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Contribution of Different Agronomic Practices and the Fungus *Beauveria bassiana* on the Coffee Berry Borer

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Abstract: The research was carried out to study the effect of varying certain ecological conditions in the coffee through the implementation of different agronomic practices such as regulation of the shade, ground cover and rehabilitation of plantations on the populations of the coffee berry borer *Hypothenemus hampei* Ferrari (Coleoptera: Curculionidae), it was also evaluated the influence of these conditions in the introduction and transfer of new variants of application of the fungus *Beauveria bassiana* (Balsamo) Vuillemin. The results showed that the pest damage was lower under a system of sustainable coffee, designed after the restoration of the population density of coffee, conducting systematic pruning and plant health, sanitation of the forest, shade management to double stratum with scattered light intensity of 60-70% and a combination of systems of denominated handling of weeds (Strip weeding - Ring weeding), it was found that under these conditions the technical effectiveness of the fungus *B. bassiana* was higher compared with applications made in the trees less enlightened, being more advantageous to spray the foliage four times with a frequency of 40 days from 60 days to peak flowering with positive economic indicators even when used as single biological control strategy against the coffee berry borer.

Key words: Coffee berry borer, coffee plantation management, *Beauveria bassiana*.

1. Introduction

Within the complex biological harmful affecting coffee in Cuba, the main problem today is the coffee berry borer *Hypothenemus hampei* Ferrari (Coleoptera: Curculionidae) which was registered in 1995. This pest is currently distributed throughout the country with high levels of damage in certain areas, regions, soil and climatic conditions of coffee agroecosystems to which have been devoted considerable resources and efforts to combat it, and at first the fundamental strategy was based on chemical control [1].

Globally emphasized in lower costs and ecological risks due to the indiscriminate use of pesticides, an issue that has been treated by different researchers in Cuba regarding the effect of agricultural management and crop technologist on the main pests in the tree, based on the leafminer (*Leucoptera coffeella* Guerin-Meneville) and coffee leaf rust (*Hemileia vastratix*, Berkeley-Broome), among others, but on the coffee berry borer appeared more recently, it has not sufficient items yet to provide new fighting tactics which require a better understanding of the ecology of this pest.

An adequate system of rehabilitation and renovation of coffee plantations greatly facilitates the management of the coffee berry borer and coffee leaf rust, as it enables the implementation of phytosanitary

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basic measures [2, 3]. However, the potential of these practices can have the coffee agro-ecological management in particular of the shadow, to create sustainable conditions that limit the development of populations of the coffee berry borer, and have not been studied in depth the vital element importance for the specific conditions of coffee production in Cuba, where there is great variability in the characteristics of coffee agroecosystems.

Similarly, the fungus *B. bassiana* is widely used as biological control of coffee berry borer, despite this studies have led to inconsistent results on a frequent basis. However, it has been observed at times corresponding to the technology application and natural performance that are achieved significant levels of epizootics [4-6].

Regarding the results of this entomopathogen sprays under field conditions in Cuba, like those in the world, not clarify the possible effects of agricultural management and the cultivation of coffee technologist akin to achieve a more sustained formulation. Hence, the objective of this research was to evaluate the contribution of the implementation of different agronomic practices and application of the fungus *B. bassiana* on the coffee berry borer.

2. Materials and Methods

The research was conducted in two experiments, and in the first experiment assessed the effect of variation in ecological conditions of the plantation, due to the performance of agricultural work on the populations of the coffee berry borer and regulation of diffuse light intensity, stratification of the shadow, green coverage soil, pruning coffee plantation, restoration of the population coffee density and agroforestry sanitation system as described below.

In the first months of implementation of the research, it was adapted in each coffee plantation module, it was planned to study ecological conditions of each option and provide plots of the features demanded by the project, which took in all cases the conditions coinciding with the natural projection of the experiments.

The measurement of directly diffuse light intensity (IL) in percent was made on the basis of stratification of the coffee according to Refs. [7, 8] for four times a year (January, April, June and September) and the use of pyranometers sampling and assessment of fragmentation or subdivision of the coffee was made in its vertical component in five stratum:

Stratum [I]: surface soil vegetation ($X < 0.5$ m) = green floor or live cover;

Stratum [II]: ($0.5 < X < 1.5$ m) = lower coffee transport;

Stratum [III]: ($1.5 < X < 3$ m) = upper coffee bearing;

Stratum [IV]: ($3 < X < 5$ m) = second stratum of the coffee agroecosystem;

Stratum [V]: space above 5 m ($X > 5$ m) = first of the coffee agroecosystem.

The experimental design was split plot with three replications bifactorial an experimental with a total area of 18 hectares.

2.1 Experiment 1. Contribution of the Implementation of Agricultural Practices on the Coffee Berry Borer

Establishment and description of the experimental treatments:

Factor L: Agroecological characteristics of coffee (large plots).

Description of experimental variations on plots:

L1: MS + NV + IL (40-50%); L2: DE + NV + IL (40-50%); L3: MS + NV + IL (60-70%); L4: DE + NV + IL (60-70%); L5: MS + FG + IL (60-70%); L6: DE + FG + IL (60-70%)

where, MS: Single stratum: Plantation characterized by a monospecific shade of trees of the specie *Erythrina poeppigiana* Valp;

DE: Double stratum: Consist in the addition of the plantation sp. *Erythrina poeppigiana* Valp as first stratum a second layer composed by other forest trees and fruit trees;

NV: Without covering (presence of weeds as soil cover among lines of plants);

FG: Green flat: Establishment of soil covering with *T. zebrina* among lines of plants;

IL: Diffuse light intensity directly into the crop coffee (%).

Factor C: Composed of two management system Co and C1 (Subplots), which was taken into account in the technological characteristics of the type of coffee cropping applied according to the indications [9] modified by Fernandez [10];

Co: Traditional technology of mountain coffee (rustic plantations): This was formed under a system away of strip weeding: to remove weeds in lines or furloughs pruning to an average height of 2.0 cm among lines of the plants and without syrup or rehabilitation of the plantation and associated agroforestry system;

C1: Sustainable technology of coffee cropping is based to enrich the traditional management technology of mountain coffee whit application of the principles of agroecological pest management, for the implementation of different cultural practices of coffee plant protection purposes as PS (systematic pruning) of 25% each year and PF (plants health pruning) according to the requirements in each case. The restoration of the coffee population density is greater than 95% and the regulation of HA (health agroforestry), including a combination of systems of denominated handling of weeds (Strip weeding - Ring weeding), which are based on the selection of broadleaf shrubs (dicotyledonous), the veneer of narrow-leaved species (monocots) or the establishment of a green covering on the soil with *T. zebrina* among lines of plants at a maxim average and maximum height of 6.0 cm for weeds or *T. zebrina* and weeding ring system based in, to remove weeds in rings around the base of the coffee trees until area of fall of the berries.

Monitoring of pest damage on fruit in the foliage was conducted according to the particulars provided in the methodology of integrated pest count for the cultivation of coffee as Monterroso et al. [11].

In both systems (C1 and Co) related work was to obtain a crop with quality according to the technical instructions for the coffee cultivation and reduce the presence in post-harvest berry on soil and in the foliage.

Alternatively control of the 12 combinations of treatments given, it was selected the double stratum, uncovered, diffuse light intensity of 40-50% under the traditional management system (L2Co).

2.2 Evaluation of the Effectiveness of the Fungus B. bassiana on the Coffee Berry Borer

It was used as a base to form part of the second experiment variation of agroecological management of this pest that most contributed to the decline of the affectations of this pest, which included yet another mode of regulation of light intensity and thus evaluate the charitable contribution of the agricultural practices employed in the technical effectiveness of the fungus *B. bassiana* on the coffee berry borer, as described below.

The design used was three-factor split plot with three replications for a total experimental area of 18 hectares according to the following description:

Factor A: The year (2004 and 2005);

Factor B: Agroecological characteristics of the coffee.

Descriptions of experimental variations on large plots:

Variant (S1): Double stratum with IL = 60-70% + (Sustainable coffee cropping technology C1);

Variant (S2): Double stratum with IL = 40-50% + (Sustainable coffee cropping technology C1);

The subplots Factor C: Different applications of the fungus *B. bassiana* (Table 1).

This berries sanitation experiment was carried out in January in all plots each year, with an initial average infestation, index plague of 1.62%.

Evaluation of population behavior of the coffee

Table 1 Variants of managing diffuse light intensity directly into the coffee and applications of *B. bassiana*.

Light intensity (%)	Treatments	Processing Applications of the formulations of *B. bassiana*										
		Foliar									Soil	
		30	50	60	90	100	120	140	150	180	60	180
60-70 + Sustainable technology C1 (S1)	1	X	-	-	-	-	-	-	-	-	-	X
	2	-	-	X	X	-	-	-	-	-	-	X
	3	-	-	-	X	-	X	-	X	-	X	X
	4	-	-	X	-	X	-	X	-	X	-	-
	5	-	X	X	X	-	X	-	X	X	-	-
	6	-	-	-	-	-	-	-	-	-	X	X
40-50 + Sustainable technology C1 (S2)	1	X	-	-	-	-	-	-	-	-	-	X
	2	-	-	X	X	-	-	-	-	-	-	X
	3	-	-	-	X	-	X	-	X	-	X	X
	4	-	-	X	-	X	-	X	-	X	-	-
	5	-	X	X	X	-	X	-	X	X	-	-
	6	-	-	-	-	-	-	-	-	-	X	X
	Year 2004	17/05	6/06	16/06	16/07	26/07	15/08	4/09	14/09	14/10		
	Year 2005	28/05	17/06	27/06	27/07	6/08	26/08	18/09	28/09	28/10		

Date of flowering:
7/01/04: Sporadic flowering; 5/04/04: First greatflowering; 17/04/04: Second greatflowering;
17/01/05: Sporadic flowering; 20/04/05: First greatflowering; 28/04/05: Second greatflowering.

berrys borer in positions A and B fruit (berry infested and infestation index from 60 to 190 dpfm).

In this case the samples were performed on ten-year, from 60 days after the second greatflowering (dpfm) until 10 days after the last spraying (190 dpfm), using the information specified in the integral pests counting methodology for the cultivation of coffee, which was implemented in the first experiment according to the positions occupied by pest in the fruit during transit to the endosperm, which are most vulnerable stages of this bioproduct: A start position of the insect penetration B is presence of the insect in the channel of the fruit.

2.2.1 Determination of Damage to Fruits by *Hypothenemus hampei* at the Beginning of the Harvest

At the beginning of the harvest, a sample of 150 fruits per plot was determined by the infection index at this stage IC (%) and assessed the overall positions of the drill penetration in the fruit (positions AB and CD) as follows: berry infested at positions A and B at the beginning of the harvest in infested grain positions C and D at the beginning of the harvest, total grain brocades at the beginning of the harvest, where C is the presence of the insect in the almond and position D is the location of the insect and its offspring in the kernel.

2.2.2 Method of Application and Evaluation of the Technical Effectiveness of the Fungus *Beauveria bassiana*

To perform the treatments entomopathogen *B. bassiana* native strain (Code 3067) of the Center for Industrial Biotechnology at the University of East in the control of coffee berry borer. It was designed a scheme of (F) foliar and (S) soil with different cadences, which took into account the two levels of light intensity described in the two large plots, plus coffee phenology (flowering) described in Table 1 and the control variant was formed from the indications Defence Program against coffee berry borer and Letters Technology of the crop by an initial system of two foliar sprays every 30 days from 60 dpfm and a final ground at 180 dpfm under a light intensity of 40-50% (S2T2) as the excess of shadow is one of the problems that affect the main country's coffee regions [12].

The based product biopreparation *B. bassiana* for all field applications was sent from the Center for Reproduction of Entomopathogenic from Niceto Perez municipality, Guantánamo province, with concentrations of 109 spores·g^{-1} solid commercial product according to Ref. [10] and as the sodium lauryl sulfate, surfactant substance at a rate of two grams per liter premix (30 L) at a dose of 1 kg·ha^{-1} broth concentration of spores in not less than 10^7 spores·mL^{-1}. Spraying was initiated from the second great flowering (peak flowering), all in the evening hours after 15:00 hours, with a crop spraying machine Still-400 calibrated in position 1 at a dissolution between 160-180 L·ha^{-1} on average and for quantification of field (ET) technical effectiveness is used Abbott’s formula.

2.2.3 Evaluation of the Effectiveness Spraying Technique on Fruit Soil

To determine the technical effectiveness on fruit, soil applications were identified five points with a good distribution in the coffee as instructed in Ref. [13]. Two rows were chosen at each point, each row was selected in two floors and is sampled with the location of a frame of 0.5 m^2 on the first floor to the right, another to the left side and took a random fruit, for a total of 20 fruits each plot was sent to the laboratory in separate vials for later analysis. This procedure is performed 10 days after each application to determine the effectiveness of the application technique *B. bassiana* in the same laboratory procedure and formula, is also assessed the contribution of soil application in the dynamics of the percentage of infestation of the pest on foliage (I%).

2.2.4 Evaluation of the Technical Effectiveness of the Sprays on Foliage Fruits

The method of sampling was taken into consideration in this case, it was the same technique procedure described to determine the effectiveness on the ground, but plants were selected in each row, on the first floor placed a branch of the middle and took a lower grain for damage caused by *H. hampei* and the second was sampled in the upper middle strata of plant and for the rest of the sampling points of the plots, for a total of 20 berry per plot. The fruit samples were placed equally in individual vials and were taken to the laboratory for analysis.

For both applications on the ground and in the foliage, It was assessed the overall technical efficiency average from baseline to the last application and its dynamics at different times in different spray treatments.

2.2.5 Determination of Mean Fruit Weight and Yield of Coffee Berries

Average weight of the fruit: the collection of 150 fruits per plot at the beginning of harvest was determined in the laboratory at each harvest, the average weight in grams (g) with the use of a digital scale.

AY (Agricultural Yield) in t·ha^{-1}: two crops were evaluated by quantifying yields through direct harvesting parcel by parcel, after this, it was calculated the crop yields per unit area of coffee cherry (t·ha^{-1}).

2.2.6 Statistical Analysis

It was used the statistical package STATGRAPHICS Plus version 5.1, with analysis of variance and multiple comparison of means with significance of 0.05 according to Duncan in both experiments. In the second experiment for variable technical effectiveness, the transformation was performed for data percentage values using the following equation 2arcoseno$\sqrt{\%}$, to determine the integral influence as evaluated variables, discriminating analysis was performed using nine canonical variables of the second experiment: (1) overall infection index in the positions A and B, (2) berry infested with *H. hampei* at positions A and B, (3) the spraying technique effectiveness of *B. bassiana*, (4) index of infestation at the start of the harvest SH (%), (5) in infested grain positions A and B at the beginning of the harvest, (6) infested berry in C and D at the beginning of the harvest, (7) total grain brocades at the beginning of harvest, (8) average weight of 150 fruits, and finally (9) the cumulative average performance of the coffee cherry 2004 and 2005.

2.2.7 Economic Valuation of the Variants of the Plantation Management and the Fungus *Beauveria bassiana* on the Coffee Berry Borer

The economic evaluation was conducted with a view to establish the cost benefit through the consideration of indicators provided by the Food and Agricultural Organization [14], in order to make a new proposal of strategic management of this pest and spraying of the entomopathogenic akin to improve the current strategy against the coffee berry borer from the perception of a local focus.

3. Results and Discussion

3.1 Experiment 1. Assessing the Contribution of the Implementation of Agricultural Practices on the Coffee Berry Borer

Infested grain variable showed in Fig. 1 was observed in most treatments, it showed a significant positive effect on the traditional sustainable system, except in four double treatments stratification in the presence of ground cover with weeds (L2Co; L2C1; L4Co and L4C1), although latter two the number of damaged berries were lower, probably due to the introduction of the light intensity of 60-70%. Likewise, the presence of damage berry was greater when the plantation is under the impact of a single stratum, the presence of weeds, light intensity (40-50%) and as the traditional management system (L1Co).

It is noteworthy that the number of infested berries was lower to the extent that richness species increased by double stratification of diffuse light intensity of 60-70% and provided the sustainable cultural management, it was not found a significant difference between the arrangement of *T. zebrina* and management of the weeds (L6C1 and L4C1), both were more beneficial than the implementation of the designed control variant (L2Co).

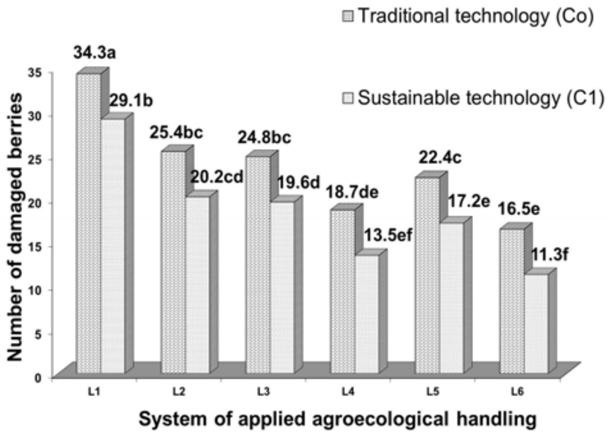

Fig. 1 Contribution of different management systems on the *H. hampei* infested berry number. Means with different letters indicate significant differences according to Duncan's test at $P \leq 0.05$, ES: ± 2.21.

L1: MS + NV + IL (40-50%); **L2**: DE + NV + IL (40-50%); **L3**: MS + NV + IL (60-70%); **L4**: DE + NV + IL (60-70%); **L5**: MS + FG + IL (60-70%); **L6**: DE + FG + IL (60-70%); **MS**: Single stratum; **DE**: Double stratum; **NV**: No covering; **FG**: Flat green; **IL**: Diffuse light intensity directly into the coffee (%).

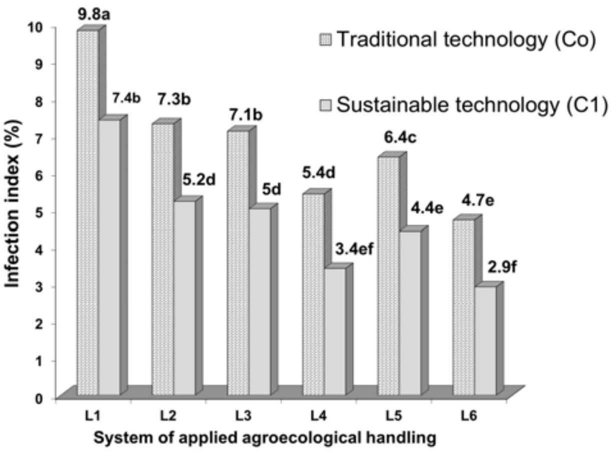

Fig. 2 Behavior of the index of infestation in the field of *H. hampei*. Means with different letters indicate significant differences according to Duncan's test at $P \leq 0.05$, ES: ± 0.86.

In the variable index of infestation (Fig. 2), it was found that the rates were lower in the coffeetrees where the system was implemented sustainable coffee regardless of the agro-ecological condition was established. It was also observed that the index of infestation in cherries was lower in the plantations of double stratification that were regulated at a light intensity of 60-70% and a green floor with *T. zebrina* under sustainable management system (L6C1), which differs from the trees that have weeds.The coffee as soil cover with the same stratification, light intensity and technological system (L4C1), where the infestation index was 57% less than the average compared to the control (L2Co), although the variant L4C1 was no significant difference compared to when the shadow was handled in a single stratum, light intensity of 60-70% and hedge *T. zebrina* in their interaction with the system development (L5C1).

It is important to point out that the management of natural vegetation of weeds in the C1 system is based on a general set of weeds to a level that does not affect crop growth, with the aim of creating an enabling environment that could facilitate the decomposition or germination of the fallen out ring berries, which resembles the establishment and management of live covering with *T. zebrina*, which can be the root cause of this behaviour which is not differentiated between the two treatments (L6C1 and L4C1) which were established under which conditions are not prone to the development of the coffee berry borer, which could be capitalized as part of the pest management strategies. In this sense, Rao et al. [15] and Staver et al. [16] reported that the structure of stratification in these cropping systems can be used to benefit the management of pests and other agricultural interest organisms.

Finally, the number of infested berries and the index of infestation of the pest had contracted a variation of the damage to the combined effects of change in coffee agro-ecological conditions in terms of stratification, light intensity and type of soil cover in accordance with the applied technology system and changes that may significantly modify just one of these elements.

3.2 Evaluation of the Technical Effectiveness of the Applications of Entomopathogenic B. bassiana in Reducing the Damage of the Coffee Berry Borer

In Fig. 3, it is usually observed different trends in the dynamics of infestation index compared to variants of operation, where the highest levels of infestation throughout the period were found in the treatments (S1T1 and S1T6) with a linear tendency that is accentuated from the 90 dpfm, culminating percentages above 4.8% to 190 dpfm.

It is important to note that starting with the ground spraying at 60 dpfm and then the foliage (S1T3) related to control populations of *H. hampei* in the soil, which did not show a significant effect in reducing infestations in foliage within 90 dpfm; The same happened to stop the cycle of foliar spray at 150 dpfm for 30 days, which held the last application to the soil.

The results of foliar sprays of infestation values were lower since the beginning of fruit development, though, when the foliage applications stopped at 90 days after peak flowering (S1T2), they also revealed an increased index of unfavorable infestation. It is equally evident that the greatest contribution to the decrease in the percentage of infestation in the field from 60 to 190 dpfm was obtained when using four or more foliar sprays (S1T4 and S1T5).

Likewise, a trend increase in the percentage of infestation (% I) before the next application of *B. bassiana* was sprayed to the foliage when the coffee with a frequency of 40 days (S1T4), although, after a new spray infestation levels (I%) in cherries reached acceptable values that close to 2.0 percent, which denotes that frequencies longer apply to the unfavorable cause an increase of pest populations.

A different behaviour was observed in Fig. 4 for the trees grown with less light (IL = 40-50%) where the percentages were generally high, it was observed that the initial management of spraying the foliage to 30 days after the second great flowering and ground at the end of the cycle (S2T1) and those that were made specifically to spraying the soil (S2T6), showed a gradual upward trend in field infestations. In a similar way, a high peak stage of the overall increase between 80-100 dpfm infestations. The control variant (S2T2) described the dynamics to be bent to a linear increase from 110 dpfm, accentuated later than 150 dpfm than that stated in the particulars provided by the phytosanitary authorities of the country. Although it

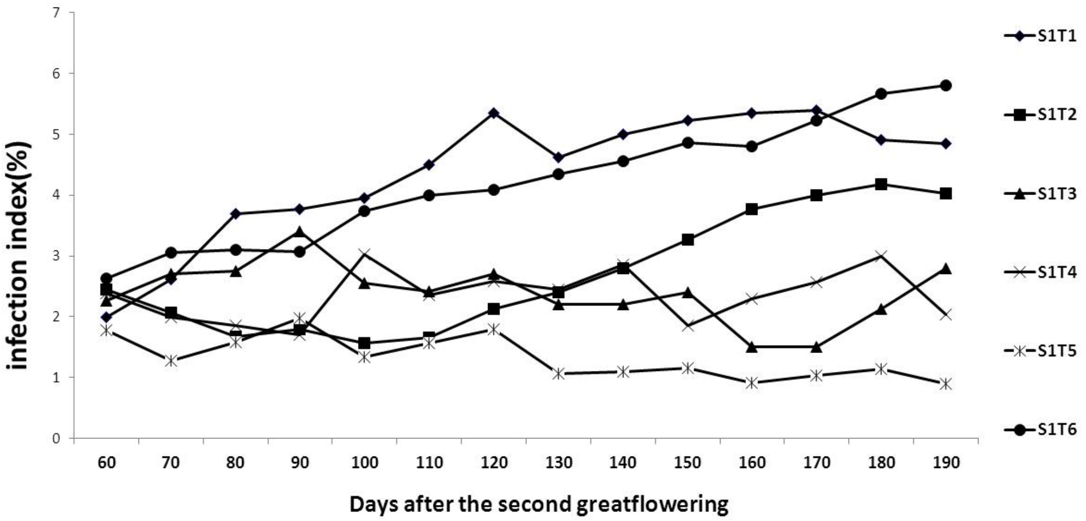

Fig. 3 Fluctuation index of infestation (%I) of coffee berry borer in different treatments with *B. bassiana*.
T1: F (30) S (180); **T2**: F (60) F (90) S (180); **T3**: S (60) F (90) F (120) F (150) S (180); **T4**: F (60) F (100) F (140) F (180); **T5**: F (50) F (60) F (90) F (120) F (150) F (180); **T6**: S (60) S (180); **F** (Leaf); **S** (Soil) (#) days after the second greatflowering dpfm and **S1**: IL = 60-70%.

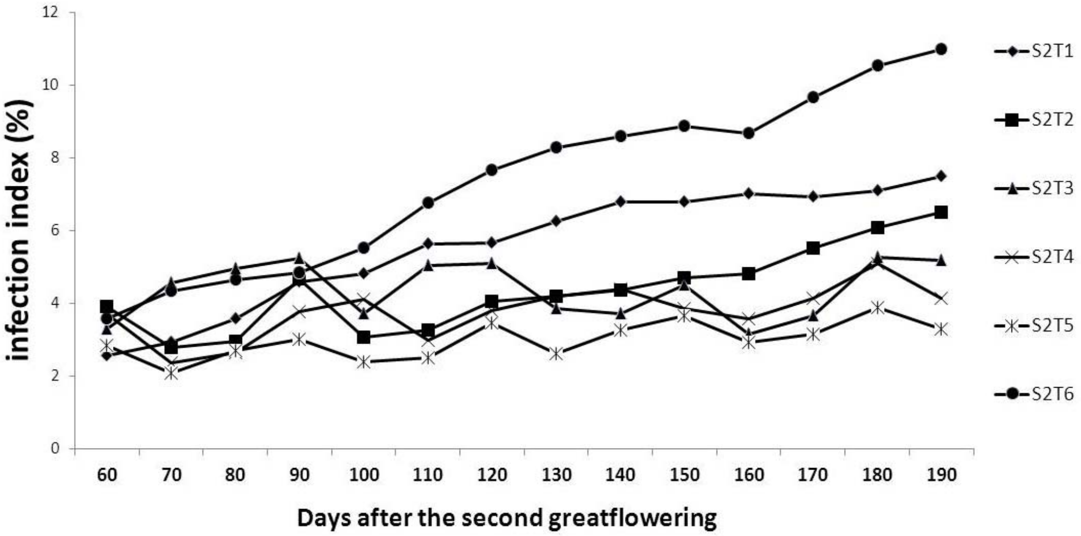

Fig. 4 Variation in infestation index (%I) of *H. hampei* in different treatments with *B. bassiana* in correspondence with the dark management system (S2).
T1: F (30) S (180); **T2**: F (60) F (90) S (180); **T3**: S (60) F (90) F (120) F (150) S (180); **T4**: F (60) F (100) F (140) F (180); **T5**: F (50) F (60) F (90) F (120) F (150) F (180); **T6**: S (60) S (180); **F** (Leaf); **S** (Soil) (#) days after the second greatflowering dpfm and **S2**: IL = 40-50%.

remains interesting the favourable effect of increased spraying in plantations with this lighting in decreasing infection index (%I), which was expressed in the variants of unique applications to the foliage of four and six sprays (S2T4 and S2T5).

About that Soto et al. [17] reported that no significant differences in the population variation of the coffee berry borer and natural enemy action, corresponding to the impact of factors such as sunlight and shadow type of coffee tree, although in this if the light was regulated in the coffee to a large gradient between 23-70%, in which these factors had no significant effect on the percentages of berry affected by the coffee berry borer, which is attributed to the abundance of natural enemies in these types of rural plantations.

In Fig. 5, it was found that in the coffee light intensity of 60-70%, only variants of spraying the foliage of four and six applications (S1T4 and S1T5) showed the highest overall percentage values, in addition, these not differ from each other and reach values higher than 42% efficiency and higher average technique to control (S2T2) in a 59.4%, however, other variants not overcome 28% of technical effectiveness.

It also showed a similar pattern in two of the models that were combined spraying the foliage to the ground and, when there were two successive applications to the foliage every 30 days from 60 dpfm and at the botton of the soil 180 dpfm (S1T2) and the other with frequency of 30 days, which initiated the application running on the ground at 60 dpfm with three more to the foliage and closing cycle at 180 dpfm towards the soil (S1T3).

Another element to specify is that low light incidence of all spray patterns showed no technically effective values greater than 20% except for the treatment of six unique applications to the foliage alternated in which frequencies of 10 and 30 days from 50 to 180 dpfm (S2T5) also was not found significant differences between the four treatments (S2T1, S2T2 control and S2T4, S2T3).

This enhancement of the technical effectiveness found in the trees most enlightened, which may be a result of the possible stimulating action of yellow and black light on the formation of conidia during fungal development over the adults of this pest, which could led to increased survival and transmission of inoculum of this entomopathogen. In this regard, Edgington et al. [18] considered the light factor, especially the high ultraviolet radiation as the main environmental factor limiting bio-insecticides most commonly used today, hence, it is necessary to emphasize that the low intensity of scattered light within agro-ecosystems coffee that also affects the effectiveness of spraying the fungus *B. bassiana*.

It is known that the fungus *B. bassiana* has the ability to develop a saprophyte in soil and persist for prolonged periods and precisely shaded coffee agro-ecosystems are characterized by significant levels of organic material on the surface that come down from the forest, crops, the covering itself existing land and culture, and this should greatly facilitate

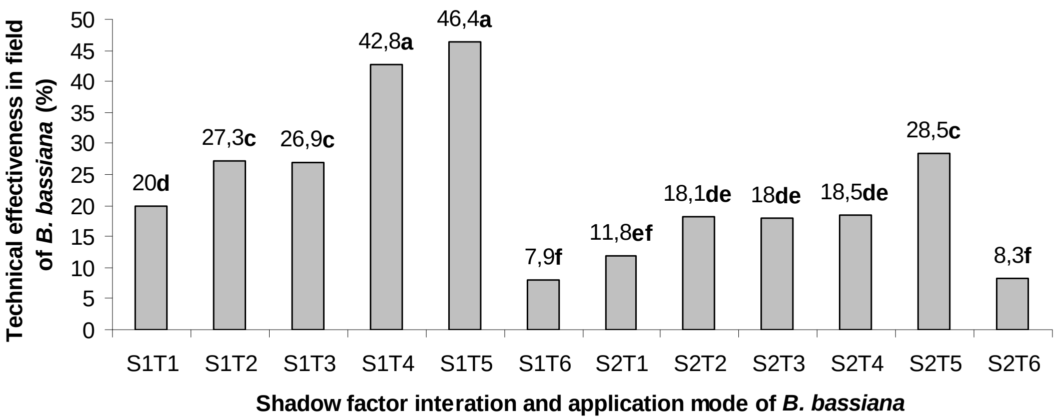

Fig. 5 Average behavior of the percentages of technical effectiveness of spraying with *B. bassiana* interaction according to the shade and bioproduct application mode. Means with different letters indicate significant differences according to Duncan's test at $P \leq 0.05$; ES: ± 0.02.

T1: F (30) S (180); **T2**: F (60) F (90) S (180); **T3**: S (60) F (90) F (120) F (150) S (180); **T4**: F (60) F (100) F (140) F (180); **T5**: F (50) F (60) F (90) F (120) F (150) F (180); **T6**: S (60) S (180); **F** (Leaf); **S** (Soil) (#) days after the second great flowering dpfm; **S1**: IL = 60-70% and **S2**: IL = 40-50%.

the establishment of the fungus in the soil, a very important element to reduce the damages of pests at this level of the agro-ecosystem. However, to produce a good and stable sporulation fungus like other fungi need favourable conditions, in which the light factor is of considerable importance [19] and precisely management system is the double stratum generally distinguishes coffee agro-ecosystems in this region, a feature that was identified by the Business Group of Mountain Agriculture in the region in the year 2003. In this regard it is reported that these agro-ecosystems can intercept up to 80% of solar radiation and reflect their foliage to about 15%, which reaches the surface soil about 5%, which causes it to increase the levels of gloom at this level, which may affect stable and sufficient sporulation of this fungus to infect adults moving drill in the soil colonizing the fallen cherries, besides the possible protective effect offered by the fruit once the insect is inside hypotheses that could explain the low effectiveness of spraying to the ground.

To determine the integral influence all variables in selecting the best variant of agronomic management of the coffee berry borer, it was performed a canonical discriminanting analysis with the results of all response variables used in the development of the second experiment, corresponding to the different variants of handling the intensity of light of the coffee, the manner of applying sprays with *B. bassiana* for each evaluation period, as shown in Fig. 6.

It was found that the first component C1 accumulated 98.51% of the total variability between groups, allowing discriminating variables with higher contribution to their formation (C1) and are listed below: infestation rate positions penetration *H. hampei* A and B throughout the experimental period (%I A and B Tp), total infested berries at the beginning of the harvest (TBI SH), infested berry at positions C and D at the beginning of the harvest (BI C and D SH), berry infested at positions A and B at the beginning of the harvest (BI A and B SH), index

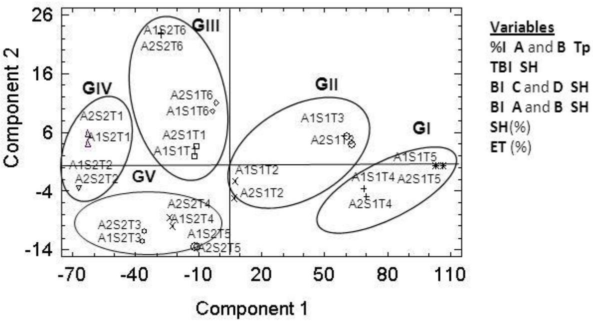

Fig. 6 Distribution of different management alternatives based on canonical discriminant analysis.

T1: F (30) S (180); **T2**: F (60) F (90) S (180); **T3**: S (60) F (90) F (120) F (150) S (180); **T4**: F (60) F (100) F (140) F (180); **T5**: F (50) F (60) F (90) F (120) F (150) F (180); **T6**: S (60) S (180); **F** (Leaf); **S** (Soil) (#) days after the second great flowering dpfm; **A1**: year 2004; **A2**: year 2005; **S1**: IL = 60-70% and **S2**: IL = 40-50%.

of infestation at the start of the harvest SH (%) and technical effectiveness of the sprays of *B. bassiana* (ET).

Similarly it is observed that the more often foliar sprays treatments were within the control of the shadow conglomerate S1 into two groups (GI and GII) and were located at the far right of the graph where the effect is greater to the formation of Component 1.

The first group were placed more variants of sprays S1T5 (combination of six frequencies of foliar sprays of 10 and 30 days) and S1T4 (foliar sprays every 40 days) and in an intermediate position provided for the second group (GII), which are combined foliar sprays and soil (S1T2 and SIT3) which confirms that under these conditions of the plantation management, implementation of a system of four applications with frequencies of 40 days (SIT4) could provide without two more applications compared with treatment S1T5, a vital element to the economic performance of these entities. Moreover, the C2 component had no significant contribution to the discrimination and accumulated only 1.49% of the variability between groups, where they formed three groups which include all variants, combining of spraying modes in the shadow system S2 (IL = 40-50%). One on top (GIII), comprising the treatment of fewer sprays of both management dark systems (only the ground and S2T6

S1T6) and that combining an early application and finishing spraying of the foliage to the ground (S1T1). Finally, group IV (S2T2 S2T1 and control) and V (S2T3, S2T4 and S2T5), were composed by the other treatments of foliar sprays more frequently within the management system of the shadow of 40-50% diffuse light.

According to the results obtained in this investigation and the variability in the clustering of individuals within each component, you can have a better understanding of the factors that are linked to the low effectiveness of this entomopathogenic technique on coffee berry borer and variability of the pest population reported in Cuba and worldwide issue that has been well addressed [20].

Regarding the (CBR) cost benefit ratio of variant management that contributed to the decrease in damage to the coffee berry borer control regarding treatment. Values were more affordable in this indicator for the variants of spraying the foliage of four applications every 40 days beginning at 60 and ending at 180 dpfm (S1T4), with a value of 4.12 and 4.53 for RBC for the time the foliage sprayed six times with onset at 50 dpfm, a second at 10 days followed by four applications more frequently than 30 days (S1T5), which had positive values of benefits in relation to the control variant, held in two applications to the foliage with an interval of 30 days from 60 dpfm and down to the last 180 days of this flowering (S2T2).

The first variant (S1T4) not only helps to have an important result in terms of this indicator, but requires fewer applications which are very important to take into consideration because the conditions under which coffee is grown in Cuba. In regard to national and international reports on the economic performance of different regions and forms of production area to implement strategies for the management of coffee berry borer, they are inclined to the execution of a major investment by acreage and per year, however, this increase in costs as a result of the management of coffee berry borer, substantially doesn't affect the economic performance of the farms of the studies, an element that is based on the reduction of losses in the yields and increased income from better quality of coffee sold.

3.3 Proposed Management Strategies of the Coffee and B. bassiana as A Biological Control of Coffee Berry Borer

Considering all the results of the investigation, can be set a series of management strategies of the agro-ecological coffee conditions, which are based on the use of different agronomic practices for plant protection purposes, which aim to integrate the current management program against the coffee berry borer as shade regulation, management of ground cover and rehabilitation of plantations in this study, which limit the development of this disease and facilitate the performance of *B. bassiana* as a biological control agent. This is specified as follows: to double stratum shade management and diffuse light intensity of 60-70% directly, management of the natural weed vegetation's soil pruned or the use of *T. zebrina* at an average height of 6.0 cm, as well as rehabilitating the plantations as required for each case and establishing a system of foliar sprays with the entomopathogen *B. bassiana*, four applications every 40 days from 60 to 180 dpfm provided as the only agent of biological control.

Finally, it was observed that the positive effect of technological variants was not only better in reducing the pest populations and increasing the technical effectiveness of this entomopathogen sprays linked to the performance of cultural practices required for operating in Cuba, but their impact was significant in increasing favourable cost benefit an indicating element which characterizes it as a more effective management strategy against coffee berry borer.

4. Conclusions

Lower affectations of the coffee berry borer occur when setting the coffee to a diffuse light intensity of 60-70%, double stratification, with the implementation of a system with the technological characteristics of a sustainable coffee type (C1), with the possibility to choose the use or not of *T. zebrina* like covering of the floor provided the combination of the systems Strip weeding- Ring weeding.

Soil applications do not provide technical effectiveness values above 10%, and contribute effectively to decrease the index of infestation of the coffee berry borer in the early stages of fruit development.

The ranges of applications to the foliage of the fungus *B. bassiana* when used as a primary strategy for biological control can not be longer than 40 days because there is an unfavourable damage increase of *H. hampei*.

The highest levels of technical efficiency of spraying and regulating populations of *H. hampei* are obtained, once the coffee produced in the foliage is sprinkled four times every 40 days from 60 dpfm (S1T4) or six times with initial frequency of 10 days and then every 30 days from the 50 dpfm (S1T5) low intensity 60-70% of light, the former being favoured by having a cost/benefit ratio more favourable.

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