delfini, García Cruzaty, & Viot, 2018).

Within this context, the integrated pest management concept has been developed from which various methods of arresting or suppression of pests are applied, such as the use of various substances, called attractant, in craft traps (Donato-Ortiz & Lucio-Quintana, 2018; Mendoza-Cervantes, Guzmán-López, & Salinas-Castro, 2021; Rajus, Bhagavan, Kharva, Rao & Olsson, 2021; Sinaga, Lisnawita & Tobing, 2020). Recently different types of craft traps (INTA; BROCA; ECOIAPAR) and different combinations of attractants in different presentations, such as gel and liquid (Alarcón *et al.*, 2017; Donato-Ortiz & Lucio-Quintana, 2018; Leiva-Espinoza, Oliva-Cruz, Rubio-Rojas, Maicelo-Quintana, & Milla-Pino, 2019) have been proved. However, there is little information about pest control for the Amazonian province of Pastaza which presents different climatic conditions. In this region coffee growers use three combinations of attractants

- in commercial and home traps - for capturing adult coffee bit. Nevertheless, there is no information to determine which mix is the most efficient and economical in the capture of adult coffee bit. For this reason, it was aimed at this research to evaluate the effectiveness of attractants placed in craft traps to reduce the bit population (*H. hampei*), in the cultivation of coffee in the Ecuadorian Amazon.

MATERIALS AND METHODS

Research Location

The research was carried out in the clone L-G-SO1 of *Coffea canephora* of the coffee program of the *Center for Research, Postgraduate and Amazonic Conservation* (CIPCA) of the Amazon State University (UEA), located between the provinces of Pastaza and Napo in Ecuador (Fig. 1).

In CIPCA the rainfall for 2019 was approximately 4151.86 mm. In October the precipitation was 439.17 mm, on the contrary, in November and December the precipitation was reduced 6.3 and 13.1% (411.48 mm and 381.76 mm respectively). The annual average temperature for 2019 was 21°C and in October it was 20.5°C, while in November and December there was an increase in temperature by 3.9 and 4.4% (21.3°C and 21.4°C, respectively).

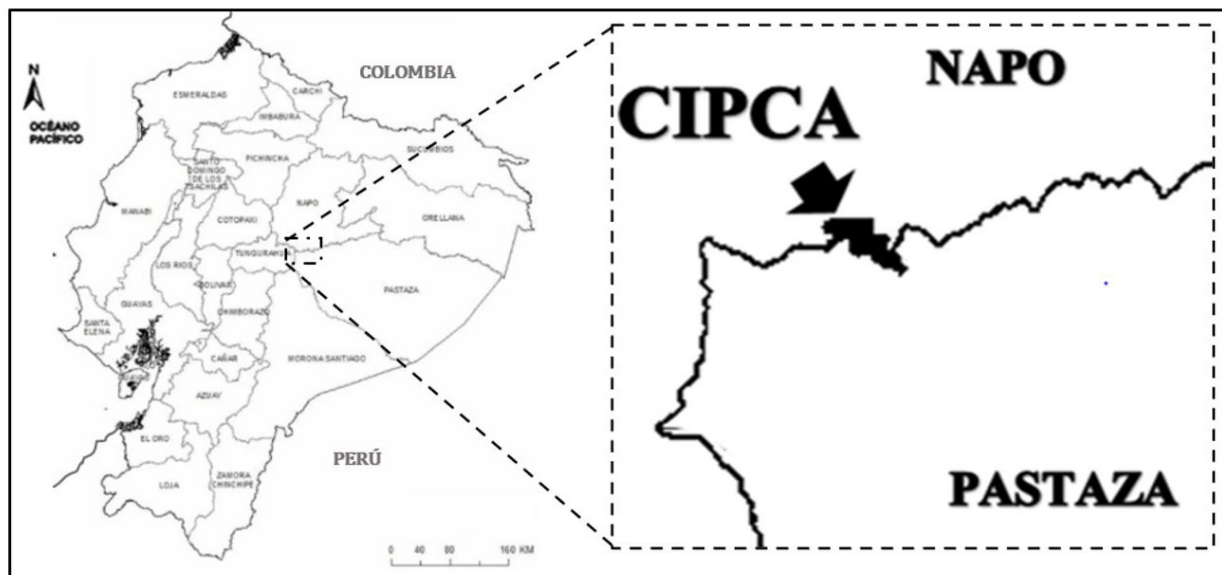


Fig. 1. Map of Ecuador. CIPCA location, between the provinces of Pastaza and Napo.

Experimental Design

A completely randomized block experiment was used, with a total of 3 blocks. Each block contained the 4 treatments with 5 replications for each treatment, totaling for 20 traps per block, and 60 experimental units for the entire experiment. The treatments used in this research were the three attractant types commonly used by farmers and control as described in the following details.

T1: 2 liters of boiled water + 200 grams of ground coffee;

T2: 1 liter of boiled water + 0.5 liters of coffee alcohol + 0.5 liters of methanol (CH_4O) + 200 grams of ground coffee;

T3: 1.4 liters of boiled water + 0.3 liters of coffee alcohol + 0.3 liters of methanol (CH_4O) + 200 grams of ground coffee; and,

TControl: control treatment: pure water (H_2O).

The different treatments were placed in handcrafted traps of type ECOIAPAR, at a height of 1.5 m, considered ideal height by Alarcón *et al.* (2017). After the harvest the fruits were removed from all the plots and the traps were placed. For trap elaboration, the instructions of Donato-Ortiz & Lucio-Quintana (2018) were followed. The variable number of captured adult drill bits was measured (NBAC) per treatment, monitored every 14 days from October to December 2019. In addition, the costs of materials for the development of treatment traps were calculated.

Data Analysis

The data of the NBAC variable was processed and analyzed in the statistical software SPSS v.22 (IBM, USA), by means of an ANOVA of one factor for each measurement. To confirm the results, MLG analyses, repeated measures over time and univariate with two factors (Attractive and Date) were performed. Tukey's test (95%) was used in all analyses. In cases where the data did not meet the ANOVA assumptions, the corresponding transformations were made.

RESULTS AND DISCUSSION

Efficacy in Capturing Coffee Bit

The NBAC by treatment during the period of study ranged between 50 and 175 catches (Table 1) for the main treatments used by coffee growers in the zone T1, T2, T3 and TControl. These results are similar to those reported by Alarcón *et al.* (2017) when evaluating three types of traps at different

heights. They found similar catch range with this study using the ETOTRAP trap in at the same placement height. Indeed, the capture of coffee bits using the trap (ECOIAPAR) has been evaluated in other studies (Alarcón *et al.*, 2017; Donato-Ortiz & Lucio-Quintana, 2018; Ruiz-Díaz & Rodrigues, 2021; Silvestre & Cordero, 2005), showing its effectiveness in capturing the bit.

In the first evaluation, for T1 has the highest NBAC (49%; 175 ± 33.8 adults) than the T2 and T3 which have 87 ± 14.6 and 77 ± 13.6 , respectively; and TControl with 1.05 ± 0.3 adults were captured (Table 1). These differences in the first measurement were significant ($F=9,867$; $p<0.001$). These results are similar with Parraga-Palacios (2017) that reported the treatment of brandy + roasted coffee + ground panela (ACP) caught greater coffee bit compared to other attractants. Donato-Ortiz & Lucio-Quintana (2018) and Silvestre & Cordero (2005) also reported that the use of methyl alcohol increased catches of coffee bit. In this sense, Silvestre & Cordero (2005) observed that saw that the catch of coffee bit was higher when the treatment had a higher proportion (3:1) of methyl alcohol than ethyl alcohol. Recently, when evaluating the effectiveness of attractants in craft traps for catching the coffee bit, Donato-Ortiz & Lucio-Quintana (2018) reported that the treatment containing methanol + coffee obtained a greater catch of coffee bit. In this case the additional ingredient was coffee, however, in Fernandez & Cordero's study the treatments containing ground coffee did not capture a greater amount of coffee bits. In all the exposed cases the craft trap has the same characteristics, however, the material for the elaboration of each trap and the conditions of the study sites were different. These conditions could determine the availability of the accumulation, dispersion and volatilization of attractants, and the efficacy of the coffee bit capture as observed by de Souza *et al.* (2020) and Leiva-Espinoza, Oliva-Cruz, Rubio-Rojas, Maicelo-Quintana, & Milla-Pino (2019) in reducing the incidence of coffee bits due to the color of the traps.

In the second evaluation, the NBAC of T1 was higher at 103 ± 22.2 than T2 and T3, with the value of 80 ± 16 and 93 ± 14.6 adults, respectively (Table 1). These values, however, were not statistically different. The lowest catch was observed for TControl (1.9 ± 0.3) which presented statistical differences ($F=6,570$; $p<0.05$) from T1, T2 and T3. In the third and fourth evaluations. The NBAC of

T2 was higher (98 ± 17.8 and 76 ± 13.8 , respectively), followed by T3 and T1 (Table 1). However, the statistical analysis on the third and fourth measurements revealed no significant differences between these treatments ($p=0.278$ and $p=0.507$). In the fifth evaluation the NBAC of T1, T2, and T3 were recorded at 97 ± 16.9 , 85 ± 13.7 , 77 ± 13.5 adults, respectively and no statistical differences among them ($p=0.775$). In contrast in TControl, fewer adult coffee bits were captured (5 ± 0.9). There were no statistical differences between treatments T1, T2 and T3 during the study time, the analysis also revealed that there is a significant difference in the interaction treatment and sampling date ($F=2.173$; $p<0.05$).

The result in the first evaluation could be related to the accumulation and dispersion of odors, which was higher in the early period in which the traps were installed. From the first measurement its effect was decreasing as the days passed due to the dispersion or volatilization of the liquid attractant. This is consistent with a study of Alarcón *et al.* (2017), who stated that the attractive liquid had a higher evaporation compared to the gel when evaluating two attractant forms (liquid and gel) in different trap types. Another possible role is that it may also be related to a greater presence of coffee beans in October as it has been reported in another study (Mendoza-Cervantes, Guzmán-López, & Salinas-Castro, 2021) where the statistical results attractant interaction, site and sampling date showed significant differences ($p<0.01$) while the attractant and site interaction had negligible differences ($p=0.4947$).

Another aspect related to the higher capture on the first measurement might be related to the period for the bit to locate the traps. In this study the traps were placed in the post-harvest period, which resulted in a lower availability of fruits and

greater competition among the drill bits and with rainfall increase by 58.9% in October compared to September, reproductive diapause was fragmented by increasing the proliferation of the plague (Alarcón *et al.*, 2017; González & Pierre Dufour, 2000). This scenario was a stimulus for the total (23.793 ± 11.9) adult coffee bits that emerged from the fruits and were captured by the treatments under study, among which T1 obtained a higher catch (Table 1). In the following field measurements, the total measurement captures were decreased by 18, 14, and 15% (measurement 2, 3 and 4, respectively), which could be due to the effect of the traps on the bit population (placed in the post-cast period). These conditions were also enforced by the environmental conditions of the site. During these periods (November and December), the precipitation was decreased (6.3 and 13.1%, respectively) and temperatures increased (3.9 and 4.3%, respectively), modifying the conditions of microclimates of the site.

As noted above, for elaborating ECOIAPAR as an artisan trap, materials and dimensions of the bottles and inlet holes as considered by each farmer were used. These characteristics influenced attractant evaporation especially if temperatures increased, thus these factors were important and influenced these results.

In terms of total number of captured bits, T1 has the highest though the value was not significantly different with T2 and T3 ($p=0.340$). The values of these three treatments were significantly higher than the control ($F=32.523$; $p<0.001$), Fig. 2). With this treatment in 8 weeks of research, approximately 500 adult coffee bits were captured. Among T1, T2 and T3 treatments, which are the treatments in which alcohol mixture was used, about 23793 adult coffee bits were captured. These were higher than what reported by Silvestre & Cordero (2005).

Table 1. Coffee bits captured in each measurement (each 14 days) per treatment

Measurements	Treatments				Value	
	T1	T2	T3	TControl	F	p
1	175.1 ± 33.8	87.0 ± 14.6	77.1 ± 13.6	1.1 ± 0.3	9.867	<0.001
2	102.8 ± 22.2	80.0 ± 16.0	93.1 ± 14.6	1.9 ± 0.3	6.570	0.001
3	59.9 ± 11.8	97.8 ± 17.8	79.1 ± 14.2	1.3 ± 0.3	7.978	<0.001
4	51.6 ± 9.6	76.2 ± 13.8	70.8 ± 13.5	2.8 ± 0.6	7.205	<0.001
5	96.9 ± 16.9	85.3 ± 13.7	76.9 ± 13.5	4.8 ± 0.9	7.893	<0.001

Remarks: Results are shown from the ANOVA, mean values $\pm$ a typical error, N = 18.

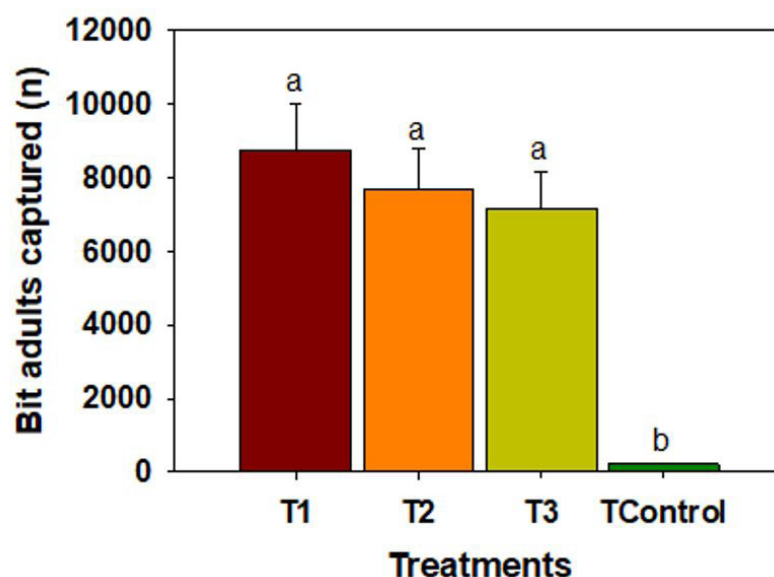


Fig. 2. Bit adults captured in treatments during the study.

In their study on the effectiveness of adult bit capture, with mixture of methyl and ethyl alcohol total catches of more than 5400 adults per trap for 13 consecutive weeks of evaluation were obtained. Indeed, the capture level also depends on the degree of infection. In this study, in a later field valuation presence of the coffee bit in the crop was not observed, nevertheless the use of attractants allowed a large capture of adult coffee bit.

Economic Assessment among the Treatments

In our results the costs per treatment varied depending on the amount of substances used. The cost of methyl alcohol on the market is the highest (\$ 6.50), on the contrary, hot water is cheaper (\$ 2.00), while coffee alcohol (\$ 3.50) is in an intermediate range. In this study, T1 was the treatment with the highest content of boiled water and was the most economical (Table 2).

The cost of T1 per trap was \$0.59, while the costs for manufacturing, and per hectare \$14.30 (Table 2). These values are higher (approximately 27%) when compared with the study by Quispe-Condori *et al.* (2015) in a similar study carried out in Bolivia. They reported that combination of methanol and ethanol (T7 in his study) in an artisanal trap ECOIAPAR was the most efficient and economical with a cost of 74 “Bolivianos” (approximately \$ 10.63). The differences in the costs were presumably related with some factors in the computation such

as currency exchange, cost of alcohol in the market, cost of labor, etc. When compared to Alarcón *et al.* (2017) and Barrera, Herrera, Chiu, Gómez, & Valle Mora (2008) in Mexico and Parraga-Palacios (2017) in the province of Manabí-Ecuador, the cost of T1 in the study was lower. Barrera, Herrera, Chiu, Gómez, & Valle Mora (2008) reported values of \$ 19.60 with the IAPAR trap, and \$ 34.64 and \$ 60.63 with the Fiesta and Brocap trap models, respectively. While Alarcón *et al.* (2017) reported that the best treatments (Etotrap-gel and Etotrap-liquid) had a separate cost of 1,144 Mexican pesos (MXN; 16 traps / year), this is approximately \$ 57.6. On the other hand, Parraga-Palacios (2017) reported values of \$ 20.00 with the AC treatment (*Aguardiente* + roasted and ground coffee (100 g L⁻¹)) per hectare. In our study T2 and T3, which containing a lower amount of boiled water and a higher content of coffee alcohol and methyl alcohol, made them more expensive and the reached values of \$ 0.70 and \$ 0.67 (T2 and T3, respectively), and per hectare T1: \$ 14.30, T2: \$ 16.8 and T3: \$ 16.1 (Table 2). Even though these costs / treatments of our study include 24 traps per hectare, and not 20 traps per hectare as considered by Parraga-Palacios (2017), in his study the costs were lower with T1 and with all treatments when compared with this study carried out in Ecuador. Finally, in the control treatment, the cost per artisanal trap was \$ 0.26.

Table 2. Material costs for the manufacture of treatments under study

Material	Unit	Treatments 1			Treatments 2			Treatments 3			TControl		
		Number	Unit (USD)	Total (USD)	Number	Unit (USD)	Total (USD)	Number	Unit (USD)	Total (USD)	Number	Unit (USD)	Total (USD)
Plastic bottles (3L)	-	24	0.1	1.4	24	0.1	1.4	24	0.1	1.4	24	0.1	1.4
Plastic bottles (100ml)	-	24	0.2	4.8	24	0.2	4.8	24	0.2	4.8	24	0.2	4.8
Boiled water	L	2	2	4	1	2	2	1.4	2	2.8	0	2	0
Coffee alcohol	L	0	3.5	0	0.5	3.5	1.25	0.3	3.5	1.05	0	3.5	0
Methyl alcohol	L	0	6.5	0	0.5	6.5	3.25	0.3	6.5	1.95	0	6.5	0
Sieves	-	1	1.5	1.5	1	1.5	1.5	1	1.5	1.5	0	1.5	0
Ground coffee	g	200	2.6	2.6	200	2.6	2.6	200	2.6	2.6	0	2.6	0
Total	USD			14.3			16.8			16.1			6.2

CONCLUSION

The use of the ECOIAPAR feature craft trap is an important and economical alternative for coffee farmers for bit monitoring and control. However, the materials for making them must be carefully chosen because they can increase costs or modify the effect on the capture of coffee bit. Subsequently, the site, the degree of infestation and the date to locate the traps was also affected the affectivity of the bit capture. Finally, the most effective attractant for the capture of adult coffee bit was 2 liters of boiled water + 200 grams of ground coffee (treatment T1). The treatment attracted 8757 bits with the average of 97 insects per trap and a cost of \$14.30 per trap.

ACKNOWLEDGEMENT

The first and second authors extend a sincere gratefulness to Carla Hidalgo Vargas, Karina Guamán and Irma Castro, for their support in the field phase; to the professor Segundo Valle, for the review of the manuscript; and, to the University Coffee Research Network (REDUCAFE), National Association of Coffee Exporters (ANECAFE), and to the Coffee Program of the Center for Research, Postgraduate and Amazonian Conservation (CIPCA) for the support of coffeemakers of Ecuador. The authors also extend a sincere gratefulness to the Amazon State University (UEA) for allowing and facilitating access to the batch where the investigated clone was located.

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