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Original Article

Insecticidal and repellent activity of native and exotic lemongrass on *Maize weevil*

Atividade inseticida e repelente do capim-limão nativo e exótico no gorgulho do milho

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Abstract

Corn crop, due to its easy adaptation to the most diverse agroecosystems, spreads throughout the different regions of the world, making it one of the most important agricultural crops. In this crop, pest insects stand out for causing losses both in the field and in warehouses. The application of essential oils can be an important technique to be investigated in the management of insects due to its known insecticidal activity and low risk to the environment. The objective of the work was to value the insecticide and repellent effect of essential oils of exotic lemongrass (*Cymbopogon citratus*) and native lemongrass (*Elionurus* sp.) for the management of maize weevil (*Sitophilus zeamais* (Mots., 1855, Coleoptera: Curculionidae)). The chemical analysis of the oils made by CG-MS showed that the chemical composition of the native and exotic lemongrass is similar, however, the exotic species presented a greater number of compounds. The essential oils of native and exotic lemon grass have efficiency on maize weevil mortality, and it is verified that the increase in the applied dose reflects in a reduction in the insect's exposure time for death to occur. The essential oil of both species showed repellent capacity at all times evaluated. Thus, it can be said that both species have the capacity and potential to be used in the management of corn weevil, and can be an alternative for smallhorders farmers and organic production.

Keywords: essential oils, *Cymbopogon citratus*, *Elionurus* sp, corn seeds, storage.

Resumo

A cultura do milho, por sua fácil adaptação aos mais diversos agroecossistemas, se espalha por diferentes regiões do mundo, tornando-se uma das mais importantes culturas agrícolas. Nesta cultura, os insetos-praga se destacam por causar prejuízos tanto no campo quanto nos armazéns. A aplicação de óleos essenciais pode ser uma importante técnica a ser investigada no manejo de insetos devido à sua conhecida atividade inseticida e baixo risco o meio ambiente. O objetivo do deste trabalho foi avaliar o efeito inseticida e repelente de óleos essenciais de capim-limão exótico (*Cymbopogon citratus*) e capim-limão nativo (*Elionurus* sp.) para o manejo do gorgulho do milho (*Sitophilus zeamais* (Mots., 1855, Coleoptera: Curculionidae). A análise química dos óleos feita por CG-MS mostrou que a composição química do capim-limão nativo e exótico é semelhante, entretanto, as espécies exóticas apresentaram maior número de compostos. Os óleos essenciais de capim-limão nativo e exótico têm eficiência na mortalidade do gorgulho do milho, e verifica-se que o aumento na dose aplicada reflete na redução do tempo de exposição do inseto até que ocorra a morte. O óleo essencial de ambas as espécies apresentou capacidade repelente em todos os momentos avaliados. Assim, pode-se afirmar que ambas as espécies possuem capacidade e potencial para serem utilizadas no manejo do gorgulho do milho, podendo ser uma alternativa para a agricultura familiar e produção orgânica.

Palavras-chave: óleos essenciais, *Cymbopogon citratus*, *Elionurus* sp, sementes de milho, armazenagem.

1. Introduction

Corn crop, due to its easy adaptation to the most diverse agroecosystems, spreads throughout the different regions of the world, making it one of the most important agricultural crops. According to the USDA (2019), a world corn production of 1,118 billion tons is estimated for the 2019/2020 crop. In Brazil, it is

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estimated for the 2020/21 season, a planting area that could reach 18.44 million hectares, and a production of 104.9 million tons, with expected export of 35.0 million tons. The Southern region is responsible for the production of 24.58 million tons, surpassed only by the Midwest region (Brasil, 2020).

Data from the United Nations Food and Agriculture - FAO (2019), for the 2019/2020 crop, show increases in corn exports, placing Brazil as the second largest exporter of grain (25% of the world total). In this scenario, the Southern region of the country appears among the ones with the highest volume of grain production, and this crop is present in 389,035 rural establishments, being 77% of them considered as familiar farmers (IBGE, 2017). This demonstrates the great economic, cultural and social significance of corn production for Brazil.

Given the volume of corn produced in Brazil, grain storage becomes a common practice, including in small properties. However, in most cases, storage is carried out improperly, a fact that can provide great losses of the stored product, both in quantity and in grain quality. Among the factors that lead to these losses are pest insects, responsible for the loss of 15% of the total grain produced annually in Brazil (Embrapa, 2015). Insects assume a significant importance, because, in addition to direct consumption, there is a deterioration of grain mass and a decrease in the nutritional value of grains and physiological quality of seeds, impairing or making their commercialization impossible (Caneppele et al., 2003; Scheepens et al., 2011; Asemu et al., 2020).

In this context, maize weevil (*Sitophilus zeamais* Motschulsky 1885 (Coleoptera: Curculionidae)) is the main pest insect of corn grains during storage (Ceruti and Lazzari, 2005; Astuti et al., 2019). Especially by its high potential to reproduce, the wide diversity of grains of plant species that it can consume, cross-infestation capacity (infests grains in the field and in warehouses) and the possibility of surviving at great depths in the grain masses.

Maize weevil control, in general, has been carried out with chemical insecticides, which, although over the years have provided an effective means of control (Chude et al., 2020), have been a constant focus of discussions, by the attention given to sustainable and low-cost technologies and that can be implemented, especially in family properties and agroecological and organic crops. This factor contributes to the importance of researches using insecticide plants as an alternative method for pest insects control, outstanding the use of essential oils. According to Peixoto et al. (2015), these oils have high complexity and synergistic and / or additive potential, generating high control efficiency, as well as rapid degradation, minimizing the environment contamination and the effects on non-target organisms.

Several studies have demonstrated the potential of natural compounds on the mortality and repellency of insects in stored grains, such as the toxicity of eucalyptus and citronella essential oils on *S. zeamais* (Ootani et al., 2011), extracts of *Mormodica charantia* and *Capsicum baccatum in* the control of *S. zeamais* (Almeida and Silva, 2013), essential oil of *Lippia alba in* the control of *S. zeamais* and *Tribolium castaneum* (Peixoto et al., 2015), with species of Lauraceae against *T. castaneum* and *Liposcelis bostrychophila* (Wang et al., 2019), *Moringa oleifera seed extract* on *S. zeamais* (Oliveira et al., 2020), citronella, moringa and goatweed oils on *Rhyzopertha dominica* (Sabbour, 2020), *Cymbopogon citratus* and *Cinnamonum camphora* essential oil in control of *Trogoderma granarium*, *Eucalyptus resinifera oil* against *Rhyzopertha dominica* (Filomeno et al., 2020), *Acorus calamus*, *Betula lenta*, *Cinnamomum cassia* and *Citrus aurantium* in mortality and eggposition of *Zabrotes subfasciatus* (Santana et al., 2021).

In this scenario, studies that enable the use of plants commonly present in the properties are relevant, among which stands out the exotic lemongrass (*C. citratus*) that produces essential oil, the main component of which is citral (Martinazzo et al., 2013), as well as native lemongrass (*Elionurus* sp.), of natural occurrence in the state of Rio Grande do Sul (Füller et al., 2015). This last one presents greater resistance to frost, being thus more indicated for the winter conditions of southern Brazil, however it is little researched and still little known. Therefore, the objective of the work was to value the insecticide and repellent effect of essential oils of exotic lemongrass (*C.-citratus*) and native lemongrass (*Elionurus* sp.) for the management of maize weevil (*S. zeamais*).

2. Material and Methods

For the bioactivity assessment tests, it was used the essential oil of exotic lemongrass and native lemongrass, obtained de plantas propagadas de mesmo biotipo. The plants pertencem a coleção cultivada in the experimental area of the Federal University of Fronteira Sul (UFFS), campus Chapecó.

The plants were grown in soil, in the open field with direct exposure to solar radiation. The cultivation plots were randomized in the area, being conducted in triplicate and with each one measuring 5 m^2. Five plants were harvested per plot, totaling 15 plants of each species to carry out the work.

2.1. Collection, extraction and identification of essential oil components

The plant material (leaves only) was collected in the early hours of the morning, after the evaporation of dew, and sent to drying in an oven with air flow at a temperature of 40 °C, until reaching constant weight. After drying, the plant material was used to extract the essential oil by hydrodistillation.

Essential oils were extracted by hydrodistillation using a Clevenger-type apparatus (Amaral et al., 2017). Hydrodistillation was carried out by three repetitions of 50 g leaves from each sample over 120 min. Essential oil samples were analyzed by gas chromatography using an Agilent GC-MS (7890B) coupled to a quadripolar mass spectrometer (5977A) (Agilent Technologies, Palo Alto, CA, USA). A Agilent19091S capillary column, dimension: 30 m × 250 µm × 0.25 µm was used with mobile phase flow (carrier gas: He) adjusted to 1.0 mL per min. The GC temperature program was 40 °C at 4.0 min, then up to 240 °C at a rate of 10 °C per min, then to 300 °C at a rate of 40 °C per min (maintained for 5 min). The injector temperature was 280 °C. Oil samples were diluted with ethyl ethanol to

10 mg mL^{-1}. One µL of sample volume was injected in a split ratio of 20:1. The MS transfer line temperature was set at 260 °C, and the ion source temperature was set at 230 °C. For GC–MS detection, an electron ionization system was used with ionization energy set at 70 eV and mass range m/z 40-300. The chemical components were detected and identified by comparison of the mass spectra using the NIST 5.01 Mass Spectral Library (Agilent P/N G1033A). The relative amounts of each individual component were calculated from their respective peaks in the chromatogram.

2.2. Insect breeding

The creation of the maize weevil was held at the entomology laboratory campus of Chapecó UFFS. The insects were raised in containers with a capacity of five liters, sealed with sheer fabric to prevent leakage and allow gas exchange with the external environment, and kept in a B.O.D. at 25 ± 2 ° C, RH of 60 ± 10% and photophase of 12 h, with broken corn grains as food.

To obtain the insects, aiming at carrying out the bioassays, 100 adult insects (removed from the aforementioned creation) were placed in glass jars containing 1 kg of broken corn kernels, remaining in the climatic chamber for 15 days, under the conditions previously described, and then removed only adult insects, keeping the eggs for hatching. This procedure was necessary because insects aged between 10 and 40 days after the hatching date were used for the bioassays.

2.3. Insecticide effect of essential oil

The experiments to evaluate the insecticidal effect were conducted according to a completely randomized design, independently for each essential oil, under a split-plot arrangement (6 doses × 7 times), with four replicates for each treatment. The observed values of mortality were adjusted as proposed by Abbott (1925) (Equation 1).

$$MC\left(\%\right) = \frac{\left(\%MO - \%Mt\right)}{\left(100 - \%Mt\right)} x100 \tag{1}$$

being: MC (%)= corrected death percentage; % MO = percentage of death in treatment; % Mt = percentage of death in control treatment.

To evaluate the insecticidal activity of essential oils, circular plates (Petri dishes with 7 cm in diameter) were used, having only broken corn grains as the food substrate. In the Petri dishes, one for each dose evaluated, 20 g of the food substrate (corn grains) were placed and, soon after, the essential oil was applied at doses of 0, 20, 40, 60, 80 and 100 µL, homogenizing immediately, which is equivalent to 0, 1, 2, 3, 4 and 5 L t^{-1} of grain. Soon afterwards, 20 adult insects (*S. zeamais*), not sexed, aged between 10 and 40 days, were placed in each plate, to test the insecticidal effect. The treatments were kept in a climatic chamber, under the same conditions described for the breeding. Observations of the insecticidal effect were made after 24, 48, 72 and 96 hours of application of the treatments, counting the number of dead insects per plate. The corn grains used in the treatments were a varietal of corn previously sterilized in an ultra freezer for 24 hours, at a temperature of -50 °C.

Due to the thanatosis presented by the insects, were considered dead those insects that did not show movement during three minutes of observation.

The data obtained were subjected to analysis of variance, by the F test ($p \leq 0.05$), with the aid of the R® software. When significant, they were submitted to regression analysis, using the SigmaPlot® 14.0 software. The mathematical models were selected based on the significance of the equation, by the F test ($p \leq 0.05$), the significance of the parameters of the equation by the "t" test ($p \leq 0.05$) and by the coefficient of determination (r2).

2.4. Repellent effect of essential oil

In experiments to evaluate the free choice of insects, a completely randomized experimental design was used, independently for each essential oil, under a 6 × 3 subdivided plot arrangement (dose of essential oil × time of exposure of insects to impregnated grains), with four repetitions.

To carry out the experiments, arenas were used, each formed by 6 circular plastic boxes with 14.0 cm in diameter and 3.0 cm in height, arranged radially and interconnected by plastic tubes to a central box. In the external containers, except in the central box, 20 g of corn kernels were deposited, previously impregnated with the following doses of essential oil: 0, 10, 20, 30, 50 and 100 µL, which are equivalent to 0.0; 0.5; 1.0; 1.5; 2.5 and 5.0 L t^{-1} of grains.

Samples of grains impregnated with essential oil, as well as the control treatment (without oil), were randomly distributed in the containers that are located radially to the central container. Shortly thereafter, 50 non-sexed adult insects, aged between 15 and 30 days, were released into the central container. After the application of the treatments, the arenas were kept in a climatic chamber, with a temperature of 25 ± 2 °C.

The evaluation of the experiment was carried out by counting the number of insects in the boxes at the beginning of the experiment (time zero), 24, 48 and 72 hours of the impregnation of the essential oil in the corn grains.

To evaluate treatments, a Preference Index (I.P.) was established, as proposed by Procópio et al. (2003), presented in Equation 2:

$$IP = \frac{\%IPTest - \%IPControl}{\%IPTest + \%IPControl} \tag{2}$$

being: IP= preference index; %IPTest= % of insects in the impregnated grain; %IPControl= % of insects in the control. Where I.P.: -1,00 a -0,10, repellent impregnated grain; I.P.: -0,10 a + 0,10, neutral plan-test; I.P.: +0,10 a + 1,00, attractive treated sample.

3. Results and Discussion

The main chemical compounds and their respective relative quantities, present in the essential oils of exotic lemongrass (*C. citratus*) and native lemongrass (*Elionurus* sp.), determined by gas chromatography, are shown in Table 1.

For *C. citratus*, eight components were identified, where the majorities were α-Citral and β-Citral, respectively with 41.04% and 35.89%, which corresponds to 76.89% of the total (Table 1). The other components, which presented small percentages, were β-Pinene; Linalol; cis-Verbenol; Geraniol; 3,7-Nonadien-2-one, 4,8-dimethyl.

For *Elionurus* sp. (Table 1), 14 components were identified, with β-Citral ; α-Citral; Trans-1-Isopropenyl-4-methyl-1,4-cyclohexanediol; 3,7-Nonadien-2-one, 4,8-dimethyl as majority, which corresponded to 85.74% of the total.

The results found, for the chromatographic analysis for exotic lemongrass, corroborate with the data obtained by Tajidin et al. (2012), where they describe Citral with the main component of lemongrass oil. Also, another study, which evaluated the chemical composition of lemongrass essential oil, grown in different regions of Vietnam, carried out by Trang et al. (2020), identified Citral as the most abundant component, with a presence between 61.2% to 76.46% in essential oil, depending on the region of production. Plata-Rueda et al. (2020) obtained neral and citral, respectively, as the main components of lemongrass essential oil. Likewise, Alves et al. (2019) found in the composition mainly the neral (34.1%) and geranial (46.83%), which are citral isomers.

In the evaluation of the chemical composition of *E. muticus*, identified by the GC-MS, Lazzarini et al.

Table 1. Chemical compounds and their respective relative quantities, present in the essential oils of exotic lemongrass (*Cymbopogon citratus*) and native lemongrass (*Elionurus* sp.).

Compound	% Area	
	C. citratus	***Elionurus* sp.**
β- Pinene	7.55	0.41
β-Ocimene	-	0.92
Linalol	1.91	2.73
cis-Verbenol	3.54	0.75
β-Citral	35.89	28.88
α-Citral	41.05	33.23
trans-1-Isopropenyl-4-methyl-1,4-cyclohexanediol	-	8.16
4,8-dimethyl-4,8-Dimethyl-nona-3,8-dien-2-one	2.97	15.47
γ-Elemene	-	1.37
Geraniol	3.73	
Geranyl butyrate	-	0.86
Spathulenol	-	2.9
Ledol	-	0.44
TOTAL	96.63	96.12

(2018) observed that the essential oil was mainly composed of monoterpenes (approximately 90%) and sesquiterpenes (2.05%), with citral as the main constituent (neral + geranial = 72.35%). Even though in the present study four major components were observed, two of these were the same as in the aforementioned work, demonstrating that the citral is among the major components of this plant.

ANOVA showed a highly significant effect between the dose of essential oil and the time of exposure of insects ($p < 0.0001$), for both essential oils (*C. citratus* and *Elionurus* sp.). The increase in the dose and time of exposure of insects to essential oils provided an increase in mortality (Figures 1A and B). In the first hours of exposure the mortality rate was more pronounced when the highest doses (5 and 2.5 L t-1 of grains) were applied, while for the lowest doses of essential oil (0.5 and 1, 0 L t-1 of grains) the highest mortality rate occurred in the intermediate period, while for the intermediate dose (1.5 L t-1 of grains) the mortality rate showed a similar behavior until the final period exposure of insects to essential oils.

In the application of the essential oil of *C. citratus*, the LD50 was reached after 6,86; 19.12; 33.27; 48.52 and 56.03 hours of exposure, respectively, for doses of 5.0; 2.5; 1.5; 1.0; 0.5 L t-1 of grains. For the essential oil of *Elionurus* sp. The results were similar, with the LD50 being reached after 7,24; 18.74; 33.14; 48.68 and 53.72 hours of exposure, respectively, for doses of 5.0; 2.5; 1.5; 1.0; 0.5 L t-1 of grains.

Both essential oils (lemon grass native and exotic), have a high mortality maize weevil, responding positively to the increase in the applied dose and exposure time. The increase in mortality due to the increase in dose and exposure time was observed by other authors (Mishra et al., 2012; Jumbo et al., 2014; Bett et al., 2016; Bounoua-Fraoucene et al., 2019; Lazzaretti et al., 2020). Except for the lowest dose evaluated (0.5 L t-1 grains), the mortality rate was higher than 90% after 96 hours of exposure of the insects.

It is believed that this similarity in the mortality rate is due to the presence of two major compounds common in both essential oils, that is, α-Citral and β-Citral. According to Oyedeji et al. (2020), when evaluating the effect of fumigation and contact of the essential oil of *Citrus sinensis* and its isolated components, found that the compounds exhibit strong toxicity against the adult insect of *Callosobrunchus maculatus* and *S. zeamais*, inferring that the insect mortality increases with the concentrations of *C. sinensis* or its isolated components. However, among the tested compounds, they found that citral was the most toxic when used in fumigation for *C. maculatus* and *S. zeamais*, with LC50 of 0.19 and 2.02 $\mu L\ L^{-1}$ of air, respectively, after 24 hours exposure. They also found that this component had a strong contact effect, with LC50 of 31.79 and 39.36 µg adult^{-1}, respectively, for *C. maculatus* and *S. zeamais*. The authors observed that acetylcholinesterase activity in both adult insects was significantly directly inhibited by increasing the dose. Among the essential

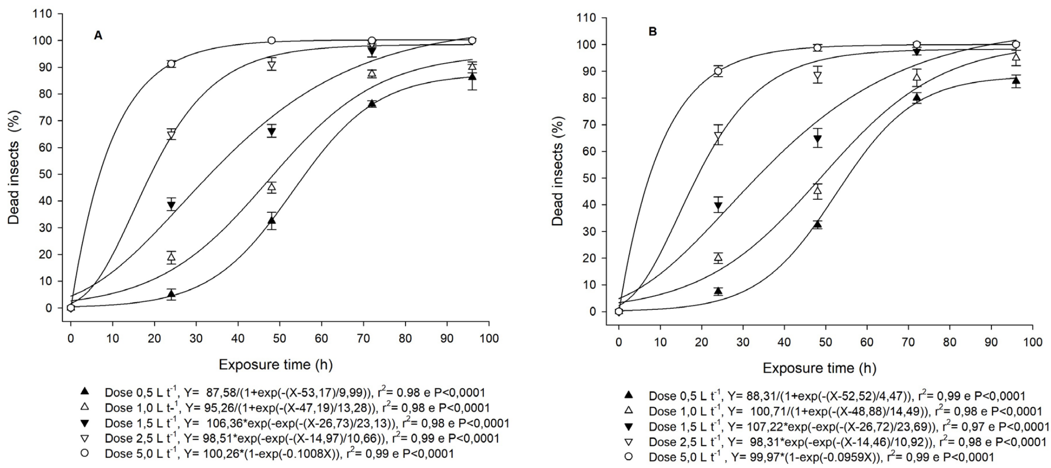

Figure 1. Mortality of *Zeamais Sitophilus* in function of the essential oil doses of exotic lemongrass (*Cymbopogon citratus*) (A) and native lemongrass (*Elionurus* sp.) (B) and different exposure time, 2019. Vertical bars indicate the standard deviation.

oil components, limonene, L-carvone and citral were the most important inhibitors.

To assess the effects of lemongrass essential oil and two of its components on *Ulomoides dermestoides* (beetle in the family Tenebrionidae), Plata-Rueda et al. (2020) carried out a toxicity bioassay, which indicated that the LD50 of the essential oil was 5.17 µg insect^{-1} and the citral component, the most toxic, with LD50 of 4.17 µg insect^{-1}. Insect survival was influenced by the interaction between essential oil (dose and time of exposure) and its components, with possible effects on the nervous system, as evidenced by its rapid lethal action on insects, indicated as a potential product for the control of storage insects. The respiration rate was also reduced, both by essential oil and citral. The authors attribute the potential of essential oil and its terpenoid components to the synergism between the compounds and their ability to penetrate the insect's body or its respiratory system.

According to Plata-Rueda et al. (2020), the lemongrass essential oil, which presents citral and geranyl acetate as the main constituents, induced the mortality of *Ulomoides dermestoides* between 24 and 48 h after exposure. Insect survival was influenced by the interaction between essential oil and its components, with possible effects on the nervous system, as evidenced by its rapid lethal action on insects. Thus, both the essential oil of exotic and native lemongrass have the potential to control *S. zeamais* in stored grains, mainly for use in family farming with organic production, as this product can be an important alternative to control these pests.

Regarding the repellent capacity of essential oils of native and exotic lemon grass (Table 2), both species showed repellency in all doses and evaluated times.

According to Bekele et al. (1997) the repellent action increases the potential value of bioactive plants in protecting grains from attack by insect pests of stored products, and the responses of each species to the toxic and repellent effects are different and this may reflect the complexity of the chemical composition of these products.

The repellent effect of essential oils is already reported in several works. Jayakumar et al. (2017) verified the repellent activity of several vegetable oils against the adults of *Sitophilus oryzae*, using concentrations of 10 and 50 µL with exposure time varying between 0.5 and 6 h, concluding that the repellency increased with increasing concentration and exposure time, suggesting that vegetable oils may be useful for the management of coleopteran insects in stored grains, especially *S. oryzae*. In their investigations, Hernandez-Lambraño et al. (2015), Kłyś et al. (2017), Chen et al. (2018), Aref and Valizadegan (2015) and Wang et al. (2020) also report the repellent effect of essential oils on stored grain insects.

Regarding the repellency of exotic lemongrass essential oil for insects, some studies have already reported this effect, such as Plata-Rueda et al. (2020), where it affected the behavior of *Ulomoide dermestoides*, Olivero-Verbel et al. (2010) against *Tribolium castaneum*, Kimutai et al. (2017) against *Phlebotomus duboscqi*. For *Elyonurus* sp. studies are scarce, where only the work of Kłyś et al. (2017), who reported that there is a repellent effect of this essential oil.

The odor produced from volatile compounds of lemon grass, both exotic and native, can be repulsive to insects, since volatile substances enter with air and insects inhale through their spiracles (Plata-Rueda et al., 2020; Martínez et al., 2018). The essential oil of lemongrass and its terpenoids also affect the behavioral response of *U. dermestoides*, with changes in displacement patterns, the result of toxic effects on the nervous system, which can stimulate or reduce the mobility of insects.

The repellent activity is attributed to the presence of monoterpenes and sesquiterpenes, which cause the death of insects by inhibiting AChE activity in the nervous system (Houghton et al., 2006).

Table 2. Preference indexes (IP) for *Sitophilus zeamais* depending on the dosage of essential oil of exotic lemongrass (*Cymbopogon citratus*) and native lemongrass (*Elionurus* sp.) at different times of exposure.

Time (h)	Dose (L t⁻¹)	IP (Preference Index)*			
		Cymbopogon citratus		*Elionurus* sp.	
		Mean	SD	Mean	SD
24	0.5	-0.67	0.08	-0.76	0.09
	1.0	-0.75	0.06	-0.78	0.04
	1.5	-0.75	0.04	-0.80	0.03
	2.5	-0.90	0.07	-0.58	0.05
	5.0	-0.95	0.05	-0.67	0.05
48	0.5	-0.66	0.05	-0.54	0.04
	1.0	-0.75	0.06	-0.67	0.07
	1.5	-0.75	0.06	-0.71	0.05
	2.5	-0.82	0.06	-0.36	0.08
	5.0	-0.94	0.07	-0.30	0.04
72	0.5	-0.50	0.07	-0.66	0.08
	1.0	-0.53	0.09	-0.80	0.03
	1.5	-0.57	0.06	-0.72	0.12
	2.5	-0.60	0.13	-0.42	0.07
	5.0	-0.82	0.11	-0.33	0.03
96	0.5	-0.66	0.10	-0.64	0.09
	1.0	-0.62	0.09	-0.81	0.14
	1.5	-0.44	0.09	-0.83	0.05
	2.5	-0.45	0.11	-0.40	0.12
	5.0	-0.82	0.17	-0.37	0.05

* $IP = \frac{\%IPTest - \%IPControl}{\%IPTest + \%IPControl}$ Scale -1 to +1.

4. Conclusion

The major components found in the essential oils of *C. citratus* and *Elyonurus* sp., in general, showed similarity, being α-Citral and β-Citral. The essential oils of native and exotic lemon grass have efficiency on maize weevil mortality, and it is verified that the increase in the applied dose reflects in a reduction in the insect's exposure time for death to occur. Regarding the repellent capacity of essential oils of native and exotic lemon grass, it can be seen that in general both species showed repellency at all times evaluated. Thus, it can be said that both species have the capacity and potential to be used in the management of corn weevil, which can be an alternative for smallhorders farmers and organic production.

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