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LEAF ESSENTIAL OIL FROM *Croton pulegiodorus* Baill SHOWS INSECTICIDAL ACTIVITY AGAINST *Sitophilus zeamais* Motschulsky[1]

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ABSTRACT - The present study aimed to assess the effects of the essential oil of *Croton pulegiodorus* Baill on eight populations of *Sitophilus zeamais* Motschulsky with different patterns of susceptibility to synthetic insecticides. Populations of *S. zeamais* were obtained from Sete Lagoas-MG, Jacarezinho-PR, Bom Conselho-PE, Garanhuns-PE, Jupi-PE, Lajedo-PE, São João-PE and Serra Talhada-PE. To estimate the lethal concentrations (LC_{50} and LC_{90}) of oil for each population, fumigation tests were performed. The susceptibility of *S. zeamais* to the essential oil varied among populations. Garanhuns and Bom Conselho was considered the susceptibility patterns, presenting the lowest LC_{50} (3.40 µL L^{-1} of air) and LC_{90} (9.60 µL L^{-1} of air) for the essential oil, respectively. The population from Jupi exhibited the highest LC_{50} (14.49 µL L^{-1} of air) and LC_{90} (19.60 µL L^{-1} of air) for *C. pulegiodorus*. The resistance ratio ranged from 1.84 for the São João to 4.26 for the Jupi population. Thus, the essential oil of *C. pulegiodorus* showed fumigant activity, causing mortality in all *S. zeamais* populations used.

Keywords: Natural products. Euphorbiaceae. Curculionidade. Stored maize.

O ÓLEO ESSENCIAL DE FOLHAS DE *Croton pulegiodorus* Baill APRESENTA ATIVIDADE INSETICIDA SOBRE *Sitophilus zeamais* Motschulsky

RESUMO - O presente estudo teve o objetivo de avaliar os efeitos do óleo essencial de *Croton pulegiodorus* Baill sobre oito populações de *Sitophilus zeamais* Motschulsky com diferentes padrões de susceptibilidade a inseticidas sintéticos. As populações foram obtidas de Sete Lagoas-MG, Jacarezinho-PR, Bom Conselho-PE, Garanhuns-PE, Jupi-PE, Lajedo-PE, São João-PE e Serra Talhada-PE. Para estimar as concentrações letais (CL_{50} e CL_{90}) do óleo para cada população, foram realizados testes de fumigação. A susceptibilidade de *S. zeamais* ao óleo essencial variou entre as populações. Garanhuns e Bom Conselho foram considerados padrões de susceptibilidade, apresentando as menores CL_{50} (3,40 µL L^{-1} de ar) e CL_{90} (9,60 µL L^{-1} de ar) para *C. pulegiodorus*. A população de Jupi apresentou as maiores CL_{50} (14,49 µL L^{-1} de ar) e CL_{90} (19,60 µL L^{-1} de ar) para *C. pulegiodorus*. A razão de resistência variou de 1,84 vezes para população de São João a 4,26 vezes para a população de Jupi. Assim, o óleo essencial de *C. pulegiodorus* apresentou efeito fumigante causando mortalidade em todas as populações de *S. zeamais* utilizadas.

Palavras-chave: Produtos naturais. Euphorbiaceae. Curculionidae. Milho armazenado.

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INTRODUCTION

The maize weevil (*Sitophilus zeamais* Motschulsky, Coleoptera: Curculionidae) is one of the main stored-cereal pests around the world, being ubiquitous and responsible for great economic loss at post-harvest due to reduced grain quality, weight, and germination power of seeds (ALONSO-AMELOT; AVILA-NÚNEZ, 2011). These losses are aggravated by improper storage methods and inadequate storage facilities which, together, result in severe damage to stored grains and, consequently, the aforementioned economic loss (NAPOLEÃO et al., 2013). Therefore, efforts to maintain adequate post-harvest grain storage conditions should accompany those made to increase crop productivity (DE LIRA et al., 2015).

Storage pest control is dependent on fumigants and other synthetic chemical protectors, mainly organophosphates and pyrethroids that have caused several cases of resistance in various insect populations (ARAÚJO et al., 2017). In fact, there are several records of resistance in insect populations of stored products, including Brazil, especially in *S. zeamais*, resulting in the complete failure of common practice to control this pest in storage facilities (SANTOS et al., 2009; BOYER et al., 2012).

Faced with the need to minimize problems with the use of synthetic insecticides, recent research has demonstrated the potential of essential oils as an alternative to conventional pest management of stored products (RAJENDRAN; SRIANJINI, 2008). These studies focus mainly on the repellent or fumigant activity of essential oils and their lethal or sublethal effects. In general, the insecticidal effect of essential oils can be attributed to their chemical composition and mode of action on insects, causing them physiological changes, behavioral disorders, and mortality (CABALLERO-GALLARDO; OLIVERO-VERBEL; STASHENKO, 2011).

The essential oils from diverse plant species of several families has been shown to have an insecticidal action against various types of insects (NERIO et al., 2010) and both, commercial oils acquired from companies specialized in selling these products and oils obtained directly from the local flora by researchers, have been widely studied. The worldwide-distributed genus *Croton* L. (Euphorbiaceae), in turn, has proven promising for the management of insect pests of stored products (PEREZ-AMADOR et al., 2007). In Brazil, where research on insects that mainly attack beans and cereals has made important progress in recent years, it is worth mentioning the studies analyzing the effect of essential oils from various *Croton* species on *Callosobruchus maculatus* Fabricius and *Zabrotes subfasciatus* Bohemann (Chrysomelidae) (BRITO et al., 2015; CARVALHO et al., 2016), *Tribolium castaneum* Herbst (Tenebrionidae) (MAGALHÃES et al., 2015), and *Rhyzopertha dominica* Fabricius (Bostrichidae) (SOUZA et al., 2016).

Considering the economic importance of *S. zeamais* for stored grains, the progress in research conducted with substances of botanical origin that have an insecticidal action and the lack of studies on the effects of essential oils from *Croton* on this insect pest in Brazil, this research aimed to evaluate the insecticidal activity of the essential oil from *C. pulegiodorus* on Brazilian populations of *S. zeamais* with different susceptibility patterns to synthetic insecticides.

MATERIAL AND METHODS

The research was conducted at the Arthropod Ecology Centre (NEA) and the Laboratory of the Postgraduate Program in Plant Production, of the Academic Unit of Serra Talhada (UAST), at the Federal Rural University of Pernambuco (UFRPE), in the municipality of Serra Talhada - PE.

Insects

To conduct the bioassays, we used eight populations of *S. zeamais* with different susceptibility patterns to synthetic insecticides, following Melo Júnior et al. (2018). The population from Sete Lagoas-MG (19°27′57″ S, 44°14′48″ W, and 761 m a.s.l.), from Embrapa - National Centre for Research on Corn and Sorghum (CNPMS), is frequently used as a susceptible population to pyrethroids, whereas the population from Jacarezinho-PR (23°09′38″ S, 49°58′10″ W, and 501 m a.s.l.), from the municipality warehouse, is frequently used as a resistant population. The other populations were from Bom Conselho-PE (09°10′11″ S, 36°40′47″ W, and 654 m a.s.l.), Garanhuns-PE (08°53′25″ S, 36°29′34″ W, and 842 m a.s.l.), Jupi-PE (08°42′42″ S, 36°24′54″ W, and 782 m a.s.l.), Lajedo-PE (08°39′49″ S, 36°19′12″ W, and 661 m a.s.l.), and São João-PE (08°52′32" S, 36°22′00″ W, and 716 m a.s.l.) (MELO JÚNIOR et al., 2018). Finally, the population from Serra Talhada-PE (07° 59′31″ S, 38°17′54″ W, and 429 m a.s.l.) has been kept for 11 years in the laboratory without exposure to insecticides.

After collection, all populations were kept in a laboratory for successive generations. The colonies started with 50 non-sexed adult insects, up to 20 days old, in plastic containers (1 L) and kept in Biochemical Oxygen Demand (B.O.D.) chambers under controlled conditions (temperature of 28 ± 2 ° C, 70 ± 10% RH and 12/12 h light/dark regime), using corn grains as food substrate.

Plant material

The plant material (*C. pulegiodorus*) was collected in the municipality of Triunfo-PE (07° 50′ 17″ S, 38° 06′ 06″ W, and 1004 m a.s.l.) between December 2015 and June 2016 and dried in a greenhouse at 50 °C for 24 hours. The reference material is stored in the Herbarium of the Brazilian Semi-arid (HESBRA) (Voucher #S.S. Matos 104).

The essential oil was extracted from 100 g of crushed dried leaves of *C. pulegiodorus* as they are more easily obtained (larger biomass) and have a greater quantity of oil (yield) compared to other plant parts. Samples leaves were then subjected to hydrodistillation for 2 h, using a Clevenger Apparatus and a rotary evaporator coupled to a vacuum and pressure pump. The oil obtained was stored in a cooler at 4 °C, in dark containers, until the bioassays were conducted.

Fumigation bioassays

Preliminary tests were conducted to determine the concentration range causing 5 to 95% mortality in each of the populations. After that, six concentrations were chosen to conduct the definitive bioassays and obtain the lethal concentrations necessary to kill 50% (LC_{50}) and 90% (LC_{90}) of the insects in each population.

Definitive bioassays were conducted using 1 L glass bottles. The oil was applied with an automatic pipette to strips of filter paper (5×2 cm) fixed on the lower surface of the lid of the containers by adhesive tape. The essential oil was applied in different concentrations (0; 2.5; 5; 10; 15; 20; and 30 $\mu L\ L^{-1}$ air), as defined in preliminary tests. To avoid the direct contact of the insects with the oil, a porous voile fabric was used between the lid and the glass jar. To prevent loss of the essential oil vapors, all containers were sealed with Parafilm®. Adults of *S. zeamais* (10 non-sexed individuals with standardized age up to 15 days) were placed inside the bottles and remained exposed to the volatile essential oil for 48 h, and then the mortality of insects was evaluated. The experiment was laid in an completely randomized design with five repetitions of each population evaluated.

The lethal concentrations (LC_{50} and LC_{90}) of oil were estimated for each population of *S. zeamais*. The values obtained in the bioassays were subjected to Probit analysis using the PROC PROBIT procedure of the SAS 9.0 statistical package (SAS Institute, 2002).

Toxicity ratios (TR) were calculated by dividing the highest value of LC_{50} or LC_{90} by the values found in each of the remaining populations. Resistance ratios (RR) were calculated by dividing each value of LC_{50} by the lowest value found, i.e., the LC_{50} of each population by the LC_{50} of the population considered most susceptible. These ratios were considered significant when 95% confidence intervals did not include the 1.0 value, as proposed by Robertson and Preisler (1992).

RESULTS AND DISCUSSION

The results of fumigation bioassays using the essential oil extracted from *C. pulegiodorus* indicate that there was significant variation in the response of *S. zeamais* populations to the toxicity of the essential oil, which implies different lethal concentrations for each population. The slopes of the concentration-response curves (angular coefficient) showed small variations among populations, being lower (2.47 ± 0.29) in the population from Garanhuns-PE and higher (4.30 ± 0.39) in the population from Bom Conselho-PE (Table 1). Among the populations evaluated, Garanhuns-PE and Bom Conselho-PE had the lowest LC_{50} (3.40 $\mu L\ L^{-1}$ air) and LC_{90} (9.60 $\mu L\ L^{-1}$ air), respectively. Thus, they were considered susceptibility patterns to the essential oil from *C. pulegiodorus*. The population from Jupi-PE had both, the highest LC_{50} (14.49 $\mu L\ L^{-1}$ air) and the highest LC_{90} (19.60 $\mu L\ L^{-1}$ air) (Table 1), thus being the most resistant/tolerant *S. zeamais* population to this essential oil.

The toxicity ratio (TR) based on LC_{50}, ranged from 1.35 in the population from Sete Lagoas-MG to 4.26-fold greater in the population from Garanhuns-PE (Table 1). The toxicity ratio based on LC_{90}, in turn, varied between 1.27 in the population from Jacarezinho-PR and 2.04-fold greater in the population from Bom Conselho-PE (Table 1). The ratio of resistance (RR) based on LC_{50} varied between 1.84 for in population from São João-PE and 4.26-fold greater in the population from Jupi-PE (Table 1). By not including the value 1.0 in the confidence intervals of the ratios (ROBERTSON; PREISLER, 1992), except for Garanhuns-PE, the other seven populations evaluated showed a significant resistance ratio for the essential oil extracted from *C. pulegiodorus*.

Table 1. Toxicity of the essential oil from *C. pulegiodorus* by fumigation of populations of *S. zeamais* (Temperature: 28 ± 2 °C; relative humidity: 70 ± 10%; 12 h photoperiod).

Populations	N	Angular coefficient ±SE	(LC_{50} µL L^{-1} air) (CI 95%)	TR (50% CI) LC_{50}	(LC_{90} µL L^{-1} air) (95% CI)	TR (90% CI) LC_{90}	RR LC_{50} (95% CI)	χ^2	P
Garanhuns - PE	350	2.47±0.29	3.40 (2.59-4.16)	4.26	10.04 (7.14-13.12)	1.95	-	32.94	0.0001
São João - PE	350	3.31±0.31	6.25 (5.40-7.14)	2.31	13.40 (9.95-17.64)	1.46	1.84 (1.40-2.42)*	28.33	0.0001
Lajedo - PE	350	3.02±0.28	7.54 (6.49-8.63)	1.92	10.60 (9.25-18.21)	1.85	2.21 (1.68-2.91)*	20.82	0.0001
Bom Conselho - PE	350	4.30±0.39	7.73 (6.83-8.65)	1.88	9.60 (8.72-17.04)	2.04	2.27 (1.75-2.95)*	35.96	0.0001
Serra Talhada - PE	350	3.54±0.32	8.88 (7.80 -10.01)	1.63	11.40 (10.86-4.97)	1.72	2.61 (2.00-3.40)*	21.61	0.0001
Jacarezinho - PR	350	2.48±0.36	10.55 (8.44-13.50)	1.37	15.40 (14.11-9.08)	1.27	3.10 (2.26-4.25)*	51.39	0.0001
Sete Lagoas - MG	350	3.44±0.67	10.74 (7.35-13.39)	1.35	14.60 (13.50-2.14)	1.34	2.96 (2.08-4.23)*	129.73	0.0001
Jupi - PE	350	3.57±0.50	14.49 (12.33-16.98)	-	19.60 (17.7-27.12)	-	4.26 (3.23-5.62)*	45.91	0.0001

N = Total number of insects; ST = Estimate standard error; LC_{50} (CI 95 %) = Lethal concentration that can kill 50% of exposed individuals and confidence interval at 95% probability; LC_{90} (CI 95 %) = Lethal concentration that can kill 90% of exposed individuals and confidence interval at 95% probability; TR (95% CI) = Toxicity ratio was calculated by dividing the highest LC_{50} or LC_{90} by the values found in each of the populations; RR (95% CI) = Resistance ratio calculated by dividing the LC_{50} of the study population by the LC_{50} of the susceptibility pattern population and confidence intervals at 95% probability; Population of *S. zeamais* that showed a significant resistance ratio by Robertson and Preisler method (1992); x--$^{2=}$ Chi-square; p = test significance level.

The resistance ratio based on LC_{50} showed that the Garanhuns-PE population was more susceptible than the other populations studied, including the susceptibility pattern to pyrethroids, Sete Lagoas-MG, which has been kept in the laboratory without insecticides for about three decades (RIBEIRO et al., 2003). The other populations had low magnitude, with the highest levels of resistance/tolerance presented by the populations of Jacarezinho-PR (3.10-fold) and Jupi-PE (4.26-fold). The level of resistance expressed by the population from Jacarezinho-PR is relatively low, but it is noteworthy that this population has been a reference in studies evaluating resistance to synthetic insecticides (RIBEIRO et al., 2003).

The difference in resistance/tolerance presented by the population from Jupi-PE is relatively marked when compared to the other populations from Pernambuco. However, previous studies conducted with these populations of *S. zeamais* have demonstrated high levels of resistance of this insect to pyrethroids (MELO JÚNIOR et al., 2018). Thus, the results obtained in this study showed that these populations may have developed mechanisms against the harmful effects of other fumigants. Thus, it is known that insects may have several biochemical, physiological and behavioral mechanisms of resistance to insecticides and fumigants, such as detoxification, increased excretion of toxic compounds, and reduced respiratory rate or mobility, and may avoid areas treated with chemical products (HEMINGWAY, 2000; GUEDES et al., 2009; PIMENTEL et al., 2009). However, the resistance levels found did not reach the levels reached for resistance to synthetic insecticides, as the oil resistance in these populations was low, i.e., less than 10-fold, suggesting that the use of the essential oil from *C. pulegiodorus* oil may be an effective alternative either alone or combined with phosphine or other conventional insecticides for control of *S. zeamais*.

With regard to insecticide potential (fumigant effect), the populations of *S. zeamais* showed different behavior in response to the essential oil from *C. pulegiodorus*, with high mortalities (80% to 98%) depending on concentration (Figures 1 to 8). Populations of Bom Conselho-PE (Figure 1), Serra Talhada-PE (Figure 2) and Sete Lagoas-MG (Figure 3) presented a quadratic curve, with mortality below 50% at the lower end of the concentration range tested, but with a significant increase in mortality at the higher concentrations. Lethal concentrations (LC_{50}) of the essential oil for the insect populations from Bom Conselho-PE and Serra Talhada-PE were between 7 and 9 µL L^{-1} air, and for the population from Sete Lagoas-MG, LC_{50} is close to 11 µL L^{-1} air.

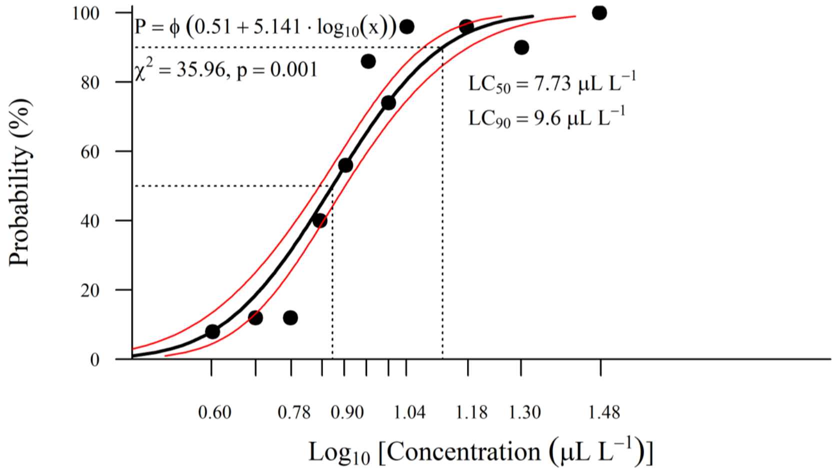

Figure 1. Mortality of *S. zeamais* from the municipality of Bom Conselho-PE subjected to different concentrations of *C. pulegiodorus* essential oil.
**Significant at p-level < 0.0001.

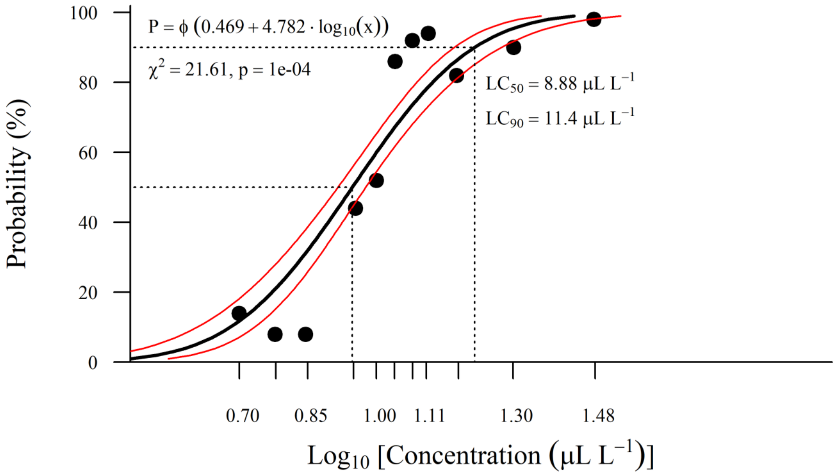

Figure 2. Mortality of *S. zeamais* from the municipality of Serra Talhada-PE subjected to different concentrations of *C. pulegiodorus* essential oil.
**Significant at p-level < 0.0001.

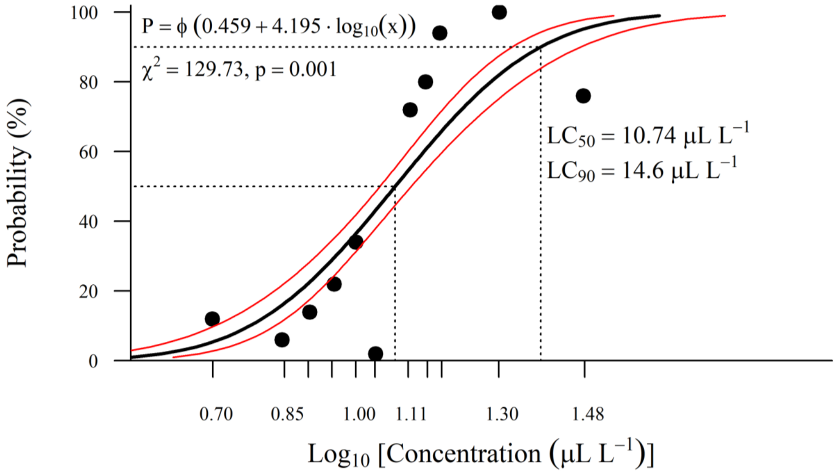

Figure 3. Mortality of *S. zeamais* from the municipality of Sete Lagoas-MG subjected to different concentrations of *C. pulegiodorus* essential oil.
**Significant at p-level < 0.0001.

Mortality in the other populations showed a linear behavior, whereby, as the concentration increased mortality also increased. Thus, the population from Garanhuns-PE (Figure 4) had the lowest LC_{50}, being close to 4 µL L^{-1} air. The populations of Lajedo-PE (Figure 5) and São João-PE (Figure 6) had LC_{50} below 8 µL L^{-1} air, followed by the population from Jacarezinho-PR (Figure 7) with LC_{50} near 11 µL L^{-1} air. However, the highest LC_{50} was exhibited by the population from Jupi-PE (Figure 8), being close to 15 µL L^{-1} air.

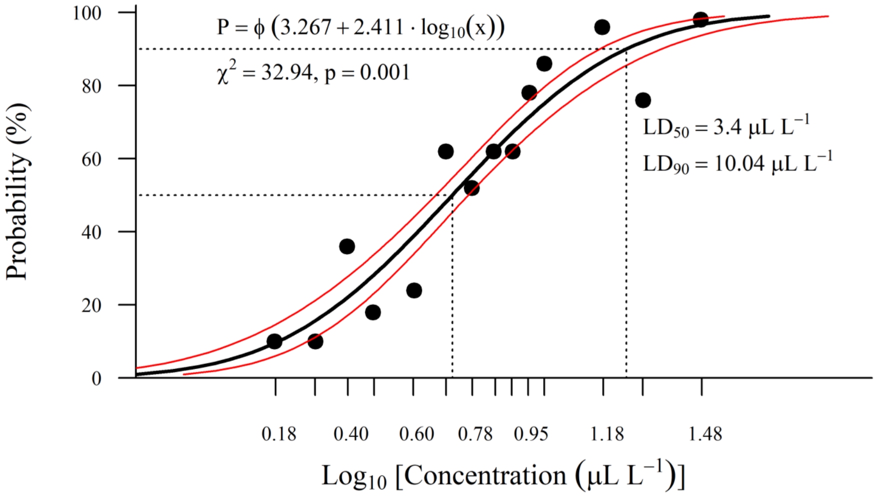

Figure 4. Mortality of *S. zeamais* from the municipality of Garanhuns-PE subjected to different concentrations of *C. pulegiodorus* essential oil.
**Significant at p-level < 0.0001.

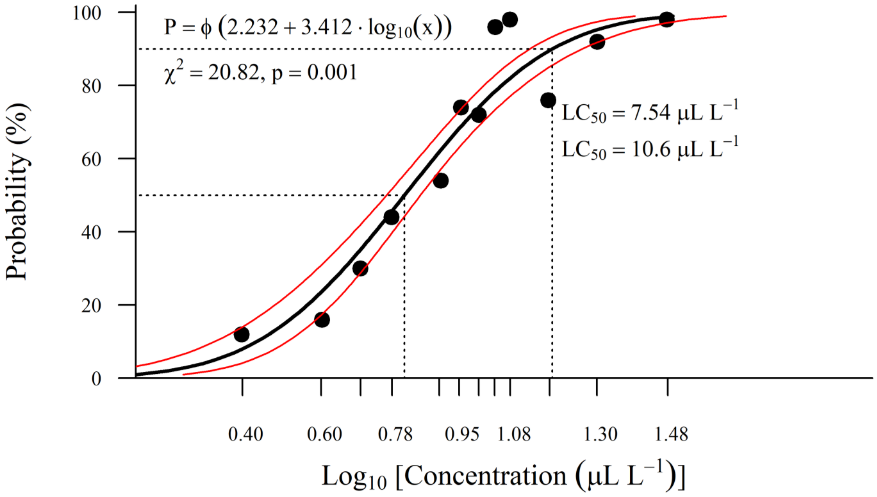

Figure 5. Mortality of *S. zeamais* from the municipality of Lajedo-PE subjected to different concentrations of *C. pulegiodorus* essential oil.
**Significant at p-level < 0.0001.

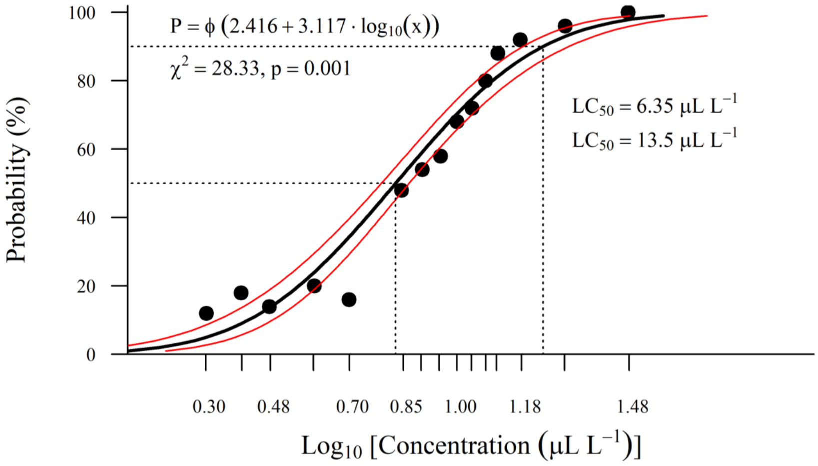

Figure 6. Mortality of *S. zeamais* from the municipality of São João-PE subjected to different concentrations of *C. pulegiodorus* essential oil.
**Significant at p-level < 0.0001.

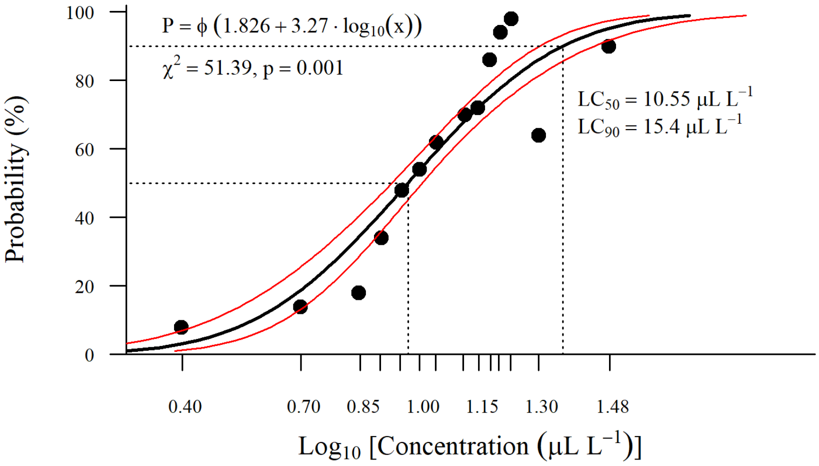

Figure 7. Mortality of *S. zeamais* from the municipality of Jacarezinho-PR subjected to different concentrations of *C. pulegiodorus* essential oil.
**Significant at p-level < 0.0001.

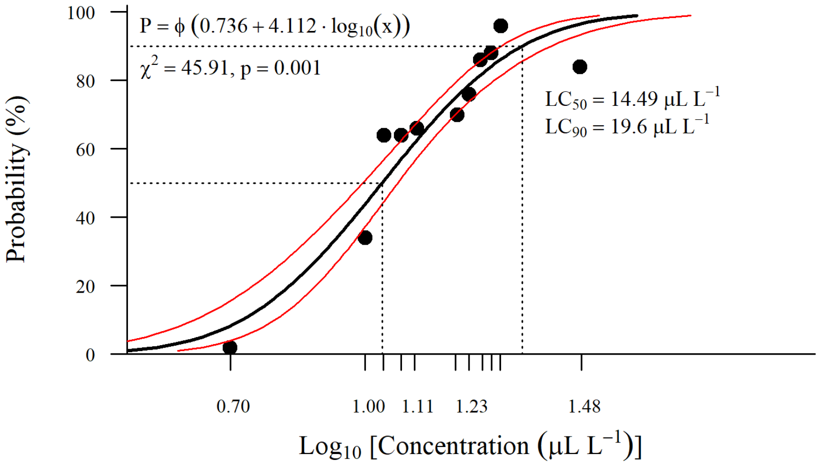

Figure 8. Mortality of *S. zeamais* from the municipality of Jupi-PE subjected to different concentrations of *C. pulegiodorus* essential oil.
**Significant at p-level < 0.0001.

The bioactivity of essential oils (fumigant or repellent effect) obtained from *Croton* species on stored bean and maize pests has been recently demonstrated. Thus, for example, in kidney beans, Silva et al. (2008) found that *Croton grewioides* Baill essential oil had a fumigant effect on adults of *Z. subfasciatus*, Brito et al. (2015) observed that *C. pulegiodorus* and *Croton heliotropiifolius* Kunth essential oils caused 100% mortality in adults of *Z. subfasciatus* at all concentrations evaluated (5, 10, 15 and 20 µL L^{-1} air), in addition to having a repellent effect on insects; Carvalho et al. (2016) observed toxicity (fumigant effect) of *Croton urucurana* Baill essential oil on *C. maculatus*, causing mortality rates greater than 80% and effects on the biology and survival of this beetle. Similarly, in maize, Magalhães et al. (2015) reported that *C. pulegiodorus* and *C. heliotropiifolius* essential oils had a repellent effect and caused zero emergence of *T. castaneum*, while Souza et al. (2016) observed that *C. pulegiodorus* essential oil caused mortality rates above 70% in *R. dominica*, when used at higher concentrations.

The population from Sete Lagoas-MG is considered a susceptibility pattern to pyrethroid insecticides (MELO JÚNIOR et al., 2018) and this behavior was expected to manifest when subjected to *C. pulegiodorus* essential oil, nevertheless, it proved reasonably resistant/tolerant to exposure to this essential oil. The population from Jacarezinho-PR, in turn, showed high levels of resistance to pyrethroids (MELO JÚNIOR et al., 2018), being considered a resistance pattern, and when exposed to *C. pulegiodorus* essential oil it showed a similar behavior, as the lethal concentrations necessary to kill 50% and 90% of this population were among the highest concentrations tested in this study.

The concentration-response curves showed small variations among populations, and it is known that greater slopes indicate a more homogeneous response, in which small variations in the concentrations used cause greater variations in mortality of these populations (ATKINS; GREYWOOD; MACDONALD, 1975). The low slope values obtained, even with small variations in concentrations, result in different changes in the mortality rate, suggesting the presence of more than one genotype in the populations and indicating a more heterogeneous response to the essential oil (SUTHISUT; FIELDS; CHADRAPATYA, 2011). It is well known that the intensive use of synthetic chemicals and their residues may cause genetic alterations and modify behavioral or physiological responses in insects (LIU; GOH; HO, 2007).

In fact, behavioral or physiological characteristics shown by different insect populations resulted from the interaction between their genotypes and the environmental conditions under which the evaluation was done (SUTHISUT; FIELDS; CHANDRAPATYA, 2011), and the plasticity of populations may cause differences in the response to exposure to different selection pressures. It is noteworthy that the populations of *S. zeamais* studied here come from different Brazilian regions that vary in altitude and temperature, even those from Pernambuco, and in selection pressure, thus supporting the interpretation of these findings.

Unlike synthetic insecticides, essential oils often consist of dozens of constituents whose overall activity is related to major compounds that act in association or synergism with minor compounds (ATKINS; GREYWOOD; MACDONALD, 1975). Thus, essential oils prevent or delay the selection of resistance in insect populations as their effects are due to different modes of action. Moreover, Abdelgaleil et al. (2016) attributed the insecticidal activity of essential oils to their inhibition of acetylcholinesterase or adenosine triphosphate action, as proposed by Abou-taleb et al. (2016) and Saad, Abou-taleb and Abdelgaleil (2018), thus, suggesting that the latter may be the main target of essential oils.

The toxic effect of essential oils can occur by inhalation, ingestion or absorption by the integument, and is generally associated with their chemical composition. Basically, the compounds involved act on the nervous system of insects, causing physiological or behavioral disorders, and generally, rapid death (ISMAN, 2006; COITINHO et al., 2011).

With regard to *Croton* plants (Euphorbiaceae), it is known that several species produce many bioactive compounds and accumulate substances of alkaloid, phenylpropanoid, and terpene nature that are abundant in essential oils and have high toxic potential (COITINHO et al., 2011). Dória et al. (2010) identified 57 constituents in leaves of *C. pulegiodorus*, which corresponded to 85.68% of their total chemical composition, with sesquiterpenes accounting for 83.49% and monoterpenes accounting for 2.19%. The authors identified as major compounds β- Caryophyllene (20.96%), Bicyclogermacrene (16.89%), Germacrene D (10.55%), τ-Cadinol (4.56%), and β-Copaen-4-α-ol (4.35%). Thus, although no chromatographic analysis was performed in this study, it can be assumed that the toxicity of the essential of extracted from *C. pulegiodorus* was related to its chemical composition, as it includes compounds of recognized bioactivity that trigger profound physiological and behavioral effects on insects.

The differences in the level of resistance of some of the populations evaluated seemed to be owing, at least partially, to the use of inappropriate techniques, such as frequent applications of incorrect dosages and the systematic use of insecticides from different chemical groups applied with or without the presence of the pest (MELO JÚNIOR et al., 2018). The differences in behavioral responses observed among populations of *S. zeamais* exposed to the essential oil obtained from *C. pulegiodorus* were probably due to genotypic plasticity and the history of selection pressure (insecticides and/or fumigants) caused by different experiments in the localities from which they originated, as none of these populations had been previously exposed to essential oils.

CONCLUSIONS

The essential oil extracted from *C. pulegiodorus* had a fumigant effect on the populations of *S. zeamais* evaluated in this study, reaching mortalities between 80 and 98% at the highest concentrations tested.

Differences in tolerance and/or response capacity to the essential oil from *C. pulegiodorus* tested were observed among populations of *S. zeamais*.

The lowest lethal concentrations (LC_{50}) and (LC_{90}) of *C. pulegiodorus* essential oil were found in the populations of Garanhuns-PE and Bom Conselho -PE, respectively.

The population from Garanhuns-PE was the most susceptible to the *C. pulegiodorus* essential oil, among all populations evaluated.

The population from Jupi-PE was the most resistant/tolerant to the *C. pulegiodorus* essential oil among all populations evaluated.

The lethal concentrations (LC_{50} and LC_{90}) of *C. pulegiodorus* essential oil may be considered low relative to those of other essential oils evaluated on stored grain pests, suggesting that it may be used for control management of *S. zeamais.*

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