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Pentahydrated copper sulphate $CuSO_4.5H_2O$ at different doses for control of *Hemileia vastatrix* berk & broome

Abstract

In order to evaluate the effect of copper sulfate pentahydrate $CuSO_4.5H_2O$ in the control of coffee rust *Hemileia vastatrix* Berk. *et* Br. the present research was carried out in the Toquián neighborhood of the San José Ixtepec ejido, municipality of Motozintla, Chiapas, Mexico. The experimental unit corresponded to 16 coffee trees and the useful plot with four central coffee trees, with five treatments: 0.5 l ha^{-1}, 1.00 l ha^{-1}, 1.50 l ha^{-1}, 2.00 l ha^{-1} of copper sulfate pentahydrate and a control without application. A randomized block design with five treatments and four replicates was used, which resulted in 20 experimental units. The percentage of infection of coffee rust was evaluated before the application of copper sulfate pentahydrate, 15, 30, 45 and 60 days after application. Data in percent were transformed to sine arc √percent. The results show that the highest percentage of coffee rust infection was observed in the control treatment without application with an average of 22.12%, and the lowest infection in the highest dose treatment 2.00 l ha^{-1} with 7.33%. The results will be fundamental to put them into practice and thus develop strategies to control and combat coffee rust that will allow better production in the coffee plantations of the study area and the region.

Keywords: coffee rust, phytopathology, chemical control, infection, defoliation, coffee plantations

Volume 9 Issue 4 - 2022

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Received: July 25, 2022 | **Published:** August 05, 2022

Introduction

Hemileia vastatrix L. (Coffee Rust) is one of the most economically important diseases affecting the coffee crop, and therefore, it is also the disease for which there is the greatest reference of studies and works carried out in relation to its management and alternatives.[1] Rust is the most destructive disease of the coffee tree and the one of greatest interest worldwide, due to the fact that it causes the premature fall of the leaves, leading to the reduction of the photosynthetic capacity, as well as the weakening of diseased trees and in severe infections it can cause regressive death in branches and even the death of trees.[2]

To date, orange rust has ruined coffee growing in many coffee growing regions of Latin America.[3] This disease, caused by the fungus *Hemileia vastatrix*, mainly attacks the leaves, branches and even the fruits of the *Coffea arabica* species, for which it is considered the most destructive and economically important pathogen for coffee growing throughout the world.[4,5] In Mexico, 95% of coffee production is obtained from the Arabica species, which is the most vulnerable to rust.[6,7] At the national level, rust has caused coffee production to decrease by more than 50% between 2012 and 2016 (from approximately 4.3 million to only 2.2 million 60-kilo bags), which is the lowest level in the last 50 years.[5]

In Mexico, coffee rust has been reported in coffee growing states such as: Chiapas, Veracruz, Oaxaca, Puebla, Guerrero, Hidalgo, Nayarit, San Luis Potosí, Jalisco, Colima, Tabasco, State of Mexico, Querétaro, Morelos and Michoacán.[8] The importance of *H. vastatrix* in Mexico lies in the fact that there is an area of coffee cultivation of 737,376.45 ha, of which 699,307.33 ha are harvested with a production of 1,166,025.82 tons of cherry coffee, with a production value of more than 5,593 million pesos.[8]

As is well known, coffee is a grain of great business in the international market, given that it is cultivated in the countries of the global South and exported to countries of the North, demonstrating that its trade clearly illustrates the relationships that prevail between producing and exporting countries.[9] Coffee is a product traditionally exported by underdeveloped countries and imported by developed countries, the latter controlling the transformation and international commercialization through transnational companies.[10] In addition, they influence the determination of prices speculated by the London and New York stock exchanges. Therefore, it is important to develop new strategies for the control of coffee rust, which constitutes the main threat to those who depend on coffee production. Therefore, the present study aims to determine the effect of different doses of copper sulfate evaluated at different seasons for the control of *Hemileia vastatrix* Berk. *et* Br. (coffee rust).

Materials and methods

Study area

The study area corresponds to the ejido San José Ixtepec. It is located at 15°20'53.53'' N latitude and 92°22'56.96'' W longitude, at an altitude of 1923 m asl, within the municipality of Motozintla, Chiapas, in southeastern Mexico. The climate is temperate-humid with abundant rainfall in summer, as well as in other higher elevations. The average annual temperature is between 14 to 24 °C. Total annual rainfall ranges from 1000 to more than 3000 mm.[11]

Description of the experiment

The study was conducted in the Toquián neighborhood, belonging to the San José Ixtepec ejido, municipality of Motozintla, Chiapas, and began with the search of the land, marking of coffee trees in the useful plot, application of copper sulfate pentahydrate $CuSO_4.5H_2O$, data collection and organic management of the crop. The study lasted six months, beginning in May and ending in October 2020. Two applications of 18-12-06 formula fertilizer were made, the first in May and the second in November. For weed control, three machete applications were made, the first in May, the second in August and

the third in October. To control the coffee berry borer *Hypothenemus hampei* Ferr. an application of the entomopathogenic fungus *Beauveria bassiana* (Bals.) Vuill. was made in May.

Experimental plot

An experimental plot of 16 coffee trees and the useful plot, the four central coffee trees, were delimited to eliminate the edge effect. The entire experiment was carried out in an area of 1,400 m^2. Four central coffee plants of the useful plot were labeled, and each plant was marked with four branches, which were distributed in the four cardinal points of the plant. The application of the treatments, which consisted of four different doses of $CuSO_4.5H_2O$, as well as an adherent to prevent the product from being washed away by rain, was carried out with a manual sprayer. First, a sampling was carried out prior to the application, the data collection of the measured variables was done every 15 days, the data were recorded in the corresponding formats.

Experimental design

The treatments evaluated were different doses of $CuSO_4.5H_2O$ and a control without application. A randomized block design with five treatments and four replications was used, which resulted in 20 experimental units, the treatments were four different doses of $CuSO_4.5H_2O$ and a control without application (Table 1).

Table 1 Distribution of field treatments in the control of coffee rust *Hemileia vastatrix* Berk. et Br. with $CuSO_4.5H_2O$

Treatments	Repetitions			
	I	II	III	IV
A= 0.5 l ha^{-1}	A	D	E	C
B= 1 l ha^{-1}	C	E	A	B
C= 1.5 l ha^{-1}	E	B	D	E
D= 2 l ha^{-1}	D	A	C	A
E= Witness/no application	B	C	B	D

Variables evaluated

Infection rate of coffee rust Hemileia vastatrix Berk. et Br.

To measure this variable, a count of the total number of leaves and of those infected by the rust of the labeled branches was made and the percentage of infection was calculated as follows:

Infection % = (No. of leaves infected by rust * 100) /total number of leaves

Monitoring and evaluation was performed:

i) Prior to application with different doses of $CuSO_4.5H_2O$

ii) 15 days after the application with different doses of $CuSO_4.5H_2O$

iii) 30 days after the application with different doses of $CuSO_4.5H_2O$

iv) 45 days after application with different doses of $CuSO_4.5H_2O$

v) 60 days after application with different doses of $CuSO_4.5H_2O$

Statistical analysis

Before performing the analysis of variance, the transformation of the data for the variables measured in percentage to arc sine√percentage was performed. As significant differences were observed in the analysis of variance, we proceeded to compare the mean of the treatments by Tukey's test at a probability of 0.05.

Results

Percentage of infection of coffee rust *Hemileia vastatrix* Berk. et Br. (before application).

The percentage of infection of coffee rust *H. vastatrix* observed before the application of copper sulfate pentahydrate CuSO4.5H2O was from 5.00 to 18.50 %, which was observed in treatment D (2.00 l ha^{-1}) and treatment E (control without application) respectively (Table 1A of the Appendix). These data were transformed to sine arc √percent (Table 2), with these data the analysis of variance was performed (Table 3).

Table 2 Percentage infection of coffee rust *Hemileia vastatrix Berk.et* Br. before application with different doses of $CuSO_4.5H_2O$ and sine arc data transformation √Percentage

Treatments	Block					
	I	II	III	IV	∑xl	X
A	12	10	14	12	48	12
B	10	9	8	10	37	9.25
C	6	5	7	8	26	6.5
D	4	3	6	7	20	5
E	14	18	20	22	74	18.5
Transformation to sine arc √percent.						
A	20.27	18.44	21.97	20.27	80.95	20.24
B	18.44	17.46	16.43	18.44	70.77	17.69
C	14.18	12.92	15.34	16.43	58.87	14.72
D	11.54	9.98	14.18	15.34	51.04	12.76
E	11.97	25.1	26.56	27.97	101.6	25.4

Table 3 Analysis of variance of percent infection of rust *Hemileia vastatrix Berk.et* Br. before application with different doses of $CuSO_4.5H_2O$

Sources of variation	GL	SC	CM	F cal	F table	
					0.05	0.01
Treatments	4	391.8525	97.96314	45.6926**	3.26	5.41
Blocks	3	27.80762	9.269206	4.3234	3.49	5.95
Error	12	25.72754	2.143962			
Total	19	445.3877				

**Highly significant difference. C.V = 8.06%.

Highly significant differences were observed (Table 3), so the means of the treatments were compared by Tukey's test at a probability of 0.05. The highest percentage of infection was observed in treatment E Witness without application with 18.50 %, followed by treatment A 0.5 l ha^{-1} with 12.00 %, treatment B 1.00 l ha^{-1} with 9.25 %, treatment C 1.50 l ha^{-1} with 6.50 % and treatment D 2.00 l ha^{-1} with 5.00 % (Table 4).

Table 4 Comparison of means of percent infection of coffee rust *Hemileia vastatrix* Berk. *et* Br. before application of $CuSO_4.5H_2O$

Treatment	Percentage*	
	Field	Transformed
E Witness without application	18.5	25.40 a
A 0.50 l ha^{-1}	12	20.24 b
B 1.00 l ha^{-1}	9.25	17.69 bc
C 1.50 l ha^{-1}	6.5	14.72 cd
D 2.00 l ha^{-1}	5	12.76 d

*Means of treatments with the same letter are statistically equal according to Tukey's test at 0.05 probability.

Percentage of infection of coffee rust *Hemileia vastatrix* Berk. et Br. (15 days)

The percentage of infection of coffee rust *H. vastatrix* observed 15 days after the application of CuSO4.5H2O, ranged from 5.88 to 19.50 % which was observed in treatment D 2.00 l ha^{-1} and treatment E Control without application respectively. These data were transformed to arc √seno percentage (Table 5), with these data the analysis of variance was performed (Table 6).

Table 5 Percentage infection of coffee rust *Hemileia vastatrix Berk.et* Br. 15 days after application with different doses of $CuSO_4.5H_2O$ and sine arc data transformation √Percentage

Treatments	Block					
	I	II	III	IV	∑xl	X
A	13	12	15	13.5	53.5	13.38
B	11	10	9	10	40	10
C	7	6	8	8	29	7.25
D	5	4	7	7	23.5	5.88
E	15	20	21	21	78	19.5
Transformation to sine arc √percent.						
A	21.13	20.27	22.79	21.56	85.75	21.44
B	19.37	18.44	17.46	18.44	73.71	18.43
C	15.34	14.18	16.43	16.43	62.38	15.6
D	12.92	11.54	15.49	15.34	55.69	13.92
E	22.79	26.56	27.97	27.28	104.6	26.15

Table 6 Analysis of variance of percent infection of rust *Hemileia vastatrix* Berk.et Br. at 15 days after application with different doses of CuSO4.5H2O

Sources of variation	GL	SC	CM	F cal	F table	
					0.05	0.01
Treatments	4	378.8394	94.70984	50.7177**	3.26	5.41
Blocks	3	14.78857	4.929525	2.6398	3.49	5.95
Error	12	22.40869	1.867391			
Total	19	416.0366				

** Highly significant difference. C.V = 7.15%.

Highly significant differences were observed (Table 6), so the means of the treatments were compared by Tukey's test at a probability of 0.05. The highest percentage of infection was observed in treatment E Witness without application with 19.50 %, followed by treatment A 0.5 l ha with 13.38 %, treatment B 1.00 l ha^{-1} with 10.00 %, treatment C 1.50 l ha^{-1} with 7.2 % and treatment D 2.00 l ha^{-1} with 5.88 % (Table 7).

Table 7 Comparison of means of percent infection of coffee rust *Hemileia vastatrix* Berk. et Br. at 15 days after application of $CuSO_4.5H_2O$

Treatment	Percentage*	
	Field	Transformed
E Witness without application	19.5	26.15 a
A 0.50 l ha^{-1}	13.38	21.44 b
B 1.00 l ha^{-1}	10	18.43 bc
C 1.50 l ha^{-1}	7.25	15.60 cd
D 2.00 l ha^{-1}	5.88	13.92 d

*Means of treatments with the same letter are statistically equal according to Tukey's test at 0.05 probability.

Percentage of infection of coffee rust *Hemileia vastatrix* Berk. et Br. (30 days)

The percentage of infection of coffee rust *H. vastatrix* observed 30 days after the application of CuSO4.5H2O was from 8.25 to 21.00 %, which was observed in the treatment D 2.00 l ha^{-1} and treatment E Control without application respectively. These data were transformed to sine arc √percent (Table 8), with these data the analysis of variance was performed (Table 9). The highest percentage of infection was observed in treatment E Witness without application with 21.00 %, followed by treatment A 0.50 l ha^{-1} with 14.50 % ha^{-1} , treatment B 1.00 lha^{-1}, treatment C 1.50 l ha^{-1} with 9.5 0% and treatment D 2.00 l ha^{-1} with 8.25% (Table 10).

Table 8 Percentage of infection of coffee rust *Hemileia vastatrix* Berk.et Br. 30 days after application with different doses of $CuSO_4.5H_2O$ and sine arc data transformation √Percentage

Treatments	Block					
	I	II	III	IV	∑xl	X
A	15	13	16	14	58	14.5
B	13	15	10	11	49	12.25
C	9	11	9	9	38	9.5
D	8	9	8	8	33	8.25
E	17	21	24	22	84	21
Transformation to sine arc √percent.						
A	22.79	21.13	23.58	21.98	89.47	22.37
B	21.13	22.79	18.44	19.37	81.73	20.43
C	14.46	19.37	17.46	17.46	71.75	17.94
D	16.43	17.46	16.43	16.43	76.75	16.69
E	24.4	27.18	29.33	27.97	108.98	27.24

Highly significant differences were observed (Table 9), so the means of the treatments were compared by Tukey's test at a probability of 0.05 (Table 10).

Table 9 Analysis of variance of percent infection of rust *Hemileia vastatrix* Berk.et Br. at 30 days after application with different doses of CuSO4.5H2O

Sources of variation	GL	SC	CM	F cal	F table	
					0.05	0.01
Treatments	4	276.5908	69.19771	30.7179**	3.26	5.41
Blocks	3	3.967773	1.322591	0.5875	3.49	5.95
Error	12	27.0127	2.251058			
Total	19	307.5713				

** Highly significant difference. C.V = 7.41%.

Table 10 Comparison of means of percent infection of coffee rust *Hemileia vastatrix* Berk. et Br. 30 days after application of $CuSO_4.5H_2O$

Treatment	Percentage*	
	Field	Transformed
E Witness without application	21	27.24 a
A 0.50 l ha^{-1}	14.5	22.37 b
B 1.00 l ha^{-1}	12.25	20.43 bc
C 1.50 l ha^{-1}	9.5	17.94 cd
D 2.00 l ha^{-1}	8.25	16.69 d

*Means of treatments with the same letter are statistically equal according to Tukey's test at 0.05 probability.

Citation: Perez-Ventura LY, Barrios-Calderon RJ. Pentahydrated copper sulphate CuSO4.5H2O at different doses for control of *Hemileia vastatrix* berk & broome. *J Appl Biotechnol Bioeng.* 2022;9(4):113–118. DOI: 10.15406/jabb.2022.09.00297

Percentage of infection of coffee rust *Hemileia vastatrix* Berk. et Br. (45 days)

The percentage of infection of coffee rust *H. vastatrix* observed 45 days after the application of $CuSO_4.5H_2O$ was from 8.75 to 24.12 %, which was observed in treatment D 2.00 l ha^{-1} and treatment E, control without application, respectively. These data were transformed to sine arc √percent (Table 11), with these data the analysis of variance was performed (Table 12). Highly significant differences were observed (Table 12), so the means of the treatments were compared by Tukey's test at a probability of 0.05. The highest percentage of infection was observed in treatment E Witness without application with 24.12 %, followed by treatment A 0.5 l ha^{-1} with 16.2 5%, treatment B 1.00 l ha^{-1} with 13.00 %, treatment C 1.50 l ha^{-1} with 10.00 % and treatment D 2.00 l ha^{-1} with 8.75 % (Table 13).

Table 11 Percentage of infection of coffee rust *Hemileia vastatrix* Berk.et Br. 45 days after application with different doses of $CuSO_4.5H_2O$ and sine arc data transformation √Percentage

Treatments	Block					
	I	II	III	IV	∑xI	X
A	17	14	18	16	65	16.25
B	14	13	11	14	52	13
C	10	11	9	10	40	10
D	9	9	8	9	35	8.75
E	17.5	23	28	28	96.5	24.12
Transformation to sine arc √percent.						
A	24.4	21.97	25.1	23.58	95.05	23.76
B	21.97	21.13	19.37	21.97	84.44	21.11
C	18.44	19.37	17.46	18.44	73.71	18.43
D	17.46	17.46	16.43	17.46	68.81	17.2
E	24.73	28.66	31.9	31.9	117.19	29.3

Table 12 Analysis of variance of the percentage of infection of *Hemileia vastatrix* Berk.et Br. rust 45 days after application with different doses of $CuSO_4.5H_2O$

Sources of variation	GL	SC	CM	F cal	F table	
					0.05	0.01
Treatments	4	3.716924	92.9231	25.9568**	3.26	5.41
Blocks	3	4.424805	1.474935	0.412	3.49	5.95
Error	12	42.95898	3.579915			
Total	19	419.0762				

**Highly significant difference. C.V= 8.62%.

Table 13 Comparison of means of percent infection of coffee rust *Hemileia Vastatrix* Berk. et Br. 45 days after application of $CuSO_4.5H_2O$

Treatment	Percentage* Percentage	
	Field	Transformed
E Witness without application	24.12	29.30 a
A 0.50 l ha^{-1}	16.25	223.76 b
B 1.00 l ha^{-1}	13	21.11 bc
C 1.50 l ha^{-1}	10	18.43 c
D 2.00 l ha^{-1}	8.75	17.20 d

*Means of treatments with the same letter are statistically equal according to Tukey's test at 0.05 probability.

Percentage of infection of coffee rust *Hemileia vastatrix* Berk. et Br. (60 days)

The percentage of infection of coffee rust *H. vastatrix* observed 60 days after the application of CuSO4.5H2O was from 8.75 to 27.5 0%, which was observed in treatment D 2.00 l ha^{-1} and treatment E, control without application, respectively. These data were transformed to sine arc √percent (Table 14), with these data the analysis of variance was performed (Table 15). Highly significant differences were observed (Table 15), so the means of the treatments were compared by Tukey's test at a probability of 0.05 (Table 16).

Table 14 Percentage of infection of coffee rust *Hemileia vastatrix* Berk.et Br. 60 days after application with different doses of $CuSO_4.5H_2O$ and sine arc data transformation √Percentage

Treatments	Block					
	I	II	III	IV	∑xI	X
A	18	15	20	18	71	17.75
B	16	14	12	16	58	14.5
C	12	10	9	11	42	10.5
D	10	8	7	10	35	8.75
E	20	25	30	35	110	27.5
Transformation to sine arc √percent						
A	25.1	22.79	26.56	25.1	99.25	24.89
B	23.57	21.97	20.27	25.38	89.39	22.35
C	20.27	18.43	17.46	19.37	75.35	18.88
D	18.43	16.43	15.34	18.43	68.63	17.16
E	26.56	30	33.21	36.27	126.04	31.51

Table 15 Analysis of variance of the percentage of infection of rust *Hemileia vastatrix* Berk.et Br. 60 days after application with different doses of $CuSO_4.5H_2O$

Sources of variation	GL	SC	CM	F cal	F table	
					0.05	0.01
Treatments	4	509.9531	127.4843	25.6584**	3.26	5.41
Blocks	3	18.92871	6.30957	1.2699	3.49	5.95
Error	12	59.62402	4.968608			
Total	19	588.5059				

**Highly significant difference. C.V= 9.71%.

Table 16 Comparison of means of percent rust infection of *Hemileia vastatrix* Berk. et Br. 60 days after application of $CuSO_4.5H_2O$

Treatment	Percentage	
	Field	Transformed
E Witness without application	27.5	31.51 a
A 0.50 l ha^{-1}	17.75	24.89 b
B 1.00 l ha^{-1}	14.5	22.35 bc
C 1.50 l ha^{-1}	10.5	18.88 cd
D 2.00 l ha^{-1}	8.75	17.16 d

* Means of treatments with the same letter are statistically 1same according to Tukey's test at 0.05 probability.

The highest percentage of infection was observed in treatment E Witness without application with 27.50 %, followed by treatment A

0.5 l ha^{-1} with 17.75 %, treatment B 1.00 l ha^{-1} with 14.50 %, treatment C 1.50 l ha^{-1} with 10.50 % and treatment D 2.00 l ha^{-1} with 8.75 %. Table 17 shows the infection of coffee rust from before to 60 days after application and Figure 1 shows the same results in graphic form.

Table 17 Percentage of infection of coffee rust *Hemileia vastatrix* Berk. et Br. from the beginning to 60 days after the application of $CuSO_4.5H_2O$

Treatment	Days						
	0	15	30	45	60	∑	X
E witness without application	18.50 a	19.50 a	21.00 a	24.12 a	27.50 a	110.62	22.12
A 0.50 l ha^{-1}	12.00 b	13.38 b	14.50 b	16.25 b	17.75 b	73.88	14.18
B 1.00 l ha^{-1}	9.25 bc	10.00 bc	12.25 bc	13.00 bc	14.50 bc	59	11.8
C 1.50 l ha^{-1}	6.50 cd	7.25 cd	9.50 cd	10.00 c	10.50 cd	43.75	8.75
D 2.00 l ha^{-1}	5.00 d	5.88 d	8.25 d	8.75 d	8.75 d	36.63	7.33

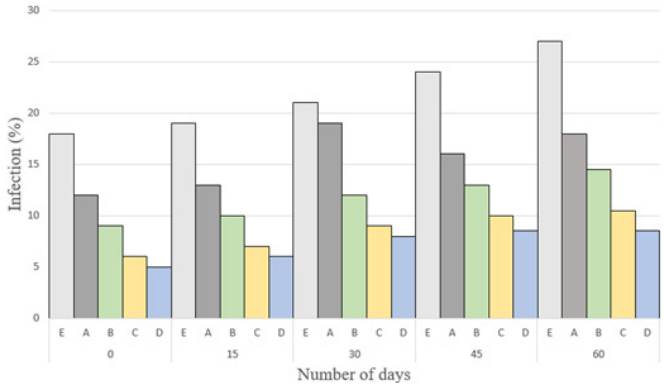

Figure 1 Percentage of infection of coffee tree rove *Hemileia vastatrix* Berk. et Br. from the beginning to 60 days after the application of $CuSO_4.5H_2O$.

Discussion

In recent years it has been necessary to implement chemical control strategies for the fungus *Hemileia vastatrix.* Anthropogenic climate change has been a key factor in the current rust outbreak in Mexico, in addition to promoting the outbreak of other pests that have affected the coffee crop in recent years (particularly "ojo de gallo" and the coffee berry borer), which cause significant national losses.[12,13] *Hemileia Vastatrix* has long been present with apparently similar intensity in medium, low and high zones, mainly when there are conditions of extreme humidity in the environment, especially during the rainy season.[14] Thus, the aggressive behavior of rust is a response to extreme precipitation and temperature conditions, which have permanently extended the range of the fungus from low altitudes to higher altitudes.[15] Increased temperature, weather changes and increased precipitation have had favorable effects on the life cycle of rust and other agricultural epidemics.[14,15] In addition, it is projected that globally the range of weeds, insect infestations and pathogens will expand to higher regions and latitudes.[16] As such, total eradication of rust is impossible; growers must adapt and learn to live.

H. vastatrix is controlled through the use of agrochemicals, fungicides, biofungicides, resistant varieties, biological control, cultural control and integrated management.[17] Some of the most commonly used strategies, as part of cultural control, have been the substitution of *Coffea arabica* for *C. canephora* (robusta coffee), a species better adapted to high temperatures and with greater resistance to coffee rust.[18] However, these types of experiments that focus on the use of chemical fungicides contribute to the development of alternatives that allow defining the adequate doses to achieve greater effectiveness in the chemical control of coffee rust. Some studies are based on the use of copper fungicides (copper oxychloride and mineral broths) considered the most efficient for the control of coffee rust, since they do not alter the biota of the agroecosystem.[19] Others have the function of penetrating the leaf tissue and have curative effects.[20] Particularly copper sulfate pentahydrate $CuSO_4.5H_2O$, which has been tested at different doses in the present study, has been used in an empirical manner, making approximations as to the doses to be used. By analyzing the results obtained, we can observe that $CuSO_4.5H_2O$ is effective in reducing the percentage of plant damage caused by *Hemileita vastatrix,* however, the treatments tested indicate that as the amount of fungicide increases in liters ha^{-1} the effectiveness is greater. Therefore, the information obtained in this experiment will be very useful for its application in the field.

Conclusions

This research constitutes an alternative to avoid losses in the quality and quantity of coffee production. According to the results obtained in this research, $CuSO_4.5H_2O$ allows reducing the infection of coffee rust *Hemileia vastatrix* Berk. *et* Br. in all treatments used, however, the lowest percentage of infection of coffee rust *Hemileia vastatrix* Berk. *et* Br. was observed in treatment D 2.00 l ha^{-1} with 7.33 % of infection after 60 days of application, this being the best dose of $CuSO_4.5H_2O$. On the other hand, the control treatment (without application) maintained 22.12 % of infection by coffee rust. Thus, the implementation of control strategies and attack against coffee rust by testing one of the fungal components that is considered essential to eradicate the impacts caused by coffee rust allowed determining which is the best treatment that can be recommended to producers in Chiapas, Mexico, and mainly in the municipality of Motozintla.

Acknowledgments

None.

Conflicts of interest

The authors declare no conflict of interest.

Funding

None.

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Citation: Perez-Ventura LY, Barrios-Calderon RJ. Pentahydrated copper sulphate CuSO4.5H2O at different doses for control of *Hemileia vastatrix* berk & broome. *J Appl Biotechnol Bioeng.* 2022;9(4):113–118. DOI: 10.15406/jabb.2022.09.00297