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CONTROL OF COFFEE RUST (*HEMILEIA VASTATRIX* BERK & BROOME) USING THE BIOFERTILIZER BIOCAFÉCASHI, MONTECRISTO DE GUERRERO, CHIAPAS

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Abstract: The objective of this research was to evaluate doses of 1.25 L, 2.5 L, 3.75 L, 5 L, and 0 L of the biofertilizer Biocafécashi to control orange rust infestations on coffee plants at the El Cedro ranch in the community of Emiliano Zapata, Montecristo de Guerrero, Chiapas, Mexico. The following variables were evaluated in the field: percentage of orange rust infestation/coffee plant, average weight per dry parchment coffee bean/coffee plant, total weight of dry parchment coffee/coffee plant, average weight per dry cherry/coffee plant, and cost/benefit analysis. A completely randomized block design was used, consisting of five treatments with three replicates, for a total of 15 experimental units, with each Bourbon coffee plant representing one experimental unit and a 5 m separation between plants. The results indicated that for the variable percentage of orange rust infestation/coffee plant, there was a statistically significant difference (P<0.05), and treatment 4 with a dose of 5 L of Biocafécashi biofertilizer had the lowest percentage of coffee rust infestation at 13.39%. Similarly, the average weight per dry parchment coffee bean/plant showed a statistically significant difference (P<0.05), with treatment 2 achieving the highest weight per bean at 0.575 g. On the other hand, the average weight per dry cherry/coffee plant showed a statistically significant difference (P<0.05), with treatment 4 having the highest weight per dry cherry at 0.389 g. According to the total weight of dry parchment coffee/plant, the treatment of 1,250 L of Biocafécashi biofertilizer recorded the highest yield with 10.78 q/ha^{-1} , followed by the 3.75 L and 5 L doses with a production of 7.14 q/ha^{-1} , 7.63 q/ha^{-1} , and the control produced 4.10 q/ha^{-1} , respectively. cost/benefit analysis, with a dose of 1.250 L of Biocafécashi biofertilizer, had a ratio of 2.95, indicating that the investment was recovered and, in addition, a profit of 1.95 pesos was obtained for each peso invested, with a net profit of $23,466.4 for the year.

Keywords: Management, coffee, Biocafécashi, rust, yield

Introduction

Mexico is one of the most important countries in organic coffee production, with Chiapas being the main producer. Today, it is one of the most important activities, as it employs more than 500,000 coffee growers with nearly 690,000 hectares of coffee plantations in 12 states and 391 municipalities across the country (González *et al.,* 2012).

Organic coffee production in Chiapas averages 15 quintals (q) per hectare (Palomares *et al.*, 2012). This is relatively low compared to other countries, where yields are much higher, with yields of up to 50 quintals per hectare under the organic production system (Norman, 2008). The problems of coffee farming are very complex, ranging from low yields due to poor management, low fertility, and plantation renewal to, in recent years, the emergence of coffee rust, which has affected coffee plantations in general, causing defoliation, immature beans, and in more drastic cases, the death of coffee plants.

The quality of the final product is greatly affected because, in an attempt to recover as much coffee as possible during the harvest, ripe beans are mixed with unripe or green beans, which damage the sensory properties and result in low-quality coffee in the cup. The plots have a low planting density due to inadequate shade management, the presence of rust, and low local, national, and international market prices, which damage the economic income of small and medium-sized coffee growers.

Therefore, it is necessary to implement measures to improve production in coffee plantations, introducing preventive, cultural, and agronomic measures to counteract this problem (Cervantes, 2010). In accordance with this, the following objective is proposed: to evaluate doses of 1.25 L, 2.5 L, 3.75 L, 5 L, and 0 L of the Biocafécashi biofertilizer to control orange rust infestations on coffee trees at the El Cedro ranch in the Emiliano Zapata community, Montecristo de Guerrero, Chiapas, Mexico.

Literature review

Since 1986, coffee production under the organic system has been promoted with good results (Escamilla *et al.*, 2005). This system represents a revival of several elements of traditional agricultural technology that allows crops to be grown without the use of chemicals, using inputs available from the plot itself and implementing soil and water conservation practices (CENICAFÉ , 2009a). As a result, producers obtain average yields of 15 quintals per hectare, while also maintaining biodiversity and natural resources (Palomares *et al.*, 2012).

Organic coffee is chemical- and pesticide-free coffee that is grown under strict quality control and in harmony with nature (González *et al.,* 2012). It is grown with more intensive cultural practices, but without the use of chemicals (fertilizers, herbicides, and pesticides), In its cultivation, organic or biological products such as organic fertilizers, compost, vermicompost, and foliar biofertilizers prepared from coffee pulp and worms, among others, are applied to improve the physical and nutritional composition of the soil (Agroentorno, 2012).

Coffee is considered one of the most important raw materials monitored in the global economy. For many of the world's least developed countries, coffee exports represent a fundamental part of their foreign exchange earnings, in some cases more than 80% (Flores, 2015).

Chiapas is the leading national producer of organic coffee, which makes Mexico the world's second largest producer of organic coffee. In the 1998-99 cycle, it had a 30% premium on the international market, as it is the main source of agricultural exports (Figueroa *et al.*, 2016). Another interesting aspect of coffee growing is its value as a point of contact between Mexico and Central America, as it is a very significant factor in the development of several countries (Haarer, 1964).

Importance of organic fertilizers

The production and use of organic fertilizers is proposed as an economical alternative for small and medium-sized producers; however, production must be standardized so that their quality is maintained over time. The advantages of organic fertilizers go beyond the economic aspect; they provide nutrients, increase moisture retention, and improve biological activity, thereby increasing soil fertility and, consequently, productivity (Ormeño and Ovalle, 2007). Organic fertilizers are all animal and plant waste from which plants can obtain significant amounts of nutrients. Thus, with the decomposition of this organic waste, the soil is enriched with organic carbon and its physical, chemical, and biological characteristics are improved (SAGARPA, 2013).

There are several types of organic fertilizers, which can be applied to the soil or foliage. Each has different methods and ingredients for its preparation. Among the soil fertilizers, the most common are compost, Bocashi, vermicompost, and among the foliar fertilizers we find humic acid and the biofertilizer Biocafécashi (Gutiérrez--Martínez and Utrilla-Corzo, 2012; Gutiérrez-Martínez *et al.*, 2017). A large number of organic materials can be used as fertilizer and nutrient supplies for plants. Some of them can be considered organic sources from the farm itself. In this way, many waste products or by-products from the farm can be used as fertilizers, recycling nutrients, which is undoubtedly very important from both an economic and ecological point of view (Salgado *et al.*, 2006).

It has advantages such as greater residual effect, increased soil moisture retention capacity through its effect on structure (granulation and aggregate stability), porosity and bulk density, reduced soil erosion, increased soil cation exchange capacity, protecting nutrients from leaching, greater release of CO_2 , which promotes the solubilization of nutrients, and supply of organic carbon as an energy source for microbial and heterotrophic flora (Paredes *et al.*, 2007).

Biofertilizers for coffee plant nutrition

The term biofertilizer can be defined as preparations containing live or dormant cells of efficient microbial strains that fix nitrogen, solubilize phosphorus, enhance various nutrients, or produce active substances. Their purpose is to increase the number of microorganisms and accelerate microbial processes in such a way as to increase the amounts of nutrients that can be assimilated by plants (Suárez, 2016).

Mineral broths enriched with rock flour can also be prepared using manure, molasses, whey, water, and various rocks such as granite and basalt, as well as bone meal. this bioferment can be used to nourish, prevent, and stimulate the protection of plants against pathogens and diseases (Félix *et al.*, 2008; Gutiérrez-Martínez and Utrilla-Corzo, 2012). Biofertilizers are super liquid fertilizers with high energy, balanced and in mineral harmony, prepared from fresh manure dissolved in water and enriched with milk, molasses, and ash, which are left to ferment for several days in plastic drums, under an anaerobic system and often enriched with minerals such as magnesium, zinc, and copper sulfates, among others (Restrepo, 2007a; Gutiérrez-Martínez and Utrilla-Corzo, 2012; Gutiérrez-Martínez *et al.*, 2017).

Biofertilizers are made up of living microorganisms which, when applied to seeds, plant surfaces, or soils, colonize the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant. They do not contaminate plant products or the soil; on the contrary, they regenerate it. In addition, some induce the development of plant defense mechanisms and create environments that are hostile to pathogens (Adriano *et al.*, 2011). They serve to nourish, restore, and reactivate soil life, strengthen fertility, mainly within plants, and activate the strengthening of nutritional balance as a defense mechanism through organic acids, carbohydrates, amino acids, and sugars present in the complexity of biological, chemical, physical, and energetic relationships established between plants and soil life (Restrepo, 2007a; Gutiérrez-Martínez and Utrilla-Corzo, 2012).

Biofertilizers are inputs formulated with one or more microorganisms, which, in one way or another, provide or improve the availability of nutrients when applied to crops (Acuña, 2015). The use of biofertilizers in agriculture has two main advantages, one ecological and the other economic, since they are cheaper to produce than chemical fertilizers and therefore reduce production costs. In addition, the use of biofertilizers increases yields (Gutiérrez-Martínez and Utrilla-Corzo, 2012; Martínez *et al.*, 2017).

Biofertilizers aid the biological nutrition process of plants, thus allowing for good use of atmospheric nitrogen, developing a root system, and helping to increase the solubility and conductivity of nutrients (González and Sarmiento, 2012). Biofertilizers can be applied at the time of planting or in the weeks following planting (Gutiérrez-Martínez and Utrilla-Corzo, 2012). For maximum benefit, it is recommended to apply before four weeks have passed since the emergence of the plants (Gutiérrez--Martínez and Utrilla-Corzo, 2012).

Coffee leaf rust (*Hemileia vastatrix*) is the most devastating disease affecting this crop (Mejía, 2015). It originated in East Africa, the center of diversity for *Coffea arabica*; However, the first formal report of this pathogen was made from specimens from a rust epidemic in Ceylon (Sri Lanka) that wiped out coffee production on the island between 1869 and 1890 (Boadella, 2011).

Orange rust is undoubtedly the most devastating disease in coffee cultivation. This disease is linked to the physiological development of the crop, the level of plant production, and the distribution and amount of rainfall. Inadequate and untimely control of the disease seriously compromises the quantity and quality of the harvest and, overall, affects the country's production (Rivillas *et al.,* 2011). The fluctuation in the incidence and severity of rust has been studied by several authors, who indicate that the epidemiological curve of the disease begins when the first rains fall and the maximum infection is reached after the rainy season. This is followed by a sharp drop in the level of infection. The attack of coffee rust begins with the release of its urediospores, the most important reproductive structure of this fungus, which can persist year after year in this state.

Materials and methods

Location of the study area

This research was carried out on the "El Cedro" ranch owned by Mrs. María Leticia Velasco López, located one kilometer from the Emiliano Zapata neighborhood, which is 15 km from the municipal capital of Montecristo de Guerrero, Chiapas, Mexico. At an altitude of 1517 meters above sea level, it has the following coordinates: latitude N 15° 63′ 94" and longitude W 92° 72′ 88" (Figure 1).

Description of the study area

The research was conducted on a 0.5 ha^{-1} area planted with Bourbon coffee on the "El Cedro" ranch, which covers 4 ha, of which 2.5 ha are planted under the organic production system, which has been in operation for 22 years.

Experimental design

A completely randomized block design was used, consisting of five treatments with three replicates, for a total of 15 experimental units, with each plant representing one experimental unit and 5 m between plants (Figure 2).

Criteria for selecting the experimental area

The following characteristics were considered when selecting the plants to be treated:

Fifteen plants were sought that had the same management conditions as mentioned below:

- Bourbon coffee variety.
- Same age (6 years).
- All had 4 main axes or branches.
- They should have a shade diameter of between 2.30 m and 2.60 m.
- They should be between 1.80 m and 2.00 m in height.

The basic ingredients needed to prepare the Biocafecashi biofertilizer were:

- Fresh cattle manure: 50 kg.
- Milk: 22 L.
- Molasses: 22 L.
- Wood ash: 6 kg.
- Untreated water: 90 L.
- Phosphate rock: 3.4 kg.
- Potassium sulfate: 800 g.
- Borax: 720 g.
- Vitamin E: 14 g.
- Vitamin C: 14 g.
- Manganese sulfate: 230 g.
- Magnesium sulfate: 360 g.
- Sodium molybdate: 40 g.
- Ferrous sulfate: 25 g.

The addition of certain mineral salts (zinc, magnesium, copper, iron, cobalt, molybdenum, etc.) to enrich biofertilizers is optional and is carried out according to the needs and recommendations for each crop at each stage of its development. Mineral salts or sulfates can be replaced by wood ash or ground rock flour, with excellent results (Gutiérrez-Martínez and Utrilla-Corzo, 2012).

Production of Biocafécashi biofertilizer

Gutiérrez-Martínez and Utrilla-Corzo (2012) mention that the process of producing Biocafécashi biofertilizer consists of eleven phases.

Analysis of the Biocafécashi biofertilizer

Table 1 shows the methods used to determine the elements and units for each of them (FERTILAB[1] , 2010).

1. Plant Nutrition Laboratory, S.C.

Element	Method	Units
Ph	NMX-FF-109-SCFI-2007	dSm^{-1}
Electrical conductivity	NMX-FF-109-SCFI-2007	%
Total nitrogen	Kjeldahl	%
Phosphorus (P_2O_5)	Wet digestion/AA	%
Potassium (K_2O)	Wet digestion/AA	%
Calcium	Moist digestion/AA	%
Magnesium	Moist digestion/AA	%
Sodium	Moist digestion/AA	%
Sulfur	Wet digestion/Turbidity measurement	%

Table 1. Methodologies used in foliar analysis according to FERTILAB (2010).

Figure 1. Location of the study area, El Cedro ranch, Emiliano Zapata, Montecristo de Guerrero, Chiapas, Mexico.

Symbols: T1=1.25 L , T2=2.5 L, T3= 3.75 L,T4=5L,T5= 0, Biocafécashi/100 water.

Figure 2. Randomized complete block design at the El Cedro ranch, Emiliano Zapata, Montecristo de Guerrero, Chiapas, Mexico.

Application of Biocafécashi biofertilizer ( )

Biocafécashi biofertilizer was applied on Saturdays every 14 days using a 20-liter backpack sprayer. Biocafécashi biofertilizer was applied to the coffee plants from top to bottom, wetting the upper and lower surfaces of the leaves until the entire plant was sprayed.

Variables evaluated

- Percentage of orange rust infestation/coffee plant,
- Average weight per dry parchment coffee bean/coffee plant,
- Total weight of dry parchment coffee/coffee plant
- Average weight per dry cherry/coffee plant,
- Cost/benefit analysis

Sampling

During the course of the project, sampling was carried out every 15 days in order to evaluate the variables. After the harvest, the yield variables were evaluated.

The percentage of rust infestation was obtained by counting the number of infested leaves, dividing it by the total number of leaves per coffee plant, and multiplying it by 100.

Example:

$$\frac{\text{No. of infested leaves}}{\text{No. of total leaves}} \quad \mathbf{X100}$$

Harvest

The harvesting method depended on a combination of processing requirements, economic considerations, and labor availability (Temis *et al.*, 2011). Harvesting began when the coffee fruits were fully ripe, cutting them as they ripened to avoid losses due to fruit drop. A total of seven harvests were carried out, and the harvested fruits were stored in brown paper bags. Each paper bag was labeled with the treatment, repetition, and date of collection.

Statistical analysis

Once the fieldwork was completed, the information collected was organized into a database. Subsequently, analysis of variance was performed, as well as a comparison of means using Duncan's multiple range test, for which the statistical package (SAS[2] , 1997) was used.

Results and discussion

Chemical analysis of Biocafécashi biofertilizer for fruit filling del caf eto

The chemical analysis of the Biocafécashi biofertilizer was performed as shown in Table 2, finding that the pH was 4.4, which means strongly acidic; a high electrical conductivity of 4.2 dS/m (deciSiemens per meter) was also obtained, i.e., extremely saline (Fassbender, 1982). A total nitrogen content of 0.18% was recorded, which is relatively low (SEAE[3] , 2008). Phosphorus content was 0.22%, potassium content was 1.09%, which is considered good, and calcium content was 0.43%, which is con-

2. Statistical Analysis System
3.Spanish Society for Organic Agriculture

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sidered sufficient. magnesium was 0.16%, which is good; sodium content was 0.69%, which is high; Biocafécashi sulfur content was 0.43%, considered moderately low; iron content was 0.01%, considered sufficient; copper obtained a content of 1.03 ppm, which is low; on the other hand, the manganese content was 454 ppm, which is sufficient; the zinc content was 222 ppm, which is sufficient; the boron content registered 71.0 ppm, which is considered low (Fassbender, 1982).

It can also be observed that potassium, copper, manganese, zinc, and boron are high, which improves plant development, leaves, photosynthesis, filling, and maturity of the coffee fruit. In the case of boron, it acts on the weight gain of the coffee fruit, preventing a reduction in the number of empty fruits.

This biofertilizer has a high organic matter content of 61.3%, which means that for every liter of Biocafécashi biofertilizer applied to coffee leaves and fruits, 613 g of nutrients are provided, enough for the coffee plants to achieve complete coffee fruit formation and filling, with positive results at the end of the harvest.

The ash content was high, and it is rich in potassium, calcium, magnesium, and other essential minerals that are found in relatively soluble forms (Somesh-War, 1996; Vance, 1996). Some of these elements are found as oxides, hydroxides, and carbonates, giving the material a strongly alkaline character (Etiégni and Campbell, 1991). The neutralizing potential, expressed in terms of $_{CaCO_3}$(calcium carbonate) equivalents, varies between 25 and 100%, making it possible to use it to correct soil acidity (Ohnot and Erich, 1990). Organic carbon was found to be high at 35.5%. According to Martínez *et al.* (2008), FAO (2001) mentions that organic carbon is an important component, accounting for 69.8% of the biosphere.

Percentage of orange rust infestation/coffee plant

According to the analysis of variance, the percentage of orange rust infestation in coffee plants showed a statistically significant difference ($P \leq 0.05$). Treatment 4, with a dose of 5 L of Biocafécashi biofertilizer, had the lowest percentage of rust infestation (13.39%), which means that Biocafécashi biofertilizer did nourish the coffee plant during the fruit filling and ripening stages, resulting in fewer attacks, compared to treatments 1, 2, and 3, while treatment 5 recorded the highest infestation (24.40%) of orange rust on coffee trees because the Biocafécashi biofertilizer was not applied; it was the control (Figure 3).

These results are consistent with the field observations made by Gutiérrez-Martínez and Utrilla-Corzo (2012), who found that early applications of the Biocafécashi foliar biofertilizer to coffee plants reduced infestations by this fungus by up to 90% ( ). According to Arcila (2003), early foliar applications prevent the proliferation of rust. It is also possible that the reduction in rust was a side effect of nutrition. The micronutrients provided, especially zinc and manganese, acted as enzymatic cofactors that allowed the plant to convert nitrogen into complex proteins. With no free amino acids in the leaf (food for the fungus) and copper to synthesize phytoalexins (defenses), the plant developed trophobiotic resilience. The coffee leaves were no longer "edible" for *H. vastratix*, confirming that health is an emergent property of mineral balance.

Element	Method	Units	Result
pH	NMX-FF-109-SCFI-2007		4.4
Electrical conductivity	NMX-FF-109-SCFI-2007	dSm-1	4.20
Total nitrogen	Kjeldahl	%	0.18
Phosphorus (P_2O_5)	Wet digestion/AA	%	0.22
Potassium (K_2 O)	Wet digestion/AA	%	1.09
Calcium	Wet digestion/AA	%	0.43
Magnesium	Moist digestion/AA	%	0.16
Sodium	Moist digestion/AA	%	0.69
Sulfur	Wet digestion/Turbidimetry	%	0.43
Iron	Wet digestion/AA	%	0.01
Copper	Wet digestion/AA	Ppm	1.03
Manganese	Wet digestion/AA	Ppm	454
Zinc	Wet digestion/AA	Ppm	222
Boron	Calcination/spectrophotometry	Ppm	71.0
Moisture	Gravimetric method	%	91.3
Organic matter	Calcination	%	61.3
Ash	Calcination	%	38.7
Organic carbon		%	35.5
C/N ratio	Dry base	%	197.2

Table 2. Chemical analysis of Biocafécashi biofertilizer for coffee fruit filling of the coffee tree.

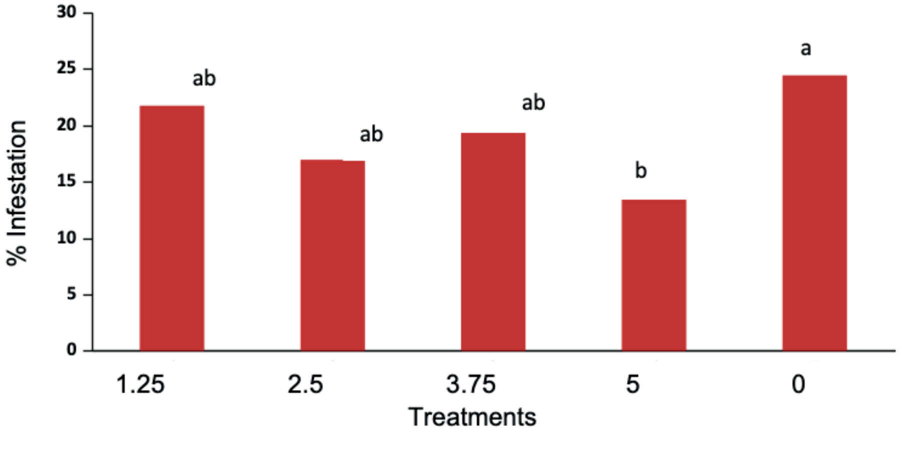

Figure 3. Percentage of orange rust infestation per coffee plant variety Bourbon, El Cedro ranch, Emiliano Zapata, Montecristo de Guerrero.

Average weight per dry parchment coffee bean/coffee plant

According to the analysis of variance, the average weight per dry parchment coffee bean showed a statistically significant difference (P≤0.05), with treatment 2 having the highest weight, indicating that it had a higher dry bean weight of 0.575 g, followed by treatments 1, 3, 5, and 4 (Figure 4). CENICAFÉ (2009b) and Ramírez *et al.* (2002) indicate that the application of organic foliar fertilizers can increase fruit size and, therefore, increase weight.

Total weight of dry parchment coffee/coffee plant

According to the analysis of variance, the total weight of dry parchment coffee did not indicate a statistically significant difference (Table 3); while treatment 1 recorded the highest yield per plant, which, when converted to ha^{-1},yields 10.78 quintals/ha^{-1}. Treatments 4, 3, 2, and 5 follow in order of importance (Table 3).

Different letters indicate differences, and those that are repeated are statistically the same.

These results are similar to those reported by Madrigal (2014), who found that applying a dose of 1,250 L of the biofertilizer Biocafécashi yielded 9.5 q/ha^{-1}. In addition, Treatment 1 (low dose of 1,250 L) managed to boost yield to 10.78 q/ha, exceeding the control (4.10 q/ha) by more than 160%, despite being in the same soil and under the same shade, because Biocafécashi provided a massive amount of microorganisms and energy (molasses and milk). This did not work as "direct food," but as a rhizosphere activator.

By inoculating the system, the decomposition of pre-existing organic waste in the coffee plantation (leaf litter from shade trees) was accelerated. The biofertilizer reestablished the interconnection of the system between the tree layer (carbon source) and the coffee crop (sink), demonstrating that synergy requires an active microbiological "engine."

Average weight per dry cherry/coffee plant

According to the analysis of variance, the weight per dry cherry indicated a statistically significant difference (*P*<0.05). Treatment 4 had the highest weight per dry cherry with 0.389 g, followed by treatments 5, 3, 1, and 2 (Figure 5).

Different letters indicate differences, and those that are repeated are statistically are the same.

Cost/benefit (C/B) analysis

The production cost considered only the Biocafécashi biofertilizer for one hectare $^{-1}$ was \$5,200.00, plus the cost of cultural practices (shading, 2 sprays, suckering, de--topping, pruning, and thinning) carried out during the production process, which amounted to \$6,800.00, for a total cost of \$12,000.00 (Table 4), which was taken into account for the analysis for all treatments except for the control treatment, where only the cost of the cultural practices carried out was considered in order to obtain a comparison of the profits obtained.

Profit

In the cost/benefit analysis, Table 3 shows the 1,250 L dose of Biocafécashi bio-

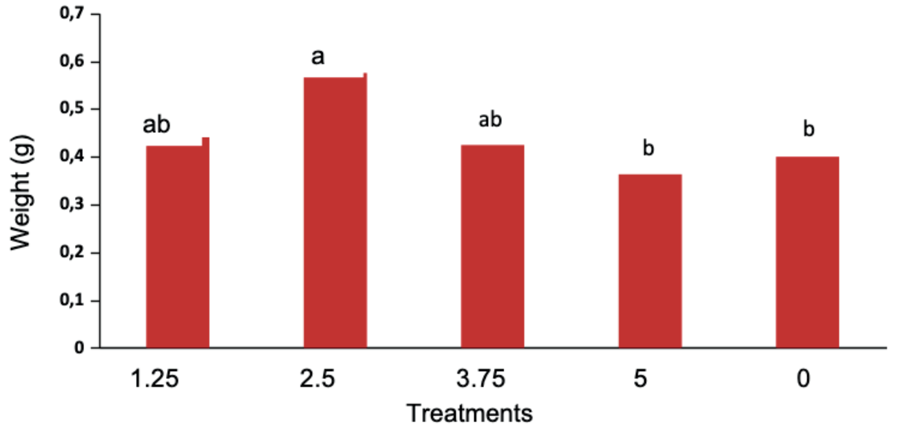

Figure 4. Average weight per dry parchment coffee bean per coffee plant variety Bourbon, El Cedro ranch, Emiliano Zapata, Montecristo de Guerrero.

Dose of Biocafécashi bio-fertilizer /100 L water	Weight of parchment coffee (g)/plant	Kg of parchment coffee/ha^{-1}	Quintals of parchment/ha^{-1}
1,250 L	206.66	620	10.78a
2,500 L	81.97	245.91	4.27b
3,750 L	136.94	410.82	7.14
5.00 L	146.33	439	7.63ab
0.00 L	78.59	235.77	4.10b

Table 3. Yield per hectare of parchment coffee using the biofertilizer Biocafécashi.

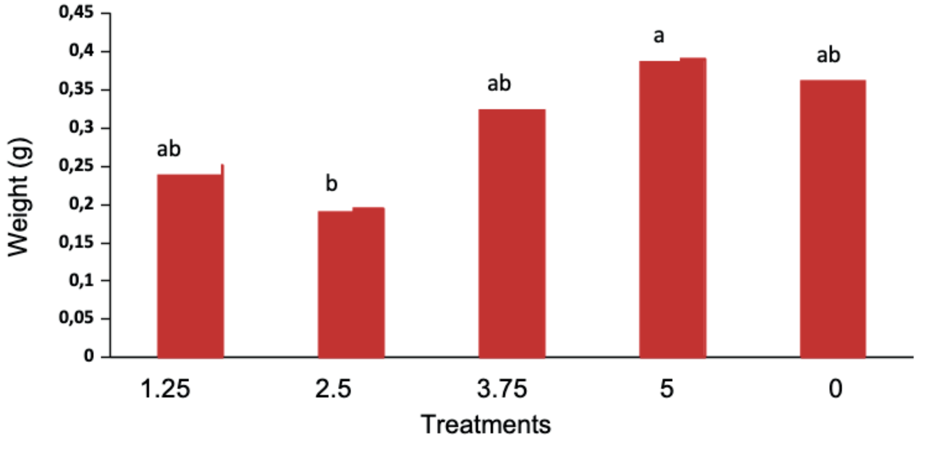

Figure 5. Average weight per dry parchment coffee bean per coffee plant variety Bourbon, El Cedro ranch, Emiliano Zapata, Montecristo de Guerrero.

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Biocafécashi L/100 L water	q/ha^{-1} parchment	Selling price	kg/ha^{-1} of cherry	Selling price	Total income	Total expenditure[1]	Net income	C/B
1.25	10.78	$3,130	69	$25	$35,466.4	$12,000	$23,466.4	2.95
2.5	4.27	$3,130	24.9	$25	$13,987.6	$12,000	$1,987.6	1.16
3.75	7.14	$3,130	92.1	$25	$24,650.7	$12,000	$12,650.7	2.05
5	7.63	$3,130	37.56	$25	$24,820.9	$12,000	$12,820.9	2.07
0	4.10	$3,130	11.1	$25	$13,110.5	$6,210.5	$ 610.5	2.11

[1] Expenses generated during the cycle, including the production and application of the biofertilizer Biocafécashi and Bordeaux mixture/ha^{-1}

Table 4. Cost/benefit ratio with the use of Biocafécashi biofertilizer

fertilizer, which recorded the highest yield with a production of 10.78 q/ha^{-1}. The quintal was sold at a price of $3,130.00/q, generating a total income of $33,741.40. However, when doses of 3.75 L and 5 L of Biocafécashi biofertilizer were applied, yields of 7.14 q/ha^{-1}and 7.63 q/ha$^{(-1)}$ were produced, generating total revenues of $22,348.20 and $23,881.90, respectively.

Conclusions

The Biocafécashi biofertilizer is an alternative for controlling rust infestation, since treatment 4 with a dose of 5 L of Biocafécashi had a lower percentage of rust infestation (13.39%), therefore, the hypothesis is not rejected.

The treatment with 1,250 L of Biocafécashi biofertilizer recorded the highest yield with 10.78 q/ha^{-1}, followed by the 3.75 L and 5 L doses with a yield of 7.14 q/ha^{-1} and 7.63 q/ha^{-1} , respectively, since the control produced 4.10 q/ha^{-1}.

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