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Plant Extracts for the Control of *Sitophilus zeamais* (Motschulsky, 1895) (Coleoptera: Curculionidae)

Juliana NAZARÉ ALVES SOUZA[1,2,a] Marcos ROBERTO POTENZA[2,b] (in memoriam)
Márcio MARTINS DE ARAUJO[1,c*] Jamile ICASSATTI SAUD ROMANO[1,d]
Valter ARTHUR[3,1,e]

[1]Institute of Energy and Nuclear Research (IPEN), Department of Radiation Technology Center, University of São Paulo, Av. Professor Lineu Prestes, 2242, 05508-000, São Paulo, SP, BRAZIL
[2]Biological Institute of São Paulo, Center of Research and Development of Plant Health, Av. Conselheiro Rodrigues Alves,1252, 04014-002, São Paulo, SP, BRAZIL
[3]Center for Nuclear Energy in Agriculture (CENA/USP), Department of Radiobiology and Environment, University of São Paulo, Av. Centenário, 303, 13416-000, Piracicaba, SP. BRAZIL
e-mails: [a]julianaalvesbiologia@gmail.com, [c*]marcio_araujo @usp.br, [d]jisaud@usp.br, [e]arthur@cena.usp.br
ORCID IDs: [a]0000-0002-9265-1083,[b]0000-0002-5836-3774, [c]0000-0002-6367-6126, [d]0000-0001-8075-2023, [e]0000-0003-3521-9136
*Corresponding Author

ABSTRACT

Brazil is one of the largest grain producers in the world, but its productive potential is threatened by the presence of stored product pests that compromise quality and quantity. The use of synthetic insecticides and selective pressure make many of these pests increasingly resistant to control. Concern for health and the environment requires the development of less toxic and persistent products for the management of these undesirable organisms. The insecticide activity of aqueous extracts of 15 vegetal species was evaluated to control grain beetles, *Sitophilus zeamais* Motschulsky in maize stored. The adult insects came from the laboratory at Biological Institute of São Paulo. They were fed with sterilized grains of maize and kept in a room at 25±2°C and 70±% of relative humidity. The plants for the aqueous extracts were crushed in distilled water and the vegetal mass was filtered next. The liquid resulting from the filtering process was stored in plastic containers and frozen for later use. Two tests were conducted: impregnation of filter paper and treatment of grains. Ten insects were evaluated in each batch. Only the aqueous extract of *Dahlia pinnata* Cavanilles was satisfactory in controlling *S. zeamais* showing an efficiency of 10.00% in the contact test and an efficiency of 56% in the treated corn kernels.

Keywords: aqueos extracts, biological control, insecticide, maize.

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INTRODUCTION

Corn is one of the three most cultivated cereals in the world, of which Brazil is the third producer and second world exporter (Coêlho, 2021). However, a reasonable portion is retained in the rural areas where it is used for food and another part is lost by the action of insects and rodents. It is estimated that losses reach 30 to 40% of yields due to problems with drying, storage, transport and pests (Garcia, Ferreira, Biagginon, & Almeida, 2000). According to Manandhar, Milind, & Shah (2018) the quantitative loss is 15% in the field, 13 to 20% during processing and 15 to 25% during storage.

Insect control methods in stored grains can be divided into: physical (artificial cooling, temperature, radiation, humidity, modified atmosphere or diatomaceous earth), biological (natural enemies) and chemical (insecticides). In Brazil, the most used method is fumigation with aluminium and magnesium phosphide, in addition to the use of protective insecticides such as pyrethroids and organophosphates (Silva, Silva, Souza, Lima, & Santos, 2020).

For these reasons, new management strategies are needed in order to meet the growing demand for food, not just produce more and better, but also provide a means for the preservation of crops, avoiding or mitigating the damage caused by pests during storage. Grain purge, a phytosanitary measure used to eliminate pests in seeds and stored grains using gas (Lorini, Kryzanowski, França-Neto, Henning, & Henning, 2015). Although it offers satisfactory coverage, there is a tendency that new treatment alternatives are necessary, due to the identification of phosphine-resistant populations of *Sitophilus zeamais* Motschulsky (Pimentel, Faroni, Guedes, Souza, & Tótola, 2009).

Considering the physiological and biochemical aspects, the main mechanisms involved in insect resistance to control chemical products are: the reduction of insecticide penetration through the insect cuticle; the detoxification or metabolization of the insecticide by enzymes and the reduction of sensitivity at the site of action of the insecticide in the nervous system (Hemingway, 2000).

Phosphine resistance in stored grain insects occurs due to lack of proper operation, which mainly includes insufficient exposure time and temperature (Athanassiou, Rumbos, Sakka, & Sotiroudas, 2016). Normally, eggs and pupae are more tolerant to phosphine than adults and larvae, due to their metabolic activity, which can be influenced by low temperatures, postponing the time of exposure to total insect mortality (Wang, Hou, Huang, & Lyu, 2020). Pimentel et al (2009) when studying 22 Brazilian populations of *Sitophilus zeamais*, observed that populations with lower respiratory rates showed higher levels of phosphine resistance, suggesting that the lower respiratory rate is associated with the physiological basis of phosphine resistance due to reduced absorption of fumigants. Phosphine resistance was also recorded and quantified in Greece by Agrafioti, Athanassiou, & Nayak (2019), who, when analyzing 53 populations from different regions belonging to the species *Rhyzopertha dominica*, *Sitophilus oryzae*, *Sitophilus granarius*, *Cryptolestes ferrugineus*, *Tribolium confusum*, *Tribolium castaneum* and *Oryzaephilus surinamensis*, observed a resistance frequency of 81%.

Since 2008, Brazil has been the largest consumer of pesticides in the world (Rigotto, Vasconcelos, & Rocha, 2014). According to the Notifiable Diseases Information System (Sinan), which collects data generated by the National Epidemiological Surveillance System (SNVE), between 2007 and 2017, 41.6 million cases of intoxication by pesticides for agricultural use occurred, on an increasing scale, considering all cases, 88% refer to acute poisoning and 42% were due to occupational exposure (Valadares, Alves, & Galiza, 2020). These impacts are associated with our current development model, which primarily focused on the production of primary goods for export (Carneiro, Rigotto, Augusto, Friedrich, & Búrigo, 2015). In 2015, Brazil sprayed approximately 899 million liters of pesticides, with soy, corn, and sugar cane accounting for 82% of the entire volume used in the country (Pignati et al, 2017). The use of chemical products guarantees protection to the means of production, but with the consumption of approximately 1 million tons per year it causes damage to man and the environment, such as diseases to human health and destruction of soils and rivers (Demartelaere et al, 2021).

Vendramim & Castiglioni (2000) reported that the use of toxic compounds of vegetable origin is not a recent technique since their use in pest control was common in tropical countries before the advent of synthetic insecticides. The use of insecticidal plants stands out among the alternative methods to conventional chemical control, due to its safety and preservation of the balance of agro ecosystems. Moreover, the flora is very rich in plant species that contain chemicals with insecticidal activity (Ferracini et al, 1990). Tropical plants constitute a reservoir of substances that are originally employed in the defense of the plants themselves against herbivores that serve them. Research on plants with insecticidal activity are quite frequent in the literature, but are very scarce in Brazil (Vilela, 1990).

Jacobson (1958, 1975) conducted two literature reviews on the plant species whose extracts showed insecticidal action on insects (*Annona spp*, *Berberis thunbergii*, *Cordia* spp, *Anthemis* spp, and other *Ocimum* spp.). Craveiro et al, (1981) reported several plants of northeastern Brazil with insecticidal properties (*Lippia* sp., *Croton compressus* Lamarck, *Anacardium occidentale* Linnaeus, *Eucalyptus alba* Von Blume, *Eugenia jambolana* Lamarck). Guerra (1985) reported that 974 plants with insecticidal properties were identified (*Calendula officinalis* Linnaeus, *Allamanda nobilis* T. Moore, *Anona squamosa* Linnaeus, *Anthemis* spp., *Capsicum annuum* Linnaeus, *Croton* spp. and others). Aguiar, Monteiro, & Calafiori (1994) evaluated the black pepper (*Piper nigrum* L.), soybean oil and garlic against *Sitophilus zeamais* in stored rice, and concluded that soybean oil had higher efficiency, with 96-100% on pest control, followed by black pepper, but with low efficiency from 14 days after treatment.

Rajapakse & Van-Emden (1997) evaluated the possibility of using powder Botanical *Vigna unguiculate* (Linnaeus) Walpers, *Vigna radiata* (Linnaeus) Wilczek, *Vigna angularis* (Willdenow) Ohwi & Ohashi, *Cymbopogon citratus* Stapf, *Ciannamomum camphora* Linnaeus, *Monodora myristica* (Gartner) Dunal, *Zingiber spectabile* Griffith and vegetable oils *Helianthus annuus* Linnaeus, *Sesamum indicum* Linnaeus, *Zea mays* Linnaeus and *Arachis hypogaea* Linnaeus in control of *Callosobruchus chinesis*

Linnaeus, *C. maculatus* Fabricius and *C. rhodesianus* Pic and observed that all vegetable oils tested significantly reduced oviposition of three species and also reduced the longevity of adults of *C. maculatus* and *C. chinensis*. Only oils *Z. mays* and *H. annuus* caused a significant reduction in the longevity of *C. rhodesianus* at 10 ml/kg. The number of eggs laid by three pest species tested was significantly reduced in treated powder Botanical *C. citratus, C. camphora, M. myristica, Z. spectabile.*

Park, Kim, & Ahn (2003) evaluated the insecticidal activity of *Acorus gramineus* Aiton (derived from a rhizome with phenylpropenes and asarones) against adults of *Sitophilus oryzae* Linnaeus*, C. chinensis* and *Lasioderma serricorne* Fabricius being examined using direct contact application and fumigation method, and verified in the test of the filter paper a mortality of 70% and 90% in adults of *S. oryzae* respectively at 4 days after treatment and 100% mortality after 7 days from the treatment. Against adults of *C. chinensis*, phenylpropenes and asarones caused 100% mortality at 3 and 7 days after treatment, respectively. Against adult *L. serricorne*, had 90% and 83% mortality after 7 days, respectively, after treatment, also indicating that the toxicity can be qualified against the adults of the three tested species.

This study evaluates the effect of some insecticidal plant extracts, seeking alternative products to conventional chemical control, which do not degrade the environment or harm human health, in addition to providing a lower final cost to the farmer.

MATERIAL AND METHODS

The study was carried out on the premises of Arthropod Protection and Plant Clinic laboratories at the Biological Institute of São Paulo. The adults of *S. zeamais* used in this study were obtained from breeding, kept in glass containers with approximately 23 cm high x 11 cm in diameter, with corn (grain) previously placed in an oven for disposal of unwanted infestations. The containers were covered with fine mesh fabric, secured by elastic bands. The insects were maintained in a room with temperature of 25±2°C and relative humidity of 70±5% (Fig. 1). We opted for the use of the corn itself in the rearing of *S. zeamais* due to the fact that there are changes in the susceptibility of insects to a certain toxic product when changing the food substrate, according the work of Teotia & Prasad (1974).

Figure 1. Creation of *Sitophilus zeamais* do Biological Institute of São Paulo.

To obtain the aqueous extracts, the method adopted by Robert (1976) was used. The fresh parts of the adult plant (150 g) (Table 1 and Table 2) were collected at the Botanical Institute and Biological Institute of São Paulo and crushed with 450 ml of distilled water, separating the plant mass with a strainer and obtaining the aqueous extract. This was stored in plastic vials and frozen for approximately 24 hours for use in assays.

Table 1. List of plants used in Experiment 1 and 3: botanical species, family, and the popular name used.

Species botanical	Family	Part used
Mirabilis jalapa Linnaeus	Nyctaginaceae	Leaves
Ricinus communis Linnaeus	Euphorbiaceae	Leaves
Euphorbia pulcherrima Willdenow ex Klotzch	Euphorbiaceae	Leaves
Pilea microphylla Linnaeus	Urticaceae	Leaves
Pteridium aquilinum (Linnaeus) Kuhn	Dennstaedtiaceae	Leaves
Sansevieria trifasciata Prain	Asparagaceae	Leaves
Dahlia pinnata Cavanilles	Asteraceae	Leaves

Control (water)

Table 2. List of plants used in Experiments 2 and 4: botanical species, family, and the popular name used.

Species botanical	Family	Part used
Codiaeum variegatum Linnaeus	Euphorbiaceae	Leaves
Agave sp.	Amaryllidaceae	Leaves
Ruta graveolens Linnaeus	Rutaceae	Leaves
Malvaviscus arboreus Cavanilles	Malvaceae	Leaves
Santolina chamaecyparissus Linnaeus	Asteraceae	Leaves
Impatiens walleriana Hooker	Balsaminaceae	Leaves
Dieffenbachia brasiliensis Veitch	Araceae	Leaves
Allamanda cathartica Linnaeus	Apocynaceae	Leaves

Control (water)

The methodology used in the execution of the experiments was adapted by Takematsu (1983). Initially, two types of tests were carried out: impregnation technique, filter paper / contact contamination and grain treatment (Fig. 2). For the impregnations of filter paper, papers with a diameter of 9 cm treated with plant extracts were used. Each paper received 1 ml of the extracts that were applied with an automatic pipette to 50 g of corn. To prevent loss of products through contact, the paper disks were supported on the ends of the pins 3, resting on a small stopper, thus reducing to a minimum the contact of the treated paper with a given surface.

Figure 2. a) Natural aqueous extracts used in research, b) impregnation of filter paper in petri dishes, c) contamination by ingestion, application of the extract.

After drying, the paper disks thus treated were transferred to plastic Petri dishes measuring 9.0 cm in diameter by 1.0 cm and left to rest for 24 hours. To contain the insects, bringing them into direct contact with the surfaces treated with insecticides, glass rings with a diameter of 4.5 cm x 2.5 cm were used, previously treated with pure talc, which prevents weevils from climbing the walls of the rings. To prevent escapes through flight, the rings were covered with a thin transparent mesh fabric and held together with elastic band.

To test the treatment of grains, 50 g of corn were placed in each glass of approximately 14 cm height x 7 cm in diameter with 10 insects, and 1 ml of extract was applied with an automatic pipette, closing the glass with a screen. In all, fifteen plant species were evaluated in each test. Each repeat was composed of 10 adult insects.

To assess the physiological criterion, insect mortality evaluations at 24 hours and 15 days after treatment were adopted, counting the number of dead insects. Mortality was checked using a heat source provided by a 100-watt lamp approximately 10 cm from the insects, for a few seconds, as the weevil (*S. zeamais*) has the habit of remaining motionless when disturbed (Takematsu, 1983). The efficiency of control (EC, %) was obtained using the equation of Abbott (1925):

$$EC=\frac{T-Tr}{T}x100$$

where: T - number of live insects in the control; and Tr - number of live insects in the treatment.

The statistical design used was completely randomized, and each treatment had 4 replications. For the purposes of statistical analysis, the data were transformed into (square root + 0.5), comparing the means using the F test and Tukey at 5% significance.

RESULTS

Contact test (Technical impregnating filter paper): In Experiment 1 (Table 3) only the extract of *E. pulcherrima* did not differ statistically from the control, and satisfactory control was not obtained with the treatments. In the second experiment, the best result was obtained with the extract of *Agave* sp., showing 20.00% efficiency (Table 4). Extracts of *I. walleriana* and *A. cathartica* did not differ statistically from the control, and satisfactory control was not obtained with the treatments.

In Experiment 3, using grain treatment, the best results were obtained with the extracts of *D. pinnata, S. trifasciata* and *R. communis*, with efficiency of 56.00%, 25.00% and 20.00%, respectively (Table 5). Extracts of *P. microphylla* and *M. jalapa* did not differ statistically from the control.

In Experiment 4, the best results were obtained with the extracts of *R. graveolens, M. arboreus* and *Agave* sp., showing efficiency of 27.50%, 22.50% and 20.00%, respectively (Table 6). Extracts of *S. chamaecyparissus, D. brasiliensis* and *A. cathartica* did not differ statistically from the control.

Table 3. Experiment 1. Evaluation of the efficacy of plant extracts in the control of *S. zeamais* by the filter paper impregnation method. Number of dead adult beetles (n.) per plot (original mean) and percentage efficiency (% Efic) of some plant extracts.

Plants	**nº**	**% Efic.***
Mirabilis jalapa	2.75a	27.50
Pteridium aquilinum	1.20b	12.00
Ricinus communis	1.20b	12.00
Sansevieria trifasciata	1.00bc	10.00
Dahlia pinnata	1.00bc	10.00
Pilea microphylla	0.50c	5.00
Euphorbia pulcherrima	0.00d	-
Control (water)	0.00d	-
C.V. (%)	13.15	

*Calculated by the formula of Abbott (1925).

Means followed by the same letter do not differ by Tukey test at 5% probability.

Table 4. Experiment 2. Evaluation of the efficacy of plant extracts in the control of *S. zeamais* by the filter paper impregnation method. Number of dead adults (n.) per plot (original mean) and percentage efficiency (% Efic.) of some plant extracts.

Plants	**nº**	**% Efic.***
Agave sp.	2.00a	20.00
Malvaviscus arboreus	1.50ab	15.00
Dieffenbachia brasiliensis	1.25ab	12.00
Ruta graveolens	1.00 bc	10.00
Santolina chamaecyparissus	1.00 bc	10.00
Codiaem variegatum	0.50cd	5.00
Impatiens walleriana	0.00d	-
Allamanda cathartica	0.00d	-
Control (water)	0.00d	-
C.V. (%)	12.03	

*Calculated by the formula of Abbott (1925).

Means followed by the same letter do not differ by Tukey test at 5% probability

Table 5. Experiment 3. Evaluation of the efficacy of plant extracts in the treatment of grain for *S. zeamais*. Number of dead adult beetles (n.) per plot (original mean) and percentage efficiency (% Efic.) of some plant extracts.

Plants	**nº**	**% Efic.***
Dahlia pinnata	5.60a	56.00
Sansevieria trifasciata	2.50b	25.00
Ricinus communis	2.00bc	20.00
Euphorbia pulcherrima	1.00cd	10.00
Pteridium aquilinum	0.75de	7.50
Pilea microphylla	0.50de	5.00
Mirabilis jalapa	0.50de	500
Control (water)	0.00e	-
C.V. (%)	14.16	

*Calculated by the formula of Abbott (1925).

Means followed by the same letter do not differ by Tukey test at 5% probability.

Table 6. Experiment 4. Evaluation of the efficacy of plant extracts in the treatment of grain for *S. zeamais.* Number of dead adults (n.) per plot (original mean) and percentage efficiency (% Efic.) of some plant extracts.

Plants	**nº**	**% Efic.***
Ruta graveolens	2.75a	27.50
Malvaviscus arboreus	2.25ab	22.50
Agave sp.	2.00ab	20.00
Codiaeum variegatum	1.50abc	15.00
Impatiens walleriana	1.00bcd	10.00
Santolina chamaecyparissus	0.75cde	7.50
Dieffenbachia brasiliensis	0.50de	5.00
Allamanda cathartica	0.25de	2.50
Control (water)	0.00e	-
C.V. (%)	14.40	

*Calculated by the formula of Abbott (1925).

Means followed by the same letter do not differ by Tukey test at 5% probability.

DISCUSSION

Plant extracts have substances in their composition that show different effects, including ovicide, repellent, phage-inhibitor, anti-nutritional and entomotoxic effects, which are generated through strategies either by contact, ingestion or by fumigant action. It is known that plants produce a wide variety of primary (protease and lectin inhibitors) and secondary (terpenes, phenolic compounds, and nitrogen-containing components) metabolites that often have no determined or relevant role in the physiological or biochemical processes of the plant, but which are increasingly cited as important mediators of interactions between plants and other organisms (Cespedes et al, 2013; Borges et al, 2019).

Diniz, Astarita, & Santarém (2007) report that depending on the temperature and drying process used to obtain plant extracts, there may be changes in the concentrations of their metabolites, as when evaluating samples of the herbal medicine Hypericum perforatum they found a decrease in the amount of flavonoids, glycosylates and hypericin a -20°C temperature. Demirgül, Divriklioğlu-Kundaki, & Sağdıç (2022), when comparing the secondary metabolites synthesized from fresh and dried plants of *Polygonum cognatum* Meissn with frozen ones (-30ºC) for a period of 6 months, observed that there was a significant decrease in the total phenolic compounds over the period of storage. This fact demonstrates that each plant species must have a standardized extraction method, in order to obtain maximum results.

With regard to secondary metabolites, Lima et al (2020) observed that the presence of tannins, saponins and phenolic compounds in the trunk bark extract of *Genipa americana* L. was able to inhibit the feeding of *Tribolium castaneum* adults, and its extract caused mortality of 73% of the insects and induced a decrease in the hatching rate (40–96%) of larvae.

Among the researches using plants with insecticidal action, we can mention the work of Procópio, Vendramim, Ribeiro Júnior, & Santos (2003), where they evaluated the insecticidal effect of powders of *Azadirachta indica* A. Jussieu, *Capsicum frutescens* Linnaeus, *Chenopodium ambrosioides* Linnaeus, *Eucalyptus citriodora* Hooker, *Melia azedarach* Linnaeus and *R. communis* on the maize weevil (*S. zeamais*) and found that *E. citriodora* had a repellent effect while the dust of *C. ambrosioides* affected the weevil survival causing mortality without any emergence of adults.

The efficiency of *Agave* sp. is presented in research by Potenza, Takematsu, Sivieri, Sato, & Passerotti (1999) carried out experiments with various plant extracts and obtained satisfactory control of *T. urticae* with extracts from *Annona* sp., *Agave* sp., *R. graveolens* and *D. brasiliensis*, with efficiency greater than 80%. Other plants showed acaricidal activity such as *Melia azedarach*, *S. oleraceus*, *Nicotiana tabacum*, *Hevea brasiliensis*, *Spondias* sp., *P. purpureum*, *C. variegatum* and *I. walleriana*, with efficacy between 51.3 and 77.3%.

Schiavon et al (2015) performed a systematic review showing that the Asteraceae family, of *D. pinnata* popularly known for its antibacterial, antifungal, larvicidal, insecticide, antiparasitic, nematicidal, antihyperglycemic, antitumor, biocidal and antioxidant activity. As well as Soberón & Francisco (2020) evaluated the anti-inflammatory effect of the methanolic extract of *D. pinnata* leaves in rats and as a result the methanolic extract of *D. pinnata* showed an anti-inflammatory effect in rats, data confirmed by Test Duncan, DMS, compared with the control group ($p<0.05$), where in thin layer chromatography, the FR of the standard was: 0.80, methanolic extract 0.79. What broadens the understanding of the tests carried out in experiment 3 presented efficiency of 56.00%, with the extracts of *D. pinnata*.

The extracts with *Sansevieira trifasciata* were also evaluated by Corassa, Machiner, Valladao, Andrighetti, & Weberling (2022) who tested the insecticidal potential of the leaves of the plants *Chrysanthemum morifolium* (Asterales: Asteraceae), *Dieffenbachia picta* (Alismatales: Araceae), *S. trifasciata* (Asparagales: Asparagaceae) and *Tagetes erecta* (Asterales : Asteraceae) on the mortality of *Spodoptera frugiperda* caterpillars and concluded that despite the low mortality with the extracts, the plants *C. morifolium* and *S. trifasciata* showed higher mortality than the others.

The extracts of *R. communis* were also investigated by Behling (2011) who evaluated the repellent activity of plant extracts from weeds on adults of *Sitophilus* spp. in rice seeds, under laboratory conditions. The experiment consisted of two tests to evaluate the effect of aqueous extracts at 10% w/v of leaves and branches of Macaé Herb (*Leonurus sibiricus* L.), Picão Preto (*Bidens pilosa* L.), Maria Mole (*Senecio brasiliensis* Less.) and Castor bean fruits (*Ricinus communis* L.). Both in the first test and in the second test, the black beggartick extract showed the best insect repellency results. Therefore, from the results presented in the two tests, it was verified that in the laboratory the extract of Picão Preto presented better repellent activity to *Sitophilus* spp. Extracts from *L. sibiricus* and *R. communis* also showed promise as natural repellents against weevil in rice.

Ruta graveolens extracts were also tested by Potenza, Junior, & Alves (2006), who analyzed the essential oil of *R. graveolens* leaves by hydrodistillation to assess its repellent and toxic activities against the rice weevil, *Sitophilus oryzae*, and the study revealed that the essential oil present in the leaves of *R. graveolens* has very high potential as a repellent, contact toxicant and a potent fumigant in the control of *S. oryzae* in pest management programs.

Malvaviscus arboreus Cavanilles were also researched by Da Costa Rocha, Bonnlaender, Sievers, Pischel, & Heinrich (2014) who shows the expansion in research with hibiscus extracts, *M. arboreus*, due to its performance against microorganisms, studies show the existence of metabolites of high pharmacological interest, mainly alkaloids and flavonoids, which can be responsible for the pharmacological action attributed to the hibiscus plant. The two compounds detected, 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one and DL-Proline-5-oxomethyl ester, potential antimutagenic, antitumor and anticancer agents, make *M. arboreus* a promising species for the manufacture of new drugs because it has cytotoxic activity (it can be used as an insecticide, analgesic and anti-tumor among others.

Almeida, Da Silva, De Melo, Gomes, & Da Silva, (2013) used a hydroalcoholic extract of the fruits of chili pepper (*Capsicum baccatum* Linnaeus) with concentration of 70% was observed a mortality of 100% of *S. zeamais* at a dose of 6 mL in 48 h, and the dust of the pepper resulted in a 94% repellency of this insect. According to Gullan & Cranston (2014), repellency is a reaction of the insect's sensory system when exposed to undesirable substances. Insects have chemoreceptors located in different parts of the body and are responsible for assessing the conditions of the environment where the insect is, fleeing if conditions are not favorable.

Regarding essential oils, Ko, Juntarajumnong, & Chandrapatya, (2009) evaluated their potential use of *Melaleuca cajuputi* Powell leaves, in the repellency and control of *S. zeamais* through fumigation and contact, and found repellency in treated grains exposed for 2 and 3 hours at a concentration of 0.47 $\mu g\ cm^{-2}$, repelling 80 and 90% of insects respectively. Through fumigation, the LD95 was 408.54 $\mu L\ L^{-1}$ and upon contact with the LD95 was 0.111 μL insect^{-1}. The chromatographic analysis showed a higher amount of terpineolene (29.77%) and γ–terpinene (25.25%). However, Jairoce et al (2016) used clove essential oil (Syzygium aromaticum (Linnaeus) Merril & Perry) to control *S. zeamais* and *Acanthoscelides obtectus* Say under laboratory conditions and observed that at concentrations of 17.9 and 35 $\mu L\ g^{-1}$ there was 100% mortality for both species 48 hours after treatment, and the main compound found was eugenol (62.72%).

The various substances from plants demonstrate the importance of analyzing the phytochemical characteristics and taxonomically and chemically identifying their compounds for human use and benefit (Ortiz-Rojas & Chaves-Bedoya, 2017).

In the present study, the extract that presented the highest efficiency in the treatment of grains was that of *D. pinnata* with 56.00%, Wang et al (2015) determined the chemical composition of the essential oil of *D. pinnata*, to understand its insecticidal activity against *S. zeamais* and *S. oryzae*, identifying three constituents that have greater toxicity and repellency against insects were D-limonene, 4-terpineol and α-terpineol.

This insecticidal activity occurs because, according to De Oliveira, Riveiro-Pinto, & Paumgartten (1997) these monoterpenes inhibit the enzyme acetylcholinesterase and cytochrome P450.

Potenza et al (2005) report that the types of solvents (water, ethanol, and hexane) involved in the extraction of compounds interfere with the efficiency of natural products, as they extract different chemical substances according to polarity. According to Andreo & Jorge (2006) water efficiently extracts phenolic compounds in a shorter time due to its high polarity. In addition, several factors can influence the content of secondary metabolites in plants, such as seasonality, circadian rhythm, developmental stage and age, temperature, water availability, UV radiation, soil nutrients, altitude, atmospheric composition, and tissue damage (Gobbo Neto & Lopes, 2007).

Thus, the use of plant extracts and/or essential oils is promising in controlling insect pests, standing out as an alternative method, which should be used in an integrated pest management.

CONCLUSIONS

Among the aqueous extracts of plants used in this experiment, only the *D. pinnata* extract can be considered satisfactory for use in the control of the weevil *S. zeamais*, as it presented 56.00% of control.

Other forms of extraction must be carried out in order to better evaluate the plant extracts used in this study for more appropriate indications and recommendations for their use as “insecticidal plants.” There is also a need to evaluate all possible forms of control or use of the extracts (ingestion, contact, repellency, attractiveness), which can be seen with the *D. pinnata* extract showing 10.00% efficiency in the contact test and 56.00% efficiency in the grain test treatment.

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