

Research Article

Application of *Beauveria Bassiana* to Control the Pest *Hypothenemus Hampei* (Ferrari) in Coffee Plantations of the Caturra Isla 6-14 Variety

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Abstract

This study was carried out on coffee plantations belonging to producers who are members of the "10 de Octubre" Agricultural Production Cooperative, Cumanayagua Municipality, Cienfuegos Province. These farmers had plantations of *Coffea arabica* L., Caturra Island 6-14 variety, between May and December 2022. Five coffee plantations were selected, with different areas planted with the aforementioned coffee varieties, to evaluate the influence of *Beauveria bassiana* (*B. bassiana*) strain LBB 1 on the control of the *Hypothenemus Hampei* (*H. hampei*) pest in these coffee plantations. The preparation and application of *B. bassiana* followed the procedure indicated in the Cuban Standard © NC 1013: 2014, the statistical processing of the results was carried out using the Statgraphics Centurion Statistical Package Version 19.5.01, assuming the levels of *H. hampei* infestation as the dependent variable and the dose to be used and the extension of the areas under study as independent variables. Some of the results obtained include: from an initial 20.6% infestation by the pathogen *H. hampei* in the areas selected for research and belonging to the aforementioned cooperative, after applying *B. bassiana* to control the pathogen, infestation levels were reduced by 50% from the initial levels, reaching a minimum infestation level of 8% in two of the evaluated areas. Another result obtained is that when a correlation test was performed between the means of the values shown by the initial and final levels of *H. hampei* infestation and the extension of the study areas, significant differences were found between them.

Keywords

Pathogen, Control, Coffee, Variety, Decrease

1. Introduction

Biological control was conceived at the beginning of the 19th century when some naturalists from different countries highlighted the important role of entomophagous organisms in nature. Biological control attempts to restore the disturbed ecological balance through the use of living organisms to eliminate or reduce the damage caused by harmful organisms [1].

Towards the end of the 1990s, several reviews were conducted on the status of progress in research and control of the coffee berry borer *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae: Scolytinae), particularly in Central America [8], Colombia [2], and Mexico [3]. These reviews primarily refer to advances in biological control. The use of

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biological control through entomophages in Cuba began in 1930, under the leadership of the eminent Cuban entomologist L. C. Scaramuza. Through studies of the biology and ecology of the Cuban fly *Lixophaga diatraeae* and research on its mass breeding, he opened the door to a new phase of biological control in sugarcane [10] and the country's agriculture.

Specifically, the national biological control program created by the Ministry of Agriculture in 1988 aimed to expand the Center for the Reproduction of Entomophages and Entomopathogens (CREE) network, and in 1991, under the guidance of the country's top leadership, they agreed to create numerous centers dedicated to the production of these media [18]. From this moment on, the production of various entomophages began in the CREE, with *L. diatraeae* and *Trichogramma* leading the way in production and in the areas where they have been released. The coffee berry borer, *Hypothenemus hampei* (Ferrari), is the most important insect pest affecting coffee crops. It is present in almost all producing countries, causing significant losses to growers [4].

Agriculture is in crisis, driven primarily by the negative impacts and high dependence on synthetic pesticides, among other causes. However, in many places, experiences are observed that demonstrate that it is possible to obtain agricultural production through sustainable alternatives for managing pest problems, provided that farmers and technicians or extension workers are involved [21]. *H. hampei*'s preference for cherries ranges from 15 to 18 weeks (green to full), depending on the characteristics of the agroecosystem, at which point the cherries are suitable for penetration by adult female berry borer beetles [12]. Of the grains that fall to the ground during harvest, a small percentage are infested with live insects at the end of the harvest; however, by the start of the next harvest, it has been determined that 100% are infested with the pest [6].

Coffee producers frequently use synthetic insecticides to control *H. hampei*, such as endosulfan and chlorpyrifos. These insecticides are highly toxic to the environment, causing harm to the health of producers and also affecting communities surrounding coffee plantations [7, 11]. Biological control of this pest has had a low impact when evaluated with parasitoids imported from other Latin American countries [19].

One of the oldest management methods for *H. hampei* is cultural management, which is effective and environmentally beneficial, but this practice considerably increases production costs because it requires the removal and destruction of infested coffee beans to reduce population levels. This method can work at any stage of coffee berry development [11]. Studies conducted at Cenicafe (Colombia) on the use of entomopathogens have demonstrated their regulatory effect on coffee berry borer populations in ground-dwelling fruit. The *Heterorhabditis* nematode species has the ability to penetrate coffee berry borer growing on trees, cause mortality, and multiply during the berry borer stages [14].

A study entitled "Effect of *Heterorhabditis bacteriophora*

on the coffee berry borer in the Algarrobo region, Trinidad, Cuba," evaluated the effectiveness of *Heterorhabditis bacteriophora* in controlling *H. hampei* [20]. They found no significant differences between the three doses evaluated. Therefore, they suggest using a dose of 500 million NEPs per hectare for pest control, as it is the most economical dose. Controlling the coffee berry borer in coffee plantations in the Cumanayagua municipality, Cienfuegos Province, is a priority for the coffee company in that territory; however, the use of chemical pesticides is extremely costly, toxic, and environmentally polluting. Therefore, the use of biological controls for this pest is a proven alternative, with good and significant results, to combat this insect, which is currently one of the causes of loss of coffee bean yield and quality in the coffee plantations of the Cumanayagua Municipal Agricultural Company, as well as for individual producers.

Research Problem: Loss of coffee bean yield and quality in Caturra variety plantations belonging to the Cumanayagua Municipal Agricultural Company and in the coffee plantations of individual producers, due to the incidence of the *H. hampei* pest.

Hypothesis: If *Beauveria bassiana* strain LBB 1 is applied as a biological control alternative to control the *H. hampei* pest in Caturra coffee plantations belonging to the Cumanayagua Municipal Agricultural Company and in coffee plantations owned by private producers in the same region, the incidence of this pest could be reduced, achieving improved yields and bean quality in the aforementioned coffee plantations.

General Objective:

To evaluate the influence of *Beauveria bassiana* strain LBB 1 on the control of the *H. hampei* pest in Caturra coffee plantations on Isla 6-14, belonging to the Cumanayagua Municipal Agricultural Company, thereby contributing to improved yields and bean quality in these coffee-growing areas.

Specific Objectives:

To measure the behavior of the *H. hampei* pest under the influence of *Beauveria bassiana* strain LBB 1 in coffee plantations of the Caturra variety Isla 6-14 belonging to the Cumanayagua Municipal Agricultural Company and individual producers in this same region.

To perform statistical analysis of the data obtained from the measurements to validate them.

2. Materials and Methods

2.1. Characterization of the Experimental Areas

This research was conducted on coffee plantations belonging to 5 individual producers of the "10 de Octubre" Agricultural Production Cooperative, located in the Cumanayagua Municipality, Cienfuegos Province. The experiment took place from May to December 2022. The average relative humidity was 85%, the average temperature was between 22 and 30°C, respectively, and the average rainfall was over 800

mm. The characteristics of the coffee plantations in terms of owners and area are shown in the table below:

Table 1. Area and owners of the coffee plantations where the experiment was conducted.

Name of the producer belonging to the CPA "10 de Octubre"	Area of the Caturra variety under exploitation. (ha)
Jesús Chaviano Ruíz	8.66
Yoandry Rosado Rosado	3.07
Rigoberto Mendoza ojeda	2.98
Vienbenido Manzano Godoy	3.02
Berto Gómez de Armas	4.06

Prepared by the authors

The coffee variety grown in all the areas selected for the study is the Caturra Isla 6-14 variety, with 25% shade cover and a slope ranging from 10% to 20%, respectively. The trees used for shade in these coffee plantations include: Samanea saman (Jacq.) Merrill (Carob), Inga vera Lin. (Guano), Guarda guidonia L. (Yamagua), and Erytrins poeppigiana (Walp.) O. F. Cook, trees recommended for shade cover in Cuban coffee plantations [16].

2.2. Methodology for Sampling *B. Bassiana*

Sampling to observe the influence of *B. bassiana* on *H. hampei* (Ferrari) in coffee plantations of the Caturra Isla 6-14 variety was carried out following the methodology proposed in the aforementioned Cuban Standard © NC 1013, which establishes that sampling should be carried out as follows:

To measure technical effectiveness, a sampling was conducted prior to application. To do this, each coffee plantation was visited using Zipzap, randomly selecting 5 sampling points. At each sampling point, rows were selected, consisting of 10 rows, each consisting of 15 plants.

If it is assumed that each established block contained a total of 10 rows with 15 plants each, then each block contained 150 plants to be sampled, and on which *B. bassiana* was subsequently applied. Multiplying the number of plants per block by the number of blocks gives a total of 750 plants, establishing the final sample size. This sample was then used to determine the initial level of *H. hampei* infestation present in each selected coffee plantation and the final level of the pathogen once *B. bassiana* was applied. This experimental design was repeated for the remaining four coffee plantations belonging to the other producers of the "10 de Octubre" CPA.

2.3. Methodology for Applying *B. Bassiana* Strain LBB 1

For the application of *B. bassiana* strain LBB 1 in the pre-

sent study, it was taken into account that the fungus is sensitive to sunlight, so its application was carried out during the cool hours of the morning. The water used for its preparation and application was maintained at a pH between 5.5 and 7.0. At the time of application, care was taken to ensure that it covered the entire plant, especially the entire leaf area [9].

The application was carried out following the methodology proposed in Cuban Standard © NC 1013: 2014 Agricultural Biotechnology - Biopreparations of the Entomopathogen *Beauveria bassiana* - Specifications, which establishes:

Requirements for use and application

The preparation for the application of the biopreparation of the entomopathogen *Beauveria bassiana* was carried out by taking 10 liters at a concentration of 8×10^7 conidia/ml, diluting it in water at a rate of 1 L of the biopreparation, at the aforementioned concentration, in 20 liters of water. The application was carried out using a backpack sprayer on the ten rows with 15 plants located in the four randomly arranged blocks in each coffee plantation to receive this treatment.

For field application, high soil moisture is required. This was achieved by applying the product during the rainy months, from May to June.

Applications of entomopathogens were carried out, as previously stated, during cool morning hours to prevent loss of fungal spore viability due to high solar radiation.

Each coffee plantation was manually weeded, eliminating weeds, a necessary condition for product application.

It was rigorously ensured that the bio-product was not mixed with any pesticide.

The fungus can cause allergies in sensitive individuals, so precautions were taken and personal protective equipment (P3 filter masks and gloves) was worn when handling the bio-preparation.

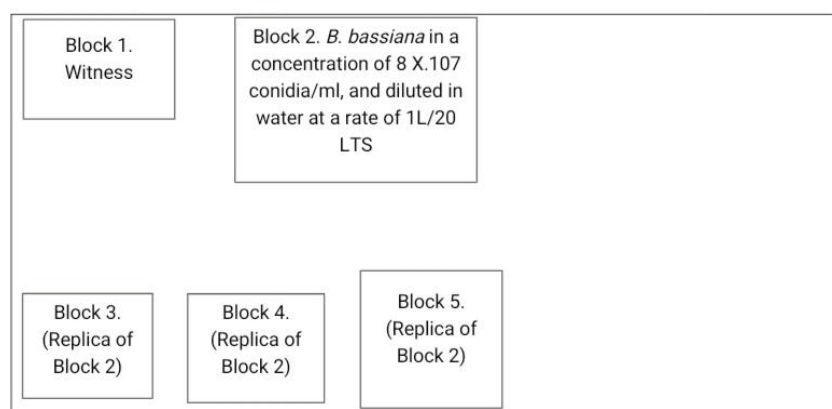
The strains of the fungus used for the applications in this research met the requirements of the Cuban Standards for marketing and application, which are listed in the table below.

Table 2. Characteristics of the *B. bassiana* strain used in this work.

Min. concentration	8 X 10 ⁷ conidia/ml
Virulence,% min.	85
Viability,% min.	85
Technical effectiveness,% min.	60 (*)
Smell	Characteristic
Purity	Impurities are not allowed

A randomized block experiment was designed for the application of *B. bassiana*, starting from the five sampling points randomly chosen in each coffee plantation belonging to each producer. Taking advantage of the sampling design

chosen, the ten rows with a total of 15 coffee plants were taken to confirm the blocks. These were arranged in each coffee plantation as shown in the figure below:

**Figure 1.** Randomized block design.

A total of 5 blocks were established for each coffee plantation under evaluation, for a total of 25 blocks in the five coffee plantations chosen to carry out this research. Of those 25, five would be assumed as controls. *B. bassiana* was not applied to them, that is, they would be free of the application, only an initial and a final sampling would be carried out to observe the levels of infestation of the pathogen. The remaining 20 blocks, which were subjected to the application of the biopreparation at concentrations of 8 X 10⁷ conidia/ml, diluted in water at a rate of 1 L/20 L of water.

This would result in a final randomized block design, consisting of two treatments (control and biopreparation (*B. bassiana* at a concentration of 8 X 10⁷ conidia/ml, diluted in water at a rate of 1 L/20 L of water), the latter with four replicates for each coffee plantation.

Monthly applications of the strains of the fungus, from June to December. The first application was made to green fruit, approximately three months after flowering, and the last after harvest, both as preventative applications (for a total of six applications). Assessments were conducted every

15 days (for a total of nine assessments).

2.4. Determining the Percentage of *H. Hampei* Infestation

To determine the percentage of *H. hampei* infestation, 200 fruits were randomly sampled from each of the five blocks established in each field belonging to each producer. The following were determined: the percentage of fruit infested and the percentage of fruit infested by the entomopathogen.

Infestation levels were determined using the following formula:

$$\text{Fruits infested by the pest} = (\text{fruit infested} \div \text{total fruits} \times 100).$$

2.5. Statistical Processing of the Results

Statistical processing of the results was performed using the Statgraphics Centurion statistical package, version

19.5.01. Assuming *H. hampei* infestation as the dependent variable and treatments and coffee plantation areas as inde-

pendent variables, an LSD test was performed to compare the means of several factors with a 95% confidence interval.

3. Results and Discussion

Table 3. Results of the application of *B. bassiana* for the control of *H. hampei* in plantations of the Caturra Isla 6-14 variety in the Municipality of Cumanayagua.

ENTITY	Producer Name	Area (ha)	variety	Initial <i>H. hampei</i> Infestation Index (%)	<i>H. hampei</i> infestation rate after application of <i>B. bassiana</i> (%)
CPA "October 10".	Jesús Chaviano Ruíz	8.66	Caturra Island 6-14	19	10
CPA "October 10".	Yoandry Rosado Rosado	3.07	Caturra Island 6-14	22	12
CPA "October 10".	Rigoberto Mendoza ojeda	2.98	Caturra Island 6-14	19	8
CPA "October 10".	Vienbenido Manzano Godoy	3.02	Caturra Island 6-14	19	8
CPA "October 10".	Berto Gómez de Armas	4.06	Caturra Island 6-14	24	9
Total Averages	---	4.36		20,6	9,4

Table 3 shows the results of the sampling in the coffee plantations selected for this study. These samplings were carried out in five coffee plantations belonging to producers belonging to the "10 de Octubre" Agricultural Production Cooperative, in the Municipality of Cumanayagua, Cienfuegos Province. The aforementioned Table 3 shows the percentage values of *H. hampei* infestation levels observed in each coffee plantation before and after the use of the *B. bassiana* bioproduct for control.

Prepared by the authors

Comparing the values shown in the table above, which refer to the *H. hampei* infestation levels shown by the coffee plantations selected for this research, before and after applying *B. bassiana*, it is true that for all the producers listed in the table above, the infestation values shown initially are higher than the values that appear after applying *B. bassiana*. These results, although they differ in the values obtained between the initial and final *H. hampei* infestation levels, coincide with those obtained by [15], with regard to a decrease from those initial infestation values to those shown finally. The aforementioned author, when studying the influence of the *B. bassiana* strain LBB 1 biopreparation on the control of *H. hampei* under similar climatic and topographic conditions, and at the same time of year as those in which the present research was carried out, However, with coffee plantations planted with the Robusta variety, he observed a decrease in the *H. hampei* infestation rates shown initially compared to those present at the end, after the application of *B. bassiana*, with the same strain, to control *H. hampei*. In Table 3, initial infestation levels by the pathogen *H. hampei*

are observed, ranging from a maximum value reached by the averages of 24% and a minimum value of 19%, if the initial percentage values of infestation shown in the coffee plantations of the 5 producers under study, where the research was carried out, are averaged, a total average value of 20.6% infestation of *H. hampei* is reached initially, in all coffee plantations under study, these levels of infestation are not considered very high when compared with the levels of infestation shown by [17], in studies carried out in coffee plantations in the State of Trujillo, Bolivarian Republic of Venezuela, these authors report levels of infestation by *H. hampei* in these coffee plantations above 50%, however these initial values of infestation appeared in the present investigation, which as mentioned above are in a total average value of 20.6%; however, if they are well above the 2% considered as the maximum permissible and acceptable value, from which it is considered economic affectation. Returning to the comparison of these results with those obtained by [15], who carried out her research under equal conditions of climate, soil, topography, shade cover and time of year when the experiment was carried out, and type of bioproduct (*B. bassiana* Strain LBB 1) applied for the control of *H. hampei*, where the only variation with respect to the present experiment was that her coffee plantations were planted with *Coffea arabica* L. var. Robusta, it can be observed that the average values of the means obtained by this author, in relation to the initial infestation levels by *H. hampei* and the final ones obtained when applying *B. bassiana* Strain LBB 1 are lower (initial value of infestation by *H. hampei*, 15% and final value of infestation of *H. hampei* after applying *B. bassiana*, 7%), in the present work

initial values of 20.6% and final values of 9% are obtained, respectively, this leads to think about the possible influence of the variety on the levels of variability observed.

In the graph below, [Figure 2](#), you can see more clearly what was said above, but going to a deeper analysis, you can see that the highest levels of infestation by *H. hampei* are

found in the areas of the coffee plantations of the producer Berto Gómez de Armas, with 24% and the lowest have the same values for the rest of the producers, with 19%, for all producers, it is fulfilled that when the application of *B. bassiana* is made there is a reduction in approximately half of the levels of infestation by *H. hampei*.

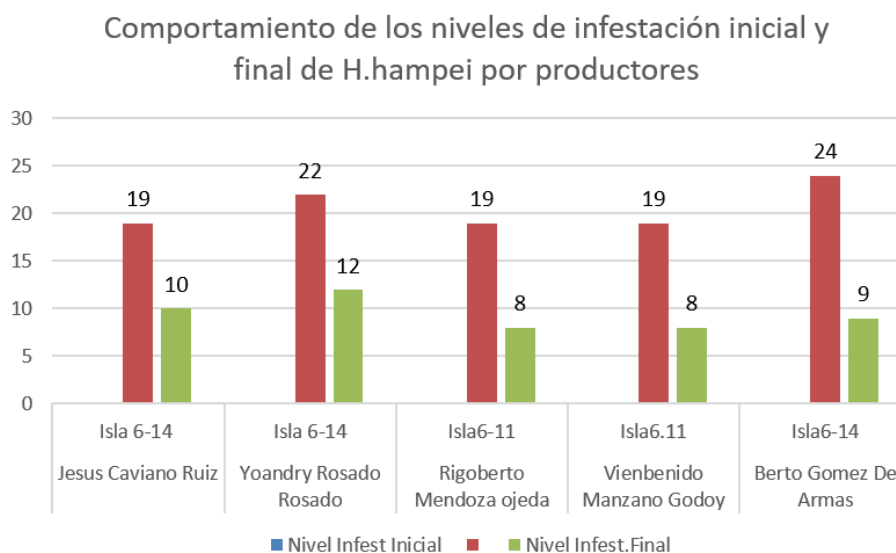


Figure 2. Behavior of initial and final infestation levels of *H. hampei* by producers.

Prepared by the authors

In the graph above, it can be observed that the levels of *H. hampei* infestation after the application of *B. bassiana* show the following behavior: in the coffee plantations of Jesús Chaviano Ruíz, the degree of infestation decreases to 10%, in the coffee plantations of Yoandry Rosado Rosado, the degree of infestation decreases to 12%, in the coffee plantations of Rigoberto Mendoza Ojeda, the degree of infestation decreases to 8%, in the coffee plantations of Bienvenido Manzano Godoy, the degree of infestation decreases to 8% and in the coffee plantations of Berto Gómez de Armas, the degree of infestation decreases to 9%. By observing the previous values, and establishing a relationship between them and the level of influence achieved by *B. bassiana* in the control of *H. hampei*, it can be observed that in the case of the coffee plantations of the producers Rigoberto Mendoza Ojeda and Bienvenido Manzano Godoy, reach the lowest values of presence of *H. hampei* after being applied *B. bassiana* for its control, reaching in both cases, the same value, 8%, in the rest of the coffee plantations, when this same comparison is made it can be observed that the values achieved are above 8%, these results differ from those obtained by [\[17\]](#) who when applying different strains of *B. bassiana* in the control of *H. hampei*, in coffee plantations of the Bolivarian Republic of Venezuela obtained that after the applications the level of infestation never exceeded 5%, demonstrating that early applications of strains of *B. bassiana* exert a certain regulato-

ry and permanent effect over time, despite the fact that its action is reduced at the end of the cycle, when a greater quantity of ripe fruits are present and coincides with the harvest time. These same authors suggest that in 2004, a more homogeneous infestation response was observed across strains, with no differentiation that would allow for a contrast. Although the values expressed were generally lower, the biocidal effect was more pronounced than the previous year; evidenced by the fact that the average percentages of CBB infestation remained below 4%.

In this regard, [\[5\]](#) pointed out that the effectiveness of *B. bassiana* is partly affected by temperature and humidity in the macroclimate, and that microclimate conditions, sunlight, and the biological activity of other organisms can affect the fungus's ability to survive and initiate infestations. This may justify the differences shown between the values obtained by [\[17\]](#) and those obtained in the present investigation, it must be kept in mind that although the humidity levels in the coffee plantations where the present study was carried out are high, the Relative Humidity is above 85%, and the time where the research was carried out guaranteed high levels of rainfall, contributing to ensuring high humidity in general, a favorable condition for the good development of the fungus; however, the average temperatures in this region are below the average of the rest of the country for this time of year, between 22 and 28 degrees Celsius, which is slightly outside the range of optimal temperatures required by the fungus for

its establishment and development, which may have influenced the fact that its level of effectiveness in controlling *H. hampei* is above 8% in most coffee plantations.

If the results obtained in this work are compared with those obtained by [15], who, as previously stated, worked under the same conditions as those present in the present experiment and applied the same *B. bassiana* strain to control *H. hampei*, but on a different coffee variety, it can be observed that the final values obtained in this work, regarding the behavior of the pathogen *H. hampei* after receiving applications of *B. bassiana* with the same strain, are higher than those obtained by the aforementioned author. In this work, an average value of 9.4% was obtained, compared to 7% obtained in the research by said author. Therefore, once again, it can be inferred that there must be some relationship between the coffee variety, the initial levels of affectation caused by the *H. hampei* pest on the variety, and the final levels of affectation that this same pathogen shows once *B.*

bassiana is applied to control the variety present. To seek veracity in the results and in the comparison of the same, a Multiple Comparison test of the means of different factors was carried out (Table 4), a homogeneity test of the groups, in order to establish if there were differences between the means of the compared factors (Table 5), in this last table, it can be observed that between the means of the factor areas planted with the Caturra Isla 6-11 variety there are no significant differences and if between these means and those of the initial and final levels that the pathogen *H. hampei* showed in these areas, the value of the means shown by the initial levels of *H. hampei* being the highest with respect to coffee areas and final levels of *H. hampei*, there are also significant differences between the means of the initial levels that appeared of *H. hampei* and what existed at the end, this makes it clear that there was effectiveness when using *B. bassiana* for the control of the *H. hampei* pest in the coffee areas under study.

Table 4. LSD test for comparing the means of several factors in the present investigation.

Contrast	Sig.	Difference	+/- Limits
Cultivated area - Final infestation level (%)	*	-5,042	2,73016
Cultivated area - Initial infestation level (%)	*	-16,242	2,73016
Cultivated area - Producer		1,358	2,73016
Final Infestation Level (%) - Initial Infestation Level (%)	*	-11,2	2,73016
Final Infestation Level (%) - Fur Product	*	6,4	2,73016
Initial infestation level (%) - Producer	*	17,6	2,73016
E. S =± 0.09232 C. V= 4.146%			

* denotes significant differences. According to LSD test for 95% confidence.

Multiple Range Tests.

Method: 95.0 percent LSD.

Table 5. Test for homogeneity between the means of the groups compared.

	Count	Mean	Homogeneous Groups
Producer	5	3,0	A
Cultivated area	5	4,358	A
Final Infestation Level (%)	5	9,4	B
Initial infestation level (%)	5	20,6	C

According to the LSD test for a 95% confidence level

Looking at the mean values of the initial and final levels of *H. hampei* infestation per producer (see Table 4), it can be

seen that the initial level of *H. hampei* infestation per producer shows a value of 17.2%, compared to 6.4% of *H. hampei* infestation after the application of *B. bassiana* for control.

Therefore, there is a reduction of more than half of the *H. hampei* individuals once *B. bassiana* is applied for control. These results coincide with those obtained by [13], who, when applying the *M. anisopliae* Ma 9236 and Cenicafé Mixture (Bb 9001, Bb 9024, Bb 9119) strains of *B. bassiana* to control *H. hampei*, obtained a reduction of the initial infestation percentages to approximately half of the final infestation values shown by *H. hampei* once *B. bassiana* was applied.

If the results obtained in this work, regarding the reduction in *H. hampei* infestation levels after applying *B. bassiana*, translate into *B. bassiana*'s efficiency in controlling *H. hampei*, then it can be stated that an efficiency of more than 50% was achieved. This level of efficiency achieved in this work confirms the findings of [22] regarding the biological states in evaluations carried out at the Paraguaicito and Naranjal experimental stations, since the applications of fungi to the soil caused a decrease in the next generation of borers that infested new fruits on the tree branches. This decrease was more effective for the mixture of *B. bassiana* Cenicafé strains and was between 55 and 75% under the field conditions evaluated. These results also agree with those obtained by [15], who obtained a reduction of approximately half of the pathogen by applying *B. bassiana*, with the same strain, and under equal experimental conditions, with respect to the present investigation, but with the difference that his work was carried out using areas planted with the Robusta coffee variety.

Economic Evaluation of the Results Obtained in This Research

If a very basic analysis is carried out, considering the relationship: cultivated area, initial level of infestation with the pathogen *H. hampei* and yield per area in production, taking as study material the coffee area belonging to the producer Jesús Chaviano Ruíz, which has a cultivation area, destined to the Caturra Isla 6-11 Variety, amounting to 8.66 ha, and assuming that it achieves good yields, and reaches the yield of 100 to 90 qq / ha, said producer should reach with the area that is currently in operation for the cultivation of the Caturra Isla 6-11 Variety, approximately a yield of 866 to 779.4 qq / ha, now if we add that the levels of infestation by the pathogen *H. hampei* that initially show their areas is a value of 19%, and assuming that according to studies carried out, the levels of infestation of *H. hampei* can influence losses of half, or more than half of the yields of an area, applying the relationship of the level of affectation caused by the insect

attack, only up to half of the yield, this implies that if the following rule of three is proposed:

$$\begin{array}{l} 8.66 \text{ ha} \text{-----} 100\% \\ X \text{-----} 19\% \end{array}$$

If x is cleared, a value of 1.64 ha is obtained. This value implies the amount of surface area infested by *H. hampei* of the total of 8.66 ha available to producer Jesús Chaviano Ruíz, if a basic rule of three is still applied and it is proposed that:

$$\begin{array}{l} 1.64 \text{ ha} \text{-----} 100\% \\ X \text{-----} 50\% \end{array}$$

Solving x , the result is that 0.82 ha of a total of 8.66 ha of the aforementioned producer are affected and are the result of that 19% initial infestation by *H. hampei*, all this, assuming that the damage caused by the pathogen to coffee yields is considered based on an affectation of the 50% of the yields per unit of cultivated area.

Finally, and applying a new rule of three:

$$\begin{array}{l} 1 \text{ ha} \text{-----} 100 \text{ qq} \\ 0.82 \text{ ha} \text{-----} x \end{array}$$

Solving x again will give a value of 82 qq, this means that this is the impact that the yields would have on 8.66 ha of this producer, with an initial impact level of 19% of the total area cultivated with the Caturra Isla 6-11 variety due to the incidence of the pathogen *H. hampei* and considering that the level of impact produced by the pathogen on the yields of the area is 50%. That is, of a possible yield of 866 qq/ha that could be achieved on an area of 8.66 ha of said producer, assuming that the yield is considered based on 100 qq/ha; So, if the 23 qq obtained is subtracted, the final yield will be 77 qq/ha. This means that those 82 qq are equivalent to yield losses. This loss, of course, translates into an impact on the family economy and that of the country. If this same procedure is performed for a 10% final impact due to the presence of *H. hampei*, after having applied *B. bassiana* to the same total area of the aforementioned producer, a final result of 43 sqq will be obtained. This means that after applying *B. bassiana* to control *H. hampei*, in this area under the production of the Caturra Isla 6-11 variety, a reduction in yields to a final 10% is achieved from an initial 19% impact that existed in this cultivated area. In other words, 39 sqq of coffee are recovered due to the decrease in the level of pathogen impact in this same area. This translates into increased profits in the area's yields, in the family economy, and in general, in the country's economy. If the entire previous procedure is applied to all producers and compiled into a table, the following will be obtained:

Table 6. Yield distribution by surface area for each producer; levels of *H. hampei* presence before and after applying *B. bassiana*.

Producer's name	Area of the Robusta variety under its care (ha)	Variety performance based on:	Initial level of <i>H. hampei</i> (%)	Yield Losses Based on Initial Level of <i>H. hampei</i> (qq)	Final Level of <i>H. hampei</i> (%)	Yield Losses Based on Final <i>H. hampei</i> Level (qq)
Jesús Chaviano Ruíz	8.66	100qq	19	82	10	43

Producer's name	Area of the Robusta variety under its care (ha)	Variety performance based on:	Initial level of <i>H. hampei</i> (%)	Yield Losses Based on Initial Level of <i>H. hampei</i> (qq)	Final Level of <i>H. hampei</i> (%)	Yield Losses Based on Final <i>H. hampei</i> (qq) Level
Yoandry Rosado Rosado	3.07	100qq	22	33	12	18
Rigoberto Mendoza ojeda	2.98	100qq	19	28	8	12
Vienbenido Manzano Godoy	3.02	100qq	19	29	8	12
Berto Gómez de Armas	4.06	100qq	24	49	9	18
TotalAverage.	4.36	-----	20,6	44,2	9,4	18

Prepared by the authors.

If we only take the total average shown in the table above, specifically the yields, and assuming that all the values shown for each unit of cultivated area of the Caturra Isla 6-11 variety of each producer have been taken based on a yield of 100 qq/ha, and that the total area of all producers is on average 4.36 ha, and if we assume that the level of losses in total initial average yield in these 4.36 ha is 44.2 qq under an initial average infestation by *H. hampei* of 20.6% and after applying *B. bassiana* in the total average surface area (4.36 ha), there is a decrease in the levels of infestation of *H. hampei* to 20.6%, causing a recovery of about 23.6 qq of coffee, as stated above this last value would produce an increase in profits per producer due to increased yields as the levels decrease. *H. hampei* infestation.

4. Conclusions

There are significant differences between the mean *H. hampei* infestation levels before and after applying *B. bassiana* strain LBB 1 for control. The mean *H. hampei* infestation levels after applying *B. bassiana* strain LBB 1 were reduced by 50% compared to the initial infestation levels.

There are significant differences between the mean initial and final *H. hampei* infestation levels and the size of the coffee-growing areas studied.

Assuming a yield of 100 qq/ha, on an average total area of 4.36 ha of *Coffea arabica* L. var. Caturra Island 6-11, when the levels of *H. hampei* infestation are reduced from an initial average value of 20.6% to a final average value of 9.4%, a recovery of 23.6 qq occurs after applying *B. bassiana* Strain LBB 1 for the control of *H. hampei*.

Abbreviations

CREE	Center for the Reproduction of Entomophages and Entomopathogens
<i>H. hampei</i>	<i>Hypothenemus Hampei</i>
<i>B. bassiana</i>	<i>Beauveria Bassiana</i> Strain LBB 1

Conflicts of Interest

The authors declare no conflicts of interest.

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