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Insecticidal and Repellent Actions of Methanolic Extracts from Five Medicinal Plants against the Saw-Toothed Grain Beetle *Oryzaephilus surinamensis* (Linn.) (Coleoptera: Silvanidae)

Acciones insecticidas y repelentes de extractos metanólicos de cinco plantas medicinales contra el escarabajo de los cereales con dientes de sierra *Oryzaephilus surinamensis* (Linn.) (Coleoptera: Silvanidae)

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Abstract: The insecticidal and repellent activities of methanolic extracts of *Ruta chalepensis* L. (Rutaceae: Sapindales), *Rhazya stricta* Decne (Apocynaceae: Gentianales), *Heliotropium bacciferum* Forssk (Boraginales: Boraginaceae), *Salvadora persica* L. (Salvadoraceae: Brassicales), and *Moringa oleifera* L. (Moringaceae: Brassicales) were investigated against the saw-toothed grain beetle *Oryzaephilus surinamensis* L. (Coleoptera: Silvanidae). Results demonstrated that all these plant extracts had variable toxicity against the beetle. The effectiveness of the tested plant extracts was shown by increasing the used concentrations. The methanolic extract from *R. stricta* performed the best and was able to cause 93.3% and 89.2% mortality for the adult and larval stage of *O. surinamensis*, respectively, at 500 ppm after six days of plant extract treatment. The tested extract of *S. persica* at 500 ppm caused 80.8% and 82.5% mortality on larvae and adults of *O. surinamensis* after six-day of treatment. On the other hand, repellent effects of extracts of *R. stricta*, *S. persica*, and *.. chalepensis* at 500 ppm were recorded, with higher values of 91.7%, 83.3%, and 78%, respectively, against the adults of *O. surinamensis*, which were under 500 ppm. These extracts especially from *R. stricta*, *S. spinosa*, and *.. chalepensis* could be useful to prevent damages and store grain production losses for *O. surinamensis*.

Keywords: Bioassay, *Heliotropium bacciferum*, Methanolic plant extracts, *Moringa oleifera*, *Oryzaephilus surinamensis*, Repellency, *Rhazya stricta*, *Ruta chalepensis*, *Salvadora persica*.

Resumen: Se investigó la actividad insecticida y repelente de los extractos metanólicos de *Ruta chalepensis* L. (Rutaceae: Sapindales), *Rhazya stricta* Decne (Apocynaceae: Gentianales), *Heliotropium bacciferum* Forssk (Boraginales: Boraginaceae), *Salvadora persica* L. (Salvadoraceae: Brassicales) y *Moringa oleifera* L. (Moringaceae: Brassicales) contra el escarabajo de los cereales *Oryzaephilus surinamensis* L. (Coleoptera: Silvanidae). Los resultados demostraron que todos estos extractos vegetales tenían una toxicidad variable contra el escarabajo. La eficacia de los extractos ensayados se puso de manifiesto al aumentar las concentraciones utilizadas. El extracto de *R. stricta* fue

el que mejor funcionó y fue capaz de causar una mortalidad del 93,3% y del 89,2% en el estado de adulto y de larva de *O. surinamensis* respectivamente a 500 ppm tras seis días de tratamiento. El extracto de *S. persica* a 500 ppm causó un 80,8% y un 82,5% de mortalidad en larvas y adultos de *O. surinamensis* respectivamente tras seis días de tratamiento. Por otra parte, se registraron efectos repelentes de los extractos de *R. stricta*, *S. persica* y *R. chalepensis* a 500 ppm, con valores superiores al 91,7%, 83,3% y 78% respectivamente contra los adultos de *O. surinamensis*, que estaban por debajo de 500 ppm. Estos extractos, especialmente los de *R. stricta*, *S. spinosa* y *R. chalepensis*, podrían ser útiles para prevenir los daños y las pérdidas de producción de grano almacenado de *O. surinamensis*.

Palabras clave: Bioensayo, Extracto metanólico de plantas, *Heliotropium bacciferum*, *Moringa oleifera*, *Oryzaephilus surinamensis*, Repelencia, *Rhazya stricta*, *Ruta chalepensis*, *Salvadora persica*.

INTRODUCTION

Damage of cereal grains through infestation of insects during the storage phase has become a severe challenge, predominantly in developing countries. Studies indicated that the stored grains, as well as products' damage due to insect pests, may amount to about 5% to 10% losses in temperate areas, whereas losses may range from 20% to 30% in tropical areas (Ileke & Oni, 2011; Akinneye & Ogungbite, 2013). Therefore, crop protection in this field must play vital and essential roles in contemporary agronomic production; the ever-lasting yield demands, as well as increased farming practices, have resulted in a rise in pest damage and control (Martins et al., 2012). The saw-toothed grain beetle *Oryzaephilus surinamensis* L. (Coleoptera: Silvanidae) is amongst serious pests of different categories of food, including nuts, dry fruits, spices, and cereal, in addition to other foodstuffs (Huda & Noor, 2019). The saw-toothed grain beetle *O. surinamensis* has a global distribution, especially in tropical and subtropical areas (Huda & Noor, 2019). Stored grain infestation usually occurs from top to bottom or vice versa through migration of pests such as rice weevils *Sitophilus oryzae* L. (Coleoptera: Curculionidae), saw-toothed grain beetle *O. surinamensis*, and red flour beetle *Tribolium castaneum* Herbs (Coleoptera: Tenebrionidae), known as vertical infestation (Kachhwaha et al., 2015). Studies reported that spoiled kernels due to insect attack by *O. surinamensis* are more susceptible than the whole grains. Hence, seeking more suitable methods of controlling stored-grains pests is required (Kachhwaha et al., 2015). Indeed, managing the infestation of pests in stored grains is predominantly attained by applying synthetic chemicals together with phosphine and methyl bromide (Pimentel et al., 2008). However, quite a lot of chemical insect repellents have been outlawed or regulated in many nation-states due to environmental concerns and hazards associated with human healthiness (Tapandjou et al., 2002).

Synthetic insecticides including artificial pyrethroids, carbamates, organophosphorus, and organochlorides are usually utilized for controlling stored-grain pests. However, applying these chemicals can lead to decreased grain quality, smelly and hazardous substances to

human, and air pollution as a side effect of insecticides on the environment. The new chemical insect repellents' adverse effects have guided researchers in finding innovative pathways of controlling insects, resulting in the discovery of plants' products as a substitute method of managing insect pests. This method can be more effective against specific target pest species, and biodegradable into nontoxic products and are suitable for application in integrated pest management programs (Akinkulere et al., 2006; Sutherland et al., 2002; Zibae, 2011).

Several studies demonstrated that some plant extracts such as Neem *Azadirachta indica* L. (Sapindales: Meliaceae) have insecticidal effects on Khapra beetle *Trogoderma granarium* Everts (Coleoptera: Bostrichidae) with variable levels (Mahmoud et al., 2015). Correspondingly, Haj et al. (2016) reported that Usher *Calotropis procera* Aiton (Apocynaceae), Argel *Solenostemma argel* Hayne (Asclepiadaceae), and *Datura stramonium* L. (Solanaceae) were more effective against the adults' saw-toothed grain beetles. Khemais et al. (2018) concluded that the essential oils of the flowering aerial portions of *Ruta chalepensis* were confirmed to be toxic and had physiological effects on *Tribolium confusum* Duval (Coleoptera: Tenebrionidae) as well. Their results also demonstrated that the maximum exposure time resulted in a maximum repellency of this pest. Moreover, Alvi et al. (2018) concluded that the leaf and seed extracts of *R. chalepensis* were toxic and repellent to *T. granarium* and *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae) under research laboratory settings.

Moreover, Eldidamony et al. (2020) recorded that the extracts of *Heliotropium curassavicum* could be considered as rodenticides in the framework of IPM programs. Similarly, sprayings *Moringa oleifera* L. plant's extracts (seed and root extracts) within cowpea crop were capable of reducing several field insect pests, including *Megalurothrips sjostedti* Trybom, *Aphis craccivora* Koch., and *Maruca vitrata* F., as well as the infestation by stored insect *Callosobruchus maculatus* L. which is reduced after harvesting cowpea (Ojiako et al., 2013).

The present study was carried out in an attempt to explore alternative, effective, and environmentally safe insecticides, specifically of botanical origins against the larval and adult stages of the saw-toothed grain beetle *O. surinamensis*. We investigated the biological effects (i.e., toxicity and repellency) of five medicinal plant extracts, including *Ruta chalepensis* L. (Rutaceae: Sapindales), *Rhazya stricta* Decne (Apocynaceae: Gentianales), *Heliotropium bacciferum* Forssk (Boraginales: Boraginaceae), *Salvadora persica* L. (Salvadoraceae: Brassicales), and *Moringa oleifera* L. (Moringaceae: Brassicales) against this dangerous stored-grain pest.

MATERIALS AND METHODS

Insect Culture

The adults and larvae of the saw-toothed grain beetles were obtained from permanent colonies of the saw-toothed grain beetle *O. surinamensis* in the Laboratory of Plant Protection, the Department of Arid Land Agriculture, King Abdulaziz University. The culture was kept at about $28\pm 2.0^{\circ}\text{C}$ and arranged $75\pm 5\%$ relative dampness inside jars enclosed with a muslin material. The insects were sustained by interchanging the consumed grains with new uncontaminated paddy rice collected from the market.

Extraction and Preparation of Plants' Material

The fresh twigs of *R. chalepensis*, *R. stricta*, *H. bacciferum*, *S. persica*, and *M. oleifera* were obtained from different places in Riyadh region (Al-Duwadimi, Al-Aflaj, Al-Qaseem, and Shagra) which is located in the center part of Saudi Arabia. These plants grown naturally without any treatment of pesticides. The plants were identified and collected by the expert staff of the Department of Arid Land Agriculture, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University. The abovementioned plants were dried under dark condition for four weeks, ground separately into fine particles, put through a sieve (1 mm mesh), and then preserved in distinct plastic bottles at 4°C with close-fitting lids before use. Methanolic extracts of *R. chalepensis*, *R. stricta*, *H. bacciferum*, *S. persica*, and *M. oleifera* were obtained through the cold extraction technique. Briefly, around 150 g of the powder was mixed discretely in extraction bottles with 500 ml of methanol. After that, the mixture was stirred using a glass rod; after seventy-two hours, the extraction was prepared to use. The resultant mix was passed through a double layer (Whatman No. 1) filter paper. The solvent was placed in a rotary evaporator at temperatures ranging from 30°C to about 40°C with a three to six rpm rotary speed for eight hours. Then, subsequent solid substances produced by the evaporation of methanol from used plants were separately air-dried in order to remove all traces of the used solvent (methanol), resulting in a final stock solution of each tested plant. From these stock solutions, different concentrations of 200, 300, 400, and 500 ppm were separately prepared for each tested plant through the use of distilled water. Preliminary tests were applied on larval and adult stages of *O. surinamensis* in order to determine these experimental concentrations.

Bioassays with Plant Extracts on O. surinamensis

About 50 g of paddy rice was weighed into 250 ml plastic jars. Afterwards, 1 ml of tested plant extracts of 200, 300, 400, and 500 ppm was separately mixed with the paddy. The mixtures were left for an hour in order to

certify volatile solvent evaporation. Control treatment received only 1 ml of distilling water. Thirty of the 3rd instars of larvae of *O. surinamensis* were separately moved into separate jars which included the mixtures of paddy rice and tested concentrations of each plant as well as the control treatment. Furthermore, this procedure was applied on thirty adults of *O. surinamensis* following the same method for the larval stage. Four replicates of each concentration from the investigated plants and untreated plants (control) were carried out in a Randomized Complete Block Design (RCBD). Both larvae and adult mortality were separately observed and recorded at 2, 4, and 6 days after treatments.

Repellence Plant Extract Assessment

The methodology employed in testing repellency was in line with the techniques of Talukder & Howse (1994) and Kundu et al. (2007). The Petri dishes contained treated as well as untreated new grain portions. Filter papers were then cut into two uniform halves. One ml solution of each concentration from each plant extract was added to one half using a pipette. Consequently, treated filter papers were then air-dried. They were brought together with the untreated half through the use of a cello-tape at the center, and they did not inhibit the beetles' free movements from a single half of the paper to the other portion of the filter-paper. Every filter paper was then placed in a Petri dish of about nine centimeters in diameter. Newly emerged *O. surinamensis* adults were then unconfined at the middle of each filter paper in groups of 20, and the Petri dish was closed. Each concentration was replicated three times for each plant extract. The insects on each half of the paper strip were then tallied after every two hours. The obtained data were finally presented as a percentage of repulsion (P.R.) according to the method of Jilani et al. (1988).

Data Analyses

The percentages of mortality of the larvae and adults of *O. surinamensis* were calculated for each observed point (2, 4, and 6 days). Then, each of them was separately analyzed by one-way ANOVA in order to assess the effect of concentrations of five plants (20 experimental units with control). Before applying ANOVA, data transformation using a Log 10 (Max+1-X) was performed in order to meet the normality and improve variances. Where significant treatment differences ($P \leq 0.05$) were observed, Fisher's least significant difference (LSD) tests were conducted in order to identify differences between treatment means. All data analyses were carried out within SPSS version 2.0 (IBM Corporation, 2011).

Moreover, the values of LC₅₀ (the lethal concentration to cause 50% mortality) were separately calculated for the larvae and adults of *O. surinamensis*, which is in line with the study of Finney (1971), while data correction for controlled mortality was adopted from Abbott's formula

(1925). In order to determine the best of the five used plants with tested concentrations (20 experimental units) as a repellent of emerged adults of *O. surinamensis*, the calculated percentages of repellency test were subjected to one-way ANOVA. However, untransformed means and standard errors are illustrated in order to simplify interpretation, and a significance difference is considered at $P \leq 0.05$.

RESULTS AND DISCUSSION

Plant Extracts' Toxicity on O. surinamensis larvae and adults

The present study demonstrated that the used plants with different concentrations for each observation time had higher significant differences on the mortality of larvae of the saw-toothed grain beetle *O. surinamensis* after 2 days ($F_{20,63}=13.04$, $P\#0.001$), 4 days ($F_{20,63}=14.28$, $P\#0.001$), and 6 days ($F_{20,63}=13.26$, $P\#0.001$). The larvae of *O. surinamensis* indicated the highest mortality (89.2%) when larvae were treated with the extract of *R. stricta* at the concentration of 500 ppm after 6 days followed by 80.83, 72.5, 71.67, and 68.33% mortality when larvae were treated with the extract of *S. persica*, *R. chalepensis*, *M. oleifera*, and *H. bacciferum*, respectively, at the same concentration and observed time (Fig. 1). Both concentrations of *R. stricta* and *S. persica* were the most effective, and the mortality of beetle larvae ranged from 60.8 to 89.2% and from 55.0 to 80.8% at 6 days, respectively (Fig. 1). Similarly, the results of toxicity presented in (Table I) indicated that the significant lower LC_{50} values of *O. surinamensis* larvae were observed when both *R. stricta* (160.77, 137.26, and 110.41 ppm) and *S. persica* (200.64, 168.68, and 126.08 ppm) were applied after 2, 4, and 6 days, respectively, in comparison with other used plant extracts. The values of LC_{50} for other plant extracts of *R. chalepensis*, *M. oleifera*, and *H. bacciferum* after 6 days following exposure were 130.91, 206.83, and 285.11 ppm, respectively. Comparing the LC_{50} values, it was observed that the methanolic extracts of *R. stricta*, *S. persica*, and *R. chalepensis* showed better performance than other plant extracts.

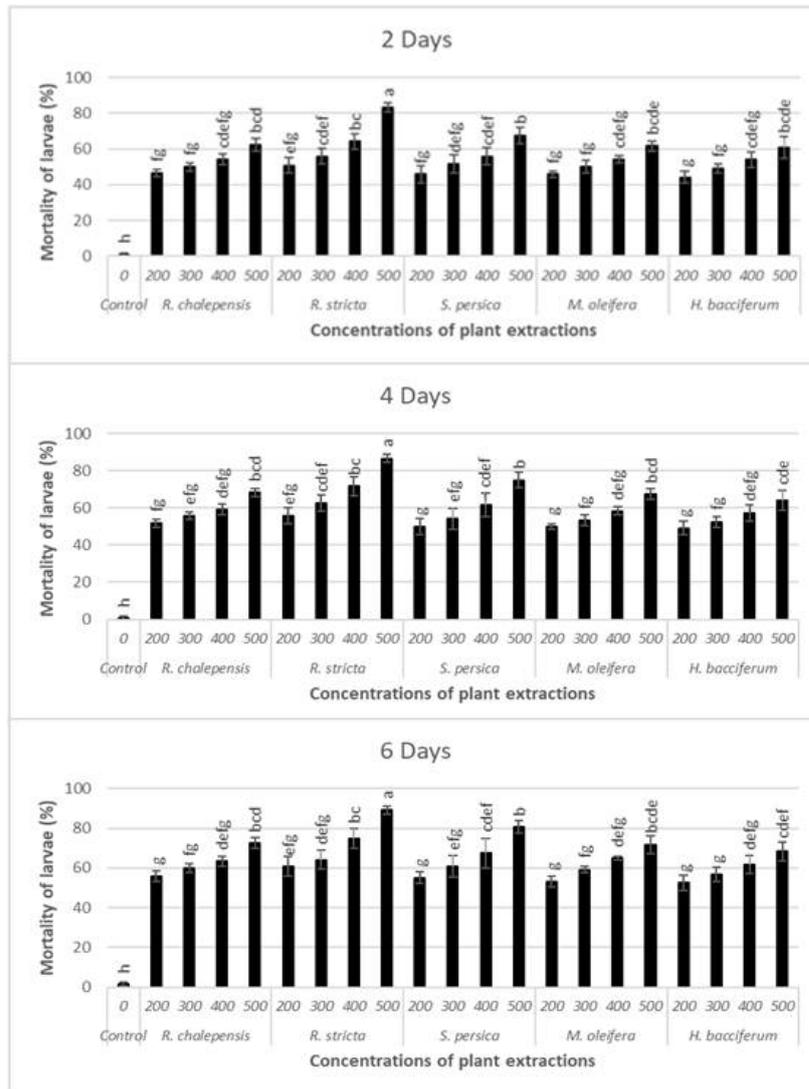


Fig. 1. Mortality of *Oryzaephilus surinamensis* larvae by five plant extracts after three observed times (2,4 and 6 days). Means and S.E. of (%) mortalities. Different letter denotes significant differences between treatments ($t \# 0.05$), according to the LSD test.

Plant extracts	Assay times (days)	Slope	LC50 (Fiducial Limits)
<i>Ruta chalepensis</i>	2	0.98	204.25 (130.25- 282.11)
	4	1.42	160.26(121.39- 280.79)
	6	1.71	130.91(076.61- 205.53)
<i>Rhazya stricta</i>	2	0.89	160.77(100.00 - 289.29)
	4	1.56	137.26 (075.31- 250.89)
	6	1.71	110.41(053.19- 189.70)
<i>Salvadora persica</i>	2	1.08	200.64(230.52- 399.57)
	4	1.51	168.68(130.02- 290.95)
	6	1.63	126.08(078.14- 210.93)
<i>Moringa oleifera</i>	2	1.09	310.73(250.66- 478.64)
	4	1.72	278.92(155.79- 410.91)
	6	1.90	206.83(132.79- 320.59)
<i>Heliotropium bacciferum</i>	2	0.58	410.30(301.05-530.06)
	4	1.79	366.88(260.00- 481.17)
	6	1.97	285.11(200.80- 408.95)

Table I.
LC50 values (ppm) and 95% confidence limits for *Oryzaephilus surinamensis* larvae reared in media containing methanolic extracts from five plant materials.

Likewise, the used plants with tested concentrations showed higher significant differences on the mortality of the adult stage of *O. surinamensis* after 2 days ($F_{20,63}=13.15$, $P\#0.001$), 4 days ($F_{20,63}=14.70$, $P\#0.001$), and 6 days ($F_{20,63}=16.46$, $P\#0.001$). The used plant extracts were found to be more effective against the adult stage of *O. surinamensis* in comparison with the larval stage in which the extract of *R. stricta* caused 93.33% adult mortality at the concentration of 500 ppm after 6 days. Meanwhile, the extracts of *S. persica*, *R. chalepensis*, *M. oleifera*, and *H. bacciferum* caused 82.50, 74.17, 73.33, and 69.17% mortality of *O. surinamensis* adults, respectively, at the same concentration and observed time (Fig. 2). Consequently, the data revealed that concentrations of *R. stricta*, *S. persica*, and *R. chalepensis* were the most effective plant extracts on controlling the adult stage of *O. surinamensis* where the mortality in adult beetle ranged from 62.5 to 93.3%, 57.5 to 82.5%, and 56.7 to 74.2% after 6 days from applying the treatments, respectively. The used plant extracts showed time- and concentration-dependent effects against the *O. surinamensis* adults in which their mortality percentage increased after 6 days of exposure for all the plant extracts. Throughout 6 days of exposure, adulticides of all the plant extracts were approximately improved showing higher mortality of the *O. surinamensis* adults with increasing exposure time and concentrations. Mortality of control was less than 5% along the exposure periods. The toxicity analyses with LC_{50s} and 95 % confidence limits for each plant extract against *O. surinamensis* adults are shown in (Table II). The lowest LC_{50s} were for *R. stricta*, *S. persica*, and *R. chalepensis* after 6 days from the treatment with the values being 108.47, 121.54, and 128.14 ppm, respectively. The respective values of LC_{50s} of the other plant extracts after the same period of exposure were 201.47 and 292.49 ppm for *M. oleifera* and *H. bacciferum*, respectively.

The obtained results demonstrated that the plant extracts of *R. stricta*, *S. persica*, and *R. chalepensis* were generally more toxic than other plant extracts and possessed lower LC_{50s}. This finding is in agreement with the results of Qureshi et al. (2018), who found that the extract of *S. persica* was very effective against *T. confusum* in which the larval growth of this pest was significantly inhibited when extract was incorporated to larval diet. Moreover, Al-Qahtani et al. (2012) reported the lethal effect of three plants named ginger (*Zingiber officinale*), cardamom (*Elettaria cardamomum*), and fennel (*Foeniculum vulgare*) against *O. surinamensis*, describing the most dangerous pest recorded in Saudi Arabia. In addition, our results supported the results of Alvi et al. (2018), who found that *R. stricta* leaf and seed extracts caused a significant mortality and repellency against *R. dominica* and *T. granarium*. In their study, mortality and repellency were increased as the concentrations and extract exposure time increased. More recently, Asiry & Zaitoun (2020) reported that the extract from *R. stricta* was very effective against *T. granarium* as an insecticide. The toxicity and repellency properties of *R. stricta* against larval and adult stages of *O. surinamensis* could be attributed to the presence of different glycosides, triterpenes, alkaloids, and volatile basis (Ali et al., 2000; Marwat et al., 2012).

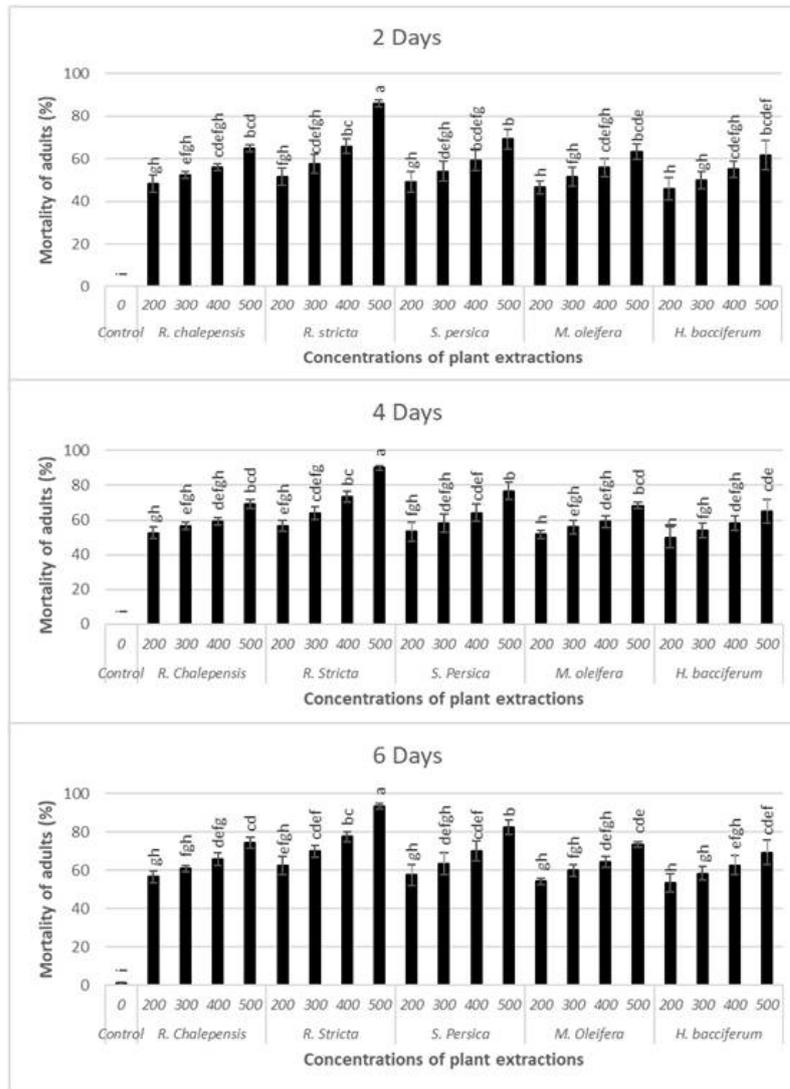


Fig. 2. Mortality of *Oryzaephilus surinamensis* adults by five plant extracts after three observed times (2,4 and 6 days). Data are Means±SE. Different letter denotes significant differences between treatments ($p \leq 0.05$), according to the LSD test.

Plant extracts	Assay times (days)	Slope	LC50 (Fiducial Limits)
<i>Ruta chalepensis</i>	2	0.81	200.99(177.07- 295.13)
	4	1.28	154.22(106.57- 232.88)
	6	1.53	128.14(98.18- 199.31)
<i>Rhazya stricta</i>	2	0.79	155.22 (111.61- 250.63)
	4	1.39	135.34(109.87- 224.92)
	6	1.67	108.47(088.19- 181.71)
<i>Salvadora persica</i>	2	0.92	196.68(150.81- 290.07)
	4	1.34	163.27(115.56- 250.71)
	6	1.69	121.54(101.90- 238.69)
<i>Moringa oleifera</i>	2	1.07	305.32(205.69- 488.13)
	4	1.83	271.21(200.30- 425.73)
	6	1.91	201.47(188.28- 380.81)
<i>Heliotropium bacciferum</i>	2	0.65	405.11(300.33- 535.95)
	4	1.71	361.98(287.56-493.45)
	6	1.87	292.49(218.12-428.34)

Table II.

LC50 values(ppm) and 95% confidence limits for *Oryzaephilus surinamensis* adults reared in media containing methanolic extracts from five plant materials.

The study of Ahmad et al. (1983) regarding the alkaloidal constituents of *R. stricta* leaves had resulted in the isolation of rhazimal (16-formylstrictamine), rhazimol (deacetylakuammiline), and rhazinol (a hydroxymethyl analogue of strictamine). In addition, two more alkaloids stricticine and strictine had also been isolated. Jeon et al. (2013) indicated that the insecticidal constituent of *R. chalepensis* leaves was isolated by chromatographic techniques and identified as quinoline-4-carbaldehyde (C₁₀H₉NO) which was very effective against *Sitophilus oryzae* L. (Coleoptera: Curculionidae). The flavonoids presented in plant extracts possess a catecholic B-ring that seems to be responsible for the toxicity to insects (Onyilagha et al., 2004). Moreover, Jabilou et al. (2006) found insecticidal activities from four medicinal plant extracts, including *Peganum harmala* (Sapindales: Nitrariaceae), *Ajuga iva* (Lamiales: Labiatae), *Aristolochia baetica* (Piperales: Aristolochiaceae), and *Raphanus raphanistrum* (Brassicales: Brassicaceae) against *O. surinamensis*. Furthermore, Haj et al. (2015) demonstrated that the three doses utilized (5, 10, and 15%) of three plant extracts of *Calotropis procera* (Gentianales: Apocynaceae), *Solenostemma argel* (Gentianales: Apocynaceae), and *Datura stramonium* (Solanales: Solanaceae) revealed some potential insecticidal effects to the adult of *O. surinamensis* and a high repellency action against this pest.

Repellency Rate of Plant Extracts against the Adults of *O. surinamensis*

The one-way ANOVA showed a higher significant difference between the tested plant extracts on the repellency rate ($F_{20,41}=40.65$, $P=0.001$) against the adults of *O. surinamensis*. Statistical analysis revealed that *R. stricta* exhibited the most extraordinary repellent action against the adult

of *O. surinamensis* (Fig. 3). At a concentration of 500 ppm, the repellent percentage of *R. stricta* was 91.7%, followed by *S. persica* (83.3%) and *R. chalepensis* (78.3%) using the same concentration (Fig. 3).

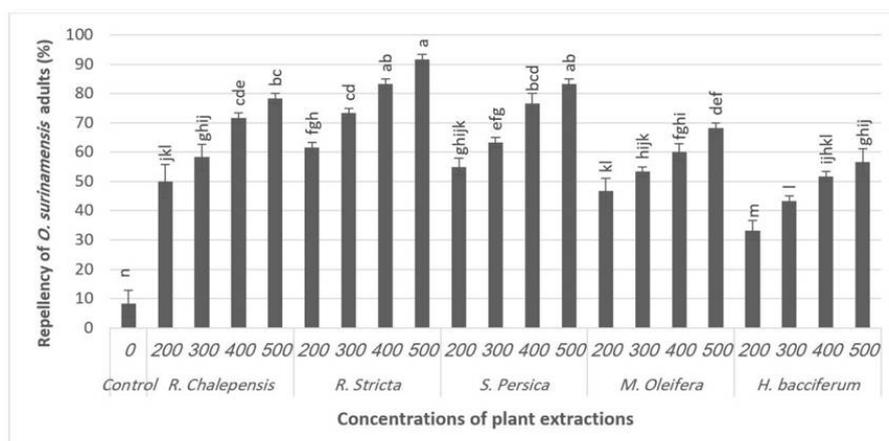


Fig. 3.

Repellence of *Oryzaephilus surinamensis* adults by five plant extracts after three observed times (2,4 and 6 days). Data are Means±S.E. Different letter denotes significant differences between treatments (P # 0.05), according to the LSD test.

The present results supported the finding of Kundu et al. (2007) and Elumalai et al. (2015), whose repellent activities of some plant extracts, *Polygonum hydropiper* L. (Caryophyllales: Polygonaceae) and *Rivina humilis* Linn (Caryophyllales: Phytolaccaceae) against *T. castaneum*, reported that the rate of repellency increased proportionately with increasing concentrations of the plant extracts. Furthermore, Abdel-Sattar et al. (2009) suggested that the leaf and fruit essential oils of *Schinus molle* L. have an insecticidal and repellent effect on *T. castaneum* and *T. granarium*. The outcomes attained from this study revealed the importance of the toxicity besides the repellent influence of the extracted plant materials, particularly *R. stricta* and *S. persica*, in regulating the stored-product insects, particularly *O. surinamensis*. Aliv et al. (2018) declared that *R. stricta* worked as a repellent material against *R. domina* and *T. granarium*. Elmhalli et al. (2019) reported that *S. persica* has a repellent effect against nymphs of *I. ricinus*. Kachhwaha et al. (2015) demonstrated that repellent behavior could be utilized as an essential measure as it does not kill insects but protects the grain from their infestation.

CONCLUSION

The discovery of natural and inexpensive insecticides from local resources that could be applied to prevent stored products from insect infestation is an essential goal for food security and safety. The plant extracts application is commonly expected not to leave harmful residues in the surroundings as they occur naturally amongst the native flora. The results of this study demonstrated that methanolic extracts of *R. stricta*, *S. persica*,

and *R. chalepensis* plants possess toxic and repellent activity that could serve adequately as a potential pest control strategy for the stored-grain protection against the saw-toothed grain beetle *O. surinamensis*.

In comparison with conventional insecticides, plants' extracts are confirmed to be relatively harmless. They also tend to degrade quickly in the surroundings (Oparaeke et al., 2005). This study put forward that there might be diverse compounds in plant extracts possessing various bioactivities. Further studies are required to isolate, identify, and assess the bioactivity of insecticide compounds present in studied plants against stored products' pests.

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