NOTA PRÉVIA

DOES SULPHUR EXPEL THE COFFEE BERRY BORER FROM *Coffea arabica* L. FRUITS?

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ABSTRACT: Technicians and insecticide retailers recommend adding sulfur to the insecticide mixture to expel coffee borer females (*Hypothenemus hampei*) from the fruit. The objective in this study was to verify if sulfur expels the coffee borer from the fruit and what the cost associated with the use of sulfur in the insecticide mixture is. Perforated fruits were collected from coffee crops (Red Catuaí, IAC 144) during the granulation phase for the experiments and divided into two lots. The first lot was used to verify the effectiveness of sulfur to expel the borer, and the second to evaluate the effect of temperature x sulfur source x expelling effect on the borer. Sources of sulfur tested were: SK30 and Kumulus DF. The first experiment was the treatments: sulfur sources (two + control without sulfur), two plastic containers (open and closed), five repetitions (factorial: 3 x 2). The second were the treatments: sulfur sources, plastic containers and under two temperatures, factorial 3x2x2. The number of adult females that left the fruits within 24 and 48 h was evaluated. There was no difference in the number of females that abandoned the fruits between treatments with sulfur and control (P> 0.05). It was concluded that sulfur does not expel *H. hampei* from *C. arabica* fruits.

Index terms: Coffee, bored fruits, *Hypothenemus hampei*, temperature.

O ENXOFRE DESALOJA A BROCA-DO-CAFÉ DE FRUTOS DE *Coffea arabica* L.?

RESUMO: Técnicos e vendedores de inseticidas, recomendam adição de enxofre à calda para desalojar as fêmeas da broca do café (*Hypothenemus hampei*) do fruto. Objetivou-se com esse trabalho verificar se o enxofre desaloja a broca do café dos frutos e o custo associado ao uso do enxofre à calda. Frutos broqueados foram coletados em cafeeiro (Catuaí Vermelho, IAC 144) na fase de granação para dois experimentos. O primeiro objetivou verificar o efeito do enxofre como desalojante da broca, e o segundo para avaliar o efeito da temperatura x fonte de enxofre x efeito desalojante da broca. As fontes de enxofre testadas foram: SK30 e , Kumulus DF. Os experimentos foram em delineamento inteiramente casualizado, esquema fatorial duplo. O 1º experimento foram os tratamentos: fontes de enxofre (duas+ controle sem enxofre),dois recipiente plástico (aberto e fechado), 5 repetições (fatorial: 3 x 2). O 2º foram os tratamentos: fontes de enxofre, recipiente plástico e sob duas temperaturas, fatorial 3x2x2. Avaliou-se o número de fêmeas adultas que abandonaram os frutos com 24 e 48 h. Não houve diferença entre o número de fêmeas que abandonaram os frutos nos tratamentos com enxofre e a testemunha (P>0,05). Conclui-se que o enxofre não atua como desalojante de *H. hampei* dos frutos de *C. arabica* .

Termos para indexação: Café, frutos broqueados, *Hypothenemus hampei*, temperatura.

The coffee berry borer, *Hypothenemus hampei* (Ferrari, 1867) (Coleoptera: Scolytidae) is a monophagous species, which perforates the coffee fruit at various phenological stages, housing itself in the seed for a significant part of its life cycle (VEGA et al., 2015). Generally, a single female infests one coffee fruit, laying its eggs and generating larva that cause damage (CONSTANTINO et al., 2011; VEGA et al., 2015). The losses caused by the coffee bery borer in productive countries such as Uganda, Colombia, Jamaica, Tanzania, Malásia and Mexico vary between 50 to 90% (VEGA, 2004), affecting many families in the rural environment (VEGA et al., 2003).

Chemical controls are the most commonly used for this pest. However, they frequently fail, are toxic to humans and non-target organisms and contaminate the environment. With the removal of the insecticide endosulfan from the market, few control alternatives for coffee berry borer remain (U.S. ENVIRONMENTAL PROTECTION AGENCY, 2010). Despite the insecticide Benevia® 100 OD (SOUZA et al., 2013) being

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registered in the state of Minas Gerais, there are still few insecticide options. As a solution to this situation, technicians and retailers recommend the addition of sulfur to the insecticidal mixture to expel coffee berry borer females from the fruits. There are however, no studies which assess the use of sulfur for the borer and existing studies evaluate its application in relation to other pests such as *Rhyzopertha dominica* (Fabricius, 1972) (Coleoptera: Bostrichidae) and *Spodoptera frugiperda* (Smith, 1797) (Lepidoptera: Noctuidae) (GONÇALVES, 2007; GUERREIRO; CAMOLES; BUSOLI, 2013). Given the need to find ways to minimize damage during coffee cultivation, we sought to verify if sulfur applied on *arabica* coffee fruits expels the adult *H. hampei* females as well as determine the costs associated with the use of sulfur in the insecticide mixture.

The trials were carried out at the entomology laboratory of the Universidade Federal de Viçosa – *Campus* Rio Paranaíba. Red Catuaí variety coffee (IAC 144) in a phenological state of granulation, without insecticide application, was collected from a coffee crop. The female borers were obtained via rearing on a diet provided by the Institute de Pesquisa do Paraná – IAPAR. Prior to conducting the experiments, 1,000 fruits were arranged on a white plastic tray (30 x 40 x 10 cm) and infested with females obtained via breeding, at a ratio of one female/fruit. After 4 h of exposure, the females perforated and entered the fruits, which were therefore ready for use in the experiments.

In the first experiment, the experimental design was totally randomized, in a double factorial scheme (3 x 2) + control (water). Three sulfur sources (Kúmulus DF - 1 L ha-1, fertilizer SK30 - 1 L ha^{-1} and Sulfur 750 - 3 L ha^{-1}) were used in two types of environment (open and closed container), with five replicates. The fruits perforated by the borer were sprayed using a 350 mL spray bottle and dried in the shade for 30 minutes. Following this, 15 fruits per plastic container were added (TP 62 100-T of 200 ml), constituting the experimental unit (repetition: 15 fruits/pot, performed 450 perforated fruits/treatment). The total was five closed and five open plastic containers containing fruits treated using the sulfur sources. The containers were sealed to verify if the sulfur sources had a fumigant effect. The open containers had their lids punctured (2 x 2 cm) and organza fabric was fixed over the top to allow gases to escape but prevent the escape of borers that left the fruits.

The second experiment was carried out using a factorial scheme (3 x 2 x 2), with three sulfur sources (as above), open and closed containers and two temperatures (25° C and 35° C) in BOD with 5 repetitions. After the preparation process of the fruits and exposure to the borer as in experiment 1, the containers were added in two BOD's, with a temperature of 25° C and the other at 35° C.

The number of female adults that abandoned the fruits was counted at 24 and 48 hours after spraying. The data were submitted to the Shapiro-Wilk and Bartlett tests with the aim of verifying the normality and independence of the residues and the homogeneity of the variance. To compare the data obtained, ANOVA (Analysis of variance) was performed and where necessary, the measures were compared using the Tukey test ($p>0.05$).

The sulfur sources (SK30 and Kúmulus DF) sold in the markets in the region of Alto Paranaíba was tested (Table 1). Data regarding dose and price were also collated to determine the cost of adding sulfur to the insecticide mixture.

Significant differences between the sulfur sources ($F= 0.09$, $p>0.05$) or type of container ($F= 2.97$, $p= 0.095$) were not observed, nor were they observed in the interactions between the sulfur sources x type of pot ($F= 0.56$, $p>0.05$). Additionally, significant differences between sulfur sources ($F= 0.13$, $p>0.05$), temperature ($F= 1.54$, $p= 0.215$), type of container ($F= 0.79$, $p>0.05$) or in the interaction between these ($F= 0.11$, $p>0.05$) were not observed in the experiment assessing the effect of temperature x sulfur sources on the number of females that abandoned the fruits (Table 1). Products with a sulfur base cost on average R$21.50 ha^{-1} (Table 2).

In the present research it was seen that under control conditions, sulfur does not affect the coffee borer, since the expected expelling effect was not observed in any of the treatments. Additionally, no effect by temperature on the action of the sulfur to expel the borer was observed. This result was different to what was claimed by the sulfur retailers/consultants, who in an informal manner affirmed that sulfur would function at higher temperatures, given that it would become a gas and expel the borer from the interior of the fruit. The cases of success with the use of sulfur on pests are rare. The same applied for the control of coffee borer, given that the borers did not abandon the grains under laboratory conditions in sealed containers. In cafe producing areas, an effect by sulfur on coffee berry borers was not expected, given that sulfur is very stable and does not evaporate.

TABLE 1 - Average ± standard error for the number of females of *Hypothenemus hampei* that abandoned *Coffea arabica* fruits in the two experiments.

Treatments	Characteristics of pots	[1]Females expelled from the fruit/container		
		1st Experiment	2nd Experiment	
	24 hours		25 °C	35 °C
Kúmulus		0.21± 0.21a	0.50± 0.29a	0.25±0.29a
SK30	Open	0.11±0.09a	0.00±0.00a	0.00±0.00a
Control		0.22±0.28a	0.50±0.29a	0.00±0.00a
Kúmulus		0.24±0.23a	0.50±0.29a	0.25±0.29a
SK30	Closed	0.21±0.21a	0.00±0.00a	0.00±0.00a
Control		0.31±0.26a	0.50±0.29a	1.00±0.00a
	48 hours			
Kúmulus		0.20±0.20a	0.25±0.25a	0.00±0.00a
SK30	Open	0.20±0.20a	0.25±0.25a	0.25±0.29a
Control		0.00±0.00a	0.00±0.00a	0.75±0.48a
Kúmulus		0.60±0.24a	0.25±0.25a	0.25±0.25a
SK30	Closed	0.60±0.40a	0.25±0.25a	1.25±0.25a
Control		0.80±0.20a	0.00±0.00a	0.50±0.50a

[1]Averages followed by the same letter in the same column do not differ between themselves according to the Tukey test with 5% probability.

TABLE 2 - Characteristics of the main products with a sulfur base in Alto Paranaíba, MG.

Commercial name	Sulfur Concentration (%)	Dose (L or Kg ha^{-1})	Unit Costs (R$ L or Kg^{-1})	Costs (R$ ha^{-1})
SK30	80	1	35.00	35.00
Kúmulus DF	80	0.5	16.00	8.00
		Average	25.50	21.50

Therefore it does not penetrate the coffee grain in the liquid formula. The formation of the gas occurs when fossil fuels are burnt (CETESB, 2017). However, authors such as BELLETTINI et al. (2005) and OLIVEIRA et al. (2006) affirm that sulfur forms hydrogen sulphide gas without even testing this hypothesis. If gas formed however, and there was an effect on the borer in the experiment with the closed container, the borer would have left the coffee fruit. This did not occur though, leading to the certainty that sulfur can be used for other purposes, but not to control the coffee berry borer.

Sulfur has been recommended for use mixed with the insecticide chlorpyrifos to increase the efficacy of the control of the coffee borer and for use as an acaricide being effective through contact and ingestion (VAN LEEUWEN et al., 2005). It is a mining subproduct destined for the production of agricultural fertilizer (DEPARTAMENTO NACIONAL DE PRODUÇÃO MINERAL, 2014). It is not however recommended as a fumigant. The little research that exists is for other pests, such as *Spodoptera frugiperda* caterpillars (GREENLEE; HARRISON, 2005). These studies showed an expelling effect on *S. frugiperda*, mainly through the liberation of sulfhydric gases. These act as an insect bio-irritant, resulting in greater movement, and consequently, contamination, as well as greater exposure to natural enemies and mortality of caterpillars (GUERREIRO; CAMOLESE; BUSOLI, 2013).

In studies carried out with sulfur applied on soil for the control of crickets (*Quesada gigas*) in coffee crops, satisfactory results were obtained, and have as a hypothesis control through the utilization of sulfur and the compounds resultant from the oxidation of sulfur and inhibitors of acetylcholinesterase. Given this, we argue that sulfur applied on soil becomes a potent insecticide (REIS et al., 2015).

As seen in the results, the use of sulfur in the control of the borer increases application costs and, does not present a satisfactory result to help control the insect. A possible explanation could be a lack of contact between the borer and the sulfur, due to its habit of staying inside the fruit. In addition to not delivering results for control of the coffee borer, it can cause population imbalances with *Leucoptera coffeella* (Guérin-Méneville, 1842) Lepidoptera: Lyonetiidae and mites (VENZON et al., 2013; ANDRADE et al., 2011). It also causes environmental contamination due to leaching of sulfur into the soil profile (REN; ZHU, 2015). Sulfur in the air can also provoke harm to human health, such as exacerbation of asthma symptoms (MATHEW et al., 2015). Additionally, there are the necessary expenses (R$21.50 ha^{-1}), taking into account the fact that the use of sulfur does not contribute to controlling the borer. This cost is variable depending on source and region, reaching higher values or not depending on the fluctuation of the prices of the products. However, the addition of sulfur to the insecticide mixture increases application costs.

We conclude that sulfur does not have the expected positive effect on the control of the borer. Consequently, it does not act to expel adult *H. hampei* females from *C. arabica* L fruits.

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REFERENCES

ANDRADE, D. J; PATTARO, F. C.; OLIVEIRA, C. A. L. Resíduos de calda sulfocálcica sobre a eficiência de acaricidas no controle de *Brevipalpus phoenicis.* **Ciência Rural**, Santa Maria, v. 41, n. 10, p. 1695-1701, out. 2011.

BELLETTINE, S. et al. Doses de enxofre associadas a inseticida em pulverização no controle do bicudo *Anthonomus grandis* Boheman, 1843 no algodoeiro. In: CONGRESSO BRASILEIRO DE ALGODÃO, 5., 2005, Salvador. **Anais**. Campina Grande: EMBRAPA-CNPA, 2005.

CETESB. **Poluentes**. Disponível em: <http://ar.cetesb.sp.gov.br/poluentes/> Acesso em: 28 nov. 2015

CONSTANTINO, L. M. et al. Biologic, morphologic, and genetic aspects of *Hypothenemus obscurus* and *Hypothenemus hampei* (Coleoptera: Curculionidae: Scolytinae). **Revista Colombiana de Entomologia**, Bogotá, v. 37, n. 2, p. 173-182, jul/dez. 2011.

DEPARTAMENTO NACIONAL DE PRODUÇÃO MINERAL. **Enxofre-sumário mineral.** 2014. Disponível em: <http://www.dnpm.gov.br/dnpm/sumarios/enxofre-sumario-minera-2014/view>. Acesso em: 23 out. 2015.

GONÇALVES, J. R. Suscetibilidade de *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae) ao enxofre. **Ciência Rural,** Santa Maria, v. 37, n. 4, p. 1145-1148, jul/ago. 2007.

GREENLEE, K. J.; HARRISON, J. F. Respiratory changes throughout ontogeny in the tobacco hornworm caterpillar, *Manduca sexta*. **Journal of Experimental Biology**, Arizona, v. 208, n. 7, p. 1385-1392, 2005.

GUERREIRO, J. C.; CAMOLESE, P. H.; BUSOLI, A. C. Eficiência de inseticidas associados a enxofre no controle de *Spodoptera frugiperda* em milho convencional. **Scientia Agraria Paranaensis**, Rondon, v. 12, n. 4, p. 275-285, jul/set. 2013.

MATHEW, J. et al. Air pollution and respiratory health of school children in industrial, commercial and residential areas of Delhi. **Air Qual Atmos Health,** Delhi, v. 8, n. 4, p. 421-427, May. 2015.

OLIVEIRA, M. G. et al. Efeito de espinosade sob diferentes dosagens e da associação de enxofre com inseticidas no controle da lagarta-do-cartucho em milho de várzea. In: REUNIÃO TÉCNICA ANUAL DE MILHO, 53., 2006, Pelotas. **Atas e resumos...** Pelotas: Embrapa Clima Temperado, 2006.

REIS, P. R.; et al. Eficácia do enxofre aplicado via solo no controle de cigarra *quesada gigas* (Olivier) em cafeeiro. **Coffee Science**, Lavras, v. 10, n. 4, p. 527 - 536, out/dez. 2015.

REN, Y.; ZHU, J**.** Leaching behavior and risk control of waste mercury chloride catalyst through mechanochemical reaction using sulfur. **Environmental Engineering Science**, New York, v. 32, n. 9, p. 816-823, Sept. 2015.

SOUZA, J. C. et al. Controle químico da broca-do-café com Cyantraniliprole. **Coffee Science**, Lavras, v. 8, n. 4, p. 404-410, out/dez. 2013.

U.S. ENVIRONMENTAL PROTECTION AGENCY. **Endosulfan phase out.** 2010. Disponível em: <http://www2.epa.gov/oppsrrd1/reregistration/endosulfan/endosulfan%E2%80%91agreement.html>. Acesso em: 15 mai, 2012.

VAN LEEUWEN, T. et al. Systemic use of spinosad to control the two-spotted spider mite (Acari: Tetranychidae) on tomatoes grown in rockwool. **Experimental and Appied Acarology**, New York, v. 37, n. 1-2, p. 93-105, Oct. 2005.

VEGA, F.E. Coffee berry borer *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae). In: CAPINERA, J. L. (Ed.), **Encyclopedia of entomology**, Dordrecht: Kluwer Academic Publishers, 2004. cap. c, p. 575–576.

VEGA, F.E.; ROSENQUIST, E.; COLLINS, W. Global project needed to tackle coffee crisis. **Nature,** London, v. 425, p.343, Sept. 2003.

VEGA, F. E. et al. A mysterious wing spine in male coffee berry borers (Coleoptera: Curculionidae: Scolytinae). **Florida Entomologist**, Flórida, v. 98, n. 1 p. 352-353, Jan/Mar. 2015.

VENZON, M. et al. Toxicity of organic farming compatible products to the coffee leaf miner. **Pesquisa Agropecuária Brasileira**, Brasília, v. 48, n. 3, p. 241-248, mar. 2013.