

# Insecticidal Activities of *Phyllanthus emblica*, *Prunus mahaleb*, *Cerasus mahaleb*, *Piper nigrum*, *Krameria lappacea* and *Phoenix dactylifera* on Larvae *Trogoderma granarium* Everts

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**Abstract** The repellency and toxic activity of some plants that are commonly used in folk medicine are evaluate against the destructive 5th instar larvae of the *Trogoderma granarium* beetle. Wheat grains were treated with selected powders of *Phyllanthus emblica*, *Prunus mahaleb*, *Cerasus mahaleb*, *Piper nigrum*, *Krameria lappacea* and *Phoenix dactylifera* at concentrations of 2, 0.9, 0.5, or 0.1% for 72 hours. The *K. lappacea*, *P. emblica* and *P. mahaleb* powders provided 53, 53 and 45% repellency respectively at 2% after 72 h; the other powders showed only medium to weak repellency. On the basis of LC50, the tested toxicity effectiveness can be arranged as *P. emblica* (0.32%) > *P. nigrum* (2.7%) > *K. lappacea* (2.8%) at ten days. Notably, the powders of *C. mahaleb*, and *P. dactylifera* resulted in a strong attraction of larvae to the treated grains at -100% at any time for any tested concentration. The repellent and toxic effects of *P. emblica* fruit powder are apparent. Powders of *P. nigrum*, *K. lappacea* and *P. emblica* can be considered promising environmentally healthy and safe pesticides to reduce the loss of stored wheat grains caused by this larvae eater.

**Keywords** *Piper Nigrum*, *Krameria Lappacea*, Secondary Metabolism, Proanthocyanidin Tannins, Physical Toxicity

## 1. Introduction

The beetle *Trogoderma granarium* Everts (Coleoptera: Dermestidae) is considered one of the most destructive pests of various types of stored grains, especially wheat, and can significantly damage the grain germs [1]. They are mainly found in India, other tropical and subtropical countries, Mediterranean countries, Iraq, and Iran. Its presence has also been recorded in southern Europe, western Africa, Asia and South America [2]. It is characterized by being able to withstand various environmental conditions [3, 4].

The difficulty of controlling this insect lies in its habitation with foodstuffs and the fact that the use of pesticides leads to the emergence of resistance to the action of pesticides [5, 6]. Furthermore, the use of methyl bromide gas as a pesticide is dangerous and carcinogenic to humans and causes genetic mutations in embryos [7-9]. Therefore, the attention and efforts of researchers have turned towards finding safe alternatives to protect the environment and human health and the wholesomeness of food. The most

prominent of these alternatives was the use of plants and their parts, extracts and oils to control harmful insects in their various stages, both in the field and in storage [10-12].

In fact, the search for effective plants to repel or kill field or storage pests was started by primitive farmers and housewives [13-16]. Such simple attempts, especially in rural communities, whether effective or not, have played an important role in the creation of these alternatives, beginning with the development of some of them into herbicides based on compounds separated from plants and commercialized; the most famous are *Azadirachta indica* neem [17-19] *Derris elliptica* (Wall.) Benth rotenone [20, 21] and *Chrysanthemum cinerariifolium* Pyrethrum [22, 23]. Due to the huge losses in quality and quantity and the economic damage to stored wheat grains caused by *Trogoderma granarium* larvae, a search for alternative controls is imperative [24]. The most important larval stage of the *Trogoderma granarium* beetle that destroys stored wheat grains is the fifth instar larvae [25]. This study was conducted to test the repellent and toxic effects of selected parts from some plants that are commonly used in traditional and alternative medicine in Asia and Saudi Arabia, namely, *Prunus mahaleb*, *Cerasus mahaleb*, *Piper nigrum*, *Krameria lappacea* and *Phoenix dactylifera*, against the fifth-instar larvae of *Trogoderma granarium*.

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## 2. Materials and Methods

### 2.1. Breeding the Insect

Adults and larvae of *Trogoderma granarium* were collected from wheat grains *Triticum aestivum* and were cultured in an incubator at a temperature of  $26 \pm 2^\circ\text{C}$  and relative humidity of 70-60% in the laboratories of the Department of Biology, Faculty of Science and Humanities at Sattam bin Abdul Aziz University. First, 200 g of sterile wheat was placed in 20-cm-long and 12-cm-diameter containers. The containers were covered with a muslin cloth with a rubber band attached and incubated in the incubator. The culture was constantly renewed after each generation.

### 2.2. Plant Materials

The tested plants and their parts are shown in Table 1. *Phyllanthus emblica*, *Prunus mahaleb*, *Cerasus mahaleb*, *Piper nigrum*, *Krameria lappacea* and *Phoenix dactylifera* were purchased from local market, analysed by a specialized taxonomist, cleaned of dust and particles, washed, air-dried and finally ground by a high-voltage electric mill, sifted through a 60 mesh sieve and kept in refrigerators until use.

**Table 1.** Scientific name of the tested plants

Scientific name	Family name	Plant part	Common name
<i>Phyllanthus emblica</i> L	Phyllanthaceae	seeds	Indian gooseberry
<i>Prunus mahaleb</i> L	Rosaceae	seeds	Mahaleb
<i>Cerasus mahaleb</i> L	Rosaceae	seeds	Rock cherry
<i>Piper nigrum</i> L	Piperaceae	Peeled seeds	White pepper
<i>Krameria lappacea</i> L	Krameriaceae	krameria root	Rhatany
<i>Phoenix dactylifera</i> L	Arecaceae	date-pits	Dates

### 2.3. Bioassay

#### 2.3.1. Repelling Effect of the Plant Powders

In accordance with the methodology given in [26] and revised by [27], glass dishes that were 11 cm in diameter and 2 cm in height were used. Each dish was divided into two equal halves, and a 2-cm-diameter circle was drawn in the centre of one of the halves. The plant powder at a given concentration was placed on one half of the paper, and the other half was free of any treatment. Then, 10 larvae 5<sup>th</sup> instar was placed in the test area (centre of the paper). The repellency percentage was measured after 15 and 30 minutes and after 24, 48 and 72 hours, and a perforated plastic lid were placed on the glass dish. The number of insects was calculated in the non-treated half (C), with 3 replicates per tested plant powder for specific concentrations (2, 0.9, 0.5 and 0.1%). The repellency percentage was calculated using the following equation:

$$PR = 2(C - 50\%)$$

PR = percentage of repellency

C = percentage of insects in non-treated half

If C is more than 50%, PR becomes positive, and the treatment by plant powder has a repellent efficiency. Conversely, if C is less than 50%, PR becomes negative, and the plant powder has an attractive effect.

#### 2.3.2. Effect of Plant Powders on Percentage of the 5th-Instar Larval Mortality

Various concentrations of plant powders (2, 0.9, 0.5 and 0.1%) were added to the sterile wheat grains, kept at  $60^\circ\text{C}$  in the electric oven for 2 hours and placed in sterilized Petri dishes. Then, 100 wheat grains treated with specific concentrations were placed in each dish, and 10 newly moulted 5<sup>th</sup>-instar larvae were added, with three replicates. In the control treatment, the 5<sup>th</sup>-instar larvae were fed untreated wheat grains, and the percentage of mortality was reported after seven days of treatment.

### 2.4. Statistical Analysis

The mortality data were corrected with control mortality following the formula given in Abbot [28]. All data were statistically analysed using a one-way analysis of variance (ANOVA, SPSS statistical analysis software, version 11) [29]. The means were compared using the least significant difference (L.S.D) at the 0.10 level.

## 3. Results

### 3.1. Repellent or Attractive Effect of the Plant Powders

The results provided in Table 2 show the repellent effects of the tested plant powders. The *K. lappacea*, *P. emblica* and *P. mahaleb* powders provided 53, 52 and 45% repellency respectively at 2% after 72 h. Conversely the attractive percentage is -47, -48 and -55% for *K. lappacea*, *P. mahaleb* and *P. emblica* respectively at 2% after 72 h. It should be noted that low concentrations (0.1 and 0.5%) of both *P. emblica* and *K. Lappacea* increased in repellent effectiveness as the exposure time increased. However, the repellency percentage was only 2% for treatments with 2% of plant powders of *P. nigrum* and *C. mahaleb*. The powder of *P. dactylifera* did not provide repellency against the larvae exposed to it at any time for any tested concentration but have a strong attractive effect for 5<sup>th</sup> treated larvae at -100% attractive percentages at all tested at any time.

### 3.2. Effect of Plant Powders on 5<sup>th</sup> Instar Larval Mortality

The effect of the plant powders was tested using the percentage of 5th-instar larvae that died. The results in Table 3 show a 100% increase in the percentage of mortality when wheat grain was treated with the *P. emblica* powder at concentrations of 2, 0.9 and 0.5% after ten days of treatment. *P. nigrum* powder at concentrations of 0.5 and 0.9 g resulted in mortality percentages of 85.7% and 89.3% after 10 days of treatment compared to the values of 60%,

64% and 57% that were found for the highest concentration (2%) of the three plant powders *P. mahaleb*, *K lappacea* and *C. Mahaleb*, respectively, after 10 days of treatment.

The means followed by the same letter (in the same column) are not significantly different at the 0.01 level of probability.

In contrast, the *P. dactylifera* powder showed no toxic effect throughout the treatment at any tested concentration. Although the toxic effect or effectiveness of the plant

powders tested on the 5<sup>th</sup> instar larvae is clearly different across powders, this activity increased slightly with the duration of the treatment. However, based on LC50 at Table 4, the toxicity sequence will be the following:

*P. emblica* (0.32%) > *P. nigrum* (2.7%) > *K. lappacea* (2.8%) >

*C. mahaleb* (8.1%) > *P. mahaleb* (11.3%) > *P. dactylifera* (18.9%).

**Table 2.** Repellent activity of tested plants powders against 5<sup>th</sup> larvae *Trogoderma granarium* after 72h

Treatments	Con. w/w	Repellency $\pm$ SE	%		F	L.S.D.0.01	S.D	95% confidence	
			Rep.	Attr.				Lower	upper
<i>Phyllanthus emblica</i> L	0	.00 $\pm$ .000	0	0	15.063	-3.244	7.154	5.37	14.46
	2	14.33 $\pm$ 2.33	50	-50					
	0.9	16 $\pm$ 2.404	52	-48					
	0.5	0.33 $\pm$ 0.33	2	-98					
	0.1	8.33 $\pm$ 21.667	26	-74					
<i>Prunus mahaleb</i> L	0	.00 $\pm$ .000	0	0	4.012	0.678	7.024	-1.13	7.80
	2	12.3 $\pm$ 5.925	45	-55					
	0.9	1 $\pm$ 1.00	2	-98					
	0.5	0.00 $\pm$ 0.00	0	-100					
	0.1	0.00 $\pm$ 0.00	0	-100					
<i>Cerasus mahaleb</i> L	0	.00 $\pm$ .000	0	0	1.212	0.045	0.985	0.04	1.29
	2	1.00 $\pm$ 0.00	2	-98					
	0.9	1.33 $\pm$ 0.333	2	-98					
	0.5	0.33 $\pm$ 0.333	2	-98					
	0.1	0.00 $\pm$ 1.00	0	-100					
<i>Piper nigrum</i> L	0	.00 $\pm$ .000	0	0	0.190	17.501	0.674	1.07	1.93
	2	1.33 $\pm$ .0.333	2	-98					
	0.9	1.67 $\pm$ .0.333	2	-98					
	0.5	1.33 $\pm$ .0.667	2	-98					
	0.1	1.67 $\pm$ .0.33	2	-98					
<i>Krameria lappacea</i> L	0	.00 $\pm$ .000	0	0	2.465	-2.376	7.521	4.97	14.53
	2	18.33 $\pm$ .3.844	53	-47					
	0.9	6.00 $\pm$ .1.00	24	-76					
	0.5	7.67 $\pm$ .4.702	26	-74					
	0.1	7.00 $\pm$ 4.00	25	-75					
<i>Phoenix dactylifera</i> L	0	0.00 $\pm$ .000	0	0	0.667	0.461	1.557	-32	1.66

**Table 3.** Toxicity activity of Different Concentrations of the plants powders tested against 5th larvae *Trogoderma granarium* after 3,7,10 days. With 30 larvae 5<sup>th</sup> instar in 3 replicates

Treatments	Conc. (w/w)gm	after 4 Days		after 7 Days		after 10 Days		Correct mortality
		No.	%	No	%	No	%	
<i>Phyllanthus emblica</i> L	2	0	0	0	0	30	100	100
	.9	1	3.3	7	33.3	22	73	100
	.5	0	0	9	30	21	70	100
	.1	0	0	0	0	6	20	14.3
<i>Prunus mahaleb</i> L	2	0	0	12	40	7	23.3	60
	.9	3	10	7	23.3	5	16.7	35.7
	.5	0	0	4	13.3	11	36.7	46.4
	.1	0	0	11	36.7	8	26.7	60.7

**Table 4.** Toxicity activity of Different Concentrations of the tested plants powders against 5th larvae *Trogoderma granarium* after 10 Day

Treatment	Conc. w/w	Mortality % ± SE	F	L.S.D.0.01	LC50	SD	95%confidence	
<i>Phyllanthus emblica</i> L	0	.00 ± .000	0.356	2.074	0.32	10.549	Lower	Lower
	2	10 ± 10					1.30	14.70
	0.9	10 ± 6.245						
	0.5	10 ± 6.083						
	0.1	2 ± 2						
<i>Prunus mahaleb</i> L	0	.00 ± .000	0.756	0	11.312	4.239	2.14	7.53
	2	6.33 ± 3.480						
	0.9	5 ± 1.155						
	0.5	1.67 ± 1.202						
	0.1	6.33 ± 3.283						
<i>Cerasus mahaleb</i> L	0	.00 ± .000	0.944	6.989	8.056	4.010	1.04	6.13
	2	6 ± 3.055						
	0.9	5 ± 2.887						
	0.5	2 ± 1.528						
	0.1	1.33 ± 1.333						
<i>Piper nigrum</i> L	0	.00 ± .000	0.165	-7.625	2.735	3.954	5.49	10.51
	2	6.67 ± .0.88						
	0.9	8.67 ± .3.283						
	0.5	9 ± .309						
	0.1	7.67 ± .3.180						
<i>Krameria lappacea</i> L	0	.00 ± .000	0.300	-11.488	2.802	2.610	3.93	7.24
	2	6.67 ± 2.186						
	0.9	4.67 ± 1.333						
	0.5	5 ± 1.528						
	0.1	6 ± 1.528						
<i>Phoenix dactylifera</i> L	0	.00 ± .000	0.300	0	18.892	5.414	-3816	.498
	2	2.33 ± 0.233						
	0.9	1.10 ± 0.100						
	0.5	3.33 ± 3.33						
	0.1	5.56 ± 0.566						

The means followed by the same letter (in the same column) are not significantly different at the 0.01 level of probability.

## 4. Discussion

The results show that the repellency and toxicity of the different plant powders varied in effectiveness, even if are not significantly different at the 0.01 level of probability, which may have been related to differences in the chemical contents of the plant powders tested.

The powders of *K. lappacea*, *P. emblica* and *P. mahaleb* each demonstrated a strong positive relationship between repellency percentage and exposure time.

In contrast, a highly toxic effect was seen only in *P. emblica*, *P. nigrum* and *P. mahaleb* powders. It is worth noting the varying effectiveness of the *K. lappacea* and *P. nigrum* powders with regard to repellency and toxicity effects, respectively. The variation of the interactions suggested that the different biological activities of the chemical contents of the tested plants may be a result of a variation in the tested parts and their use in the test as a powder, aqueous or alcoholic extract [12, 30-32].

It should be noted that the fruit powders of *P. emblica* and *P. mahaleb* retained the effects of repellency and toxicity on the larvae exposed to treated food.

To explain the mechanism underlying the potential toxicity effects of the applied treatments, although a repellency effect was demonstrated for the 5th-instar treated larvae, the behavioural indicators of the repellency effect were also observed for escaped larvae that were far from the treated wheat grains. This dual effect is due to the physical and chemical properties of some plants that possess general larvicidal activity. This result is close to that observed by Ivbijaro [33], who determined some physical and chemical toxicity requirements for plants to be considered to have larvicidal activity. Additionally, some possible explanations for our results are as follows:

Additionally, it is possible the powder particles from treated wheat grains closed the spiracles and prevented the larvae from obtaining oxygen [34].

Considering the weak movement of the treated larvae compared to untreated ones, and their movement towards the bottom of the experiment dish, under the treated grains, this behaviour may preliminarily indicate diapause due to fasting from the inappropriate food available. This hypothesis agrees with feeding deterrence effects caused by treatment with other plant powders [35, 36]. The adhesion of plant powder on the body wall of treated larvae can have harmful chemical effects on some physiological functions. The most prominent of these changes are the scraping of the wax layer of the insect's cuticle and the resulting loss of water, thus exposing the insect to drying and potential mortality [37-39] and the possibility of absorption of cuticle fat, especially in

some of the tested plants. *K. lappacea*, *P. emblica*, and *P. mahaleb* are characterized by high contents of tanning compounds, which are known [40, 41] for their ability to drain the surfaces on which they rest due to their astringent properties; these plants in particular have proanthocyanidin tannins [42] and are used to treat burns and stitching wounds [43].

The diversity in repellency and toxic activity among the tested plants is due to the diversity of their chemical content. Therefore, some of these plants may be accepted by some insects. It is clear that seed powder of *C. mahaleb* and date-pits of *P. dactylifera* show this kind of acceptance, as they were not effective in the repellency and toxicity tests. However, Abushaala *et al.* [44] proved that a date-pits extract of *P. dactylifera* had anti-fungal activity at a concentration of 15. According to [45] *P. dactylifera* date-pits contain moisture, protein and carbohydrate contents of 12.5, 6.9 and 86.9 g/100 g date-pits, respectively. This nutritional content may explain the main reason why the larvae accepted wheat grains treated with powder from the date-pits.

Samuel *et al.* [46] demonstrated the larvicidal effect of piperine alkaloid on the 4<sup>th</sup>-instar larvae of mosquitoes in the Anopheles Malaria Complex Strains by feeding the larvae with a dose of piperine. In that study, a dose of 10% of pepper powder resulted in more than 70% mortality. Additionally,

Adnan *et al.* [47] and Hasan *et al.* [48] reported *P. emblica* to have many bioactive compounds that are important in medicinal uses, including anti-bacterial, anti-oxidant, and anti-inflammatory compounds. The effectiveness of *P. emblica* may be due to the plant's content of different levels of terpenoids, ascorbic acids and secondary metabolites, such as tannins.

*K. lappacea* roots are popular medical treatments for burns, wounds and dental care and were used 200 years ago in Europe in pharmacology [49, 50]. The main chemical content of root extracts is tannin compounds, which are effective in combating microbes and antioxidants [51, 52]. In a previous literature review, it is clear that tannin compounds are available in the three plants *K. lappacea*, *P. emblica*, and *P. mahaleb*, which demonstrated repellency and toxicity against *T. granarium* 5<sup>th</sup> instar larvae. Tannin compounds are also indicated by the potent odour of the piperine compound in *P. nigrum* and the burning effect of direct contact [53-56], two characteristics that are likely to play a role in the toxic and repellent activity on treated larvae.

## 5. Conclusions

*K. lappacea*, *P. emblica*, *P. nigrum* and *P. mahaleb* plant powders were possess some of the biological activities compounds can be used to treat wheat grains and protect them from infection *Trogoderma granarium* and its larvae phases.

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## REFERENCES

- [1] M. P. Parashar, Post Harvest Profile of Black Gram. Nagpur: Government of India, Ministry of Agriculture Department of Agriculture and Cooperation, Directorate of Marketing and Inspection, 2006.
- [2] J. H. Viljoen, "The occurrence of *Trogoderma* (Coleoptera: Dermestidae) and related species in southern Africa with special reference to *T. granarium* and its potential to become established," J. Stored Products Res., vol. 26, no. 1, pp. 43–51, Feb. 1990.
- [3] R. W. Howe and D. L. Lindgren, "How much can the khapra beetle spread in the U.S.A.?" J. Econ. Entomology, vol. 50, no. 3, pp. 374–375, Jun. 1957.
- [4] J. A. Kerr, "Khapra beetle, *Trogoderma granarium* everts (Coleoptera: Dermestidae)," Pest Control, vol. 49, pp. 24–25, 1998.
- [5] H. J. Banks, "Distribution and establishment of *Trogoderma granarium* everts (Coleoptera: Dermestidae): climatic and other influences," J. Stored Products Res., vol. 13, no. 4, pp. 183–202, Dec. 1977.
- [6] L. J. Zettler and G. W. Cuperus, "Pesticide resistance in *Tribolium castaneum* (Coleoptera: Tenebrionidae) and *Rhyzopertha dominica* (Coleoptera: Bostrichidae) in wheat," J. Econ. Entomology, vol. 83, no. 5, pp. 1677–1681, Oct. 1990.
- [7] FAO, Report of Food Security Review Mission to Tanzania. Rome, Italy: Food Security Assistance Scheme, 1986.
- [8] P. G. Fields, Y. S. Xie, and X. Hou, "Repellent effect of pea (*Pisum sativum*) fractions against stored-product insects," J. Stored Products Res., vol. 37, no. 4, pp. 359–370, Oct. 2001.
- [9] M. B. Isman, "Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world," Annu. Rev. Entomology, vol. 51, pp. 45–66, Jul. 2006.
- [10] A. Prakash and J. Rao, Botanical Pesticides in Agriculture. Boca Raton, FL: CRC Press, 1996.
- [11] A. C. Chagas *et al.*, "Efficacy evaluation of a commercial neem cake for control of *Haematobia irritans* on Nelore cattle," Revista Brasileira de Parasitologia Veterinaria, vol. 19, no. 4, pp. 217–221, Oct-Dec. 2010.
- [12] A. T. Showler, "Botanically based repellent and insecticidal effects against horn flies and stable flies (Diptera: Muscidae)," J. Integrated Pest Manage., vol. 8, no. 1, pp. 15–15, Jan. 2017.
- [13] Z. L. Liu and S. H. Ho, "Bioactivity of the essential oil extracted from *Evodia rutaecarpa* Hook f. et Thomas against the grain storage insects, *Sitophilus zeamais* Motsch. and *Tribolium castaneum* (Herbst)," J. Stored Products Res., vol. 35, no. 4, pp. 317–328, Oct. 1999.
- [14] S. Chaudhari, "Herbal control of stored grain pest *Bruchus chinensis* Linnaeus (Coleoptera: Bruchidae)," Int. J. Innovative Res. Develop., vol. 2, no. 3, pp. 397–402, Mar. 2013.
- [15] S. Mahai, G. Y. Jamala, D. A. Mada, and I. A. Medugu, "Assessment of sorghum storage methods in Madagali and Ganye areas of Adamawa state, Nigeria," Int. J. Eng. Sci., vol. 4, no. 10, pp. 1–6, Oct. 2015.
- [16] M. Sagheer *et al.*, "Toxicological and growth regulatory effects of acetone extract oils of indigenous medicinal plants against a stored grain pest, *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Cucujidae)," Pakistan J. Zoology, vol. 48, no. 3, pp. 903–906, May 2016.
- [17] N. L. Sadre, V. Y. Deshpande, K. N. Mendulkar, and D. H. Nandal, "Male antifertility activity of *Azadirachta indica* in different species," in Proc. 2nd Int. Neem Conf., Rauischholzhausen, Germany, 1983, pp. 473–482.
- [18] H. Schmutterer, "Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*," Annu. Rev. Entomology, vol. 35, pp. 271–297, 1990.
- [19] B. S. Siddiqui, F. Afshan, S. Faizi, S. N. H. Naqvi, and R. M. Tariq, "Two new triterpenoids from *Azadirachta indica* and their insecticidal activity," J. Natural Products, vol. 65, no. 8, pp. 1216–1218, Aug. 2002.
- [20] E. R. H. Moor, "Insecticidal plants: physiology and agronomy of rotenone crops," Puerto Rico (Mayaguez) Agr. Expt. Sta. Rpt., vol. 1941, pp. 15–17, 1942.
- [21] N. Ling, Rotenone—a Review of its Toxicity and Use for Fisheries Management, Science for Conservation Series 211. Wellington: Department of Conservation, 2003.
- [22] R. Winney, "Performance of pyrethroids as domestic insecticides," Pyrethrum Post, vol. 13, no. 4, pp. 132–136, 1976.
- [23] K. Polatoğlu *et al.*, "Composition, insecticidal activity and other biological activities of *Tanacetum abrotanifolium* Druce. Essential oil," Ind. Crops Products, vol. 71, no. Supplement C, pp. 7–14, Sep. 2015.
- [24] D. Rees, Insects of Stored Grain: A Pocket Reference. Australia: CSIRO Publishing, 2007.
- [25] A. Musa and M. Dike, "Life cycle, morphometrics and damage assessment of the Khapra beetle, *Trogoderma granarium* Everts (Coleoptera: Dermestidae) on stored groundnut," J. Agricultural Sci. Belgrade, vol. 54, no. 2, pp. 135–142, Jan. 2009.
- [26] L. L. McDonald, R. H. Guy, and R. D. Speirs, "Preliminary Evaluation of New Candidate Materials as Toxicants, Repellents and Attractants against Stored-Product Insect," Marketing Research Report No. 882. Washington, DC: Agricultural Research Service, US Department of Agriculture, 1970.
- [27] F. A. Talukder and P. E. Howse, "Repellent, toxic, and food protectant effects of pithraj, *Aphanamixis polystachya* extracts against pulse beetle, *Callosobruchus chinensis* in

- storage," J. Chemical Ecology, vol. 20, no. 4, pp. 899–908, Apr. 1994.
- [28] W. S. Abbott, "A method of computing the effectiveness of an insecticide," J. Econ. Entomology, vol. 18, no. 2, pp. 265–267, Apr. 1925.
- [29] A. G. Bluman, Elementary Statistics: A Step by Step Approach. New York, NY: McGraw-Hill, 2009.
- [30] H. Tunón, W. Thorsell, A. Mikiver, and I. Malander, "Arthropod repellency, especially tick (*Ixodes ricinus*), exerted by extract from *Artemisia abrotanum* and essential oil from flowers of *Dianthus caryophyllum*," Fitoterapia, vol. 77, no. 4, pp. 257–261, Jun. 2006.
- [31] J. Wei *et al.*, "Plants attract parasitic wasps to defend themselves against insect pests by releasing hexenol," PLoS One, vol. 2, no. 9, p. e852, Sep. 2007.
- [32] L. S. Nerio, J. Olivero-Verbel, and E. Stashenko, "Repellent activity of essential oils: a review," Bioresource Technol., vol. 101, no. 1, pp. 372–378, Jan. 2010.
- [33] M. Ivbijaro, "Groundnut oil as a protectant of maize from damage by the maize weevil, *Sitophilus zeamais*," Protection Ecology, vol. 6, no. 4, pp. 267–270, Jul. 1984.
- [34] K. N. Don-Pedro, "Mode of action of fixed oils against eggs of *Callosobruchus maculatus* (F.)," Pesticide Sci., vol. 26, no. 2, pp. 107–115, Jan. 1989.
- [35] E. Shaaya, M. Kostjukovski, J. Eilberg, and C. Sukprakarn, "Plant oils as fumigants and contact insecticides for the control of stored-product insects," J. Stored Products Res., vol. 33, no. 1, pp. 7–15, Jan. 1997.
- [36] M. K. Mahmud, M. M. H. Khan, M. Husain, M. I. Alam, and M. S. I. Afrad, "Toxic effects of different plant oils on pulse beetle *Callosobruchus chinensis* Linn. (Coleoptera: Bruchidae)," J. Asiatic Soc. Bangladesh: Sci., vol. 28, no. 1, pp. 11–18, Jan. 2002.
- [37] S. Lee, C. J. Peterson, and J. R. Coats, "Fumigation toxicity of monoterpenoids to several stored product insects," J. Stored Products Res., vol. 39, no. 1, pp. 77–85, Jan. 2003.
- [38] C. G. Athanassiou *et al.*, "Insecticidal efficacy of diatomaceous earth against *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) and *Tribolium confusum* du Val (Coleoptera: Tenebrionidae) on stored wheat: influence of dose rate, temperature and exposure interval," J. Stored Products Res., vol. 41, no. 1, pp. 47–55, Jan. 2005.
- [39] M. Asrar *et al.*, "Toxicity and repellence of plant oils against *Tribolium castaneum* (Herbst), *Rhyzopertha dominica* (F.) and *Trogoderma granarium* (E.)," Pakistan Entomologist, vol. 38, no. 1, pp. 55–63, 2016.
- [40] M. M. Cowan, "Plant products as antimicrobial agents," Clinical Microbiology, Rev., vol. 12, no. 4, pp. 564–582, Oct. 1999.
- [41] C. P. Constabel, K. Yoshida, and V. Walker, "Diverse ecological roles of plant tannins: plant defense and beyond," in Recent Advances in Polyphenol Research, A. Romani, V. Lattanzio, and S. Quideau, Eds. West Sussex, UK: John Wiley & Sons, 2011, pp. 115–142.
- [42] A. P. Singh, "Krameria triandra (R. and P.): source of tannin," Ethnobotanical Leaflets, vol. 11, pp. 71–72, 2007.
- [43] L. Chokotho and E. van Hasselt, "The use of tannins in the local treatment of burn wounds - a pilot study," Malawi Medical J., vol. 17, no. 1, pp. 19–20, Jun. 2005.
- [44] F. A. Abushaala, A. R. B. Ramadan, and M. A. S. Fahej, "In vitro antifungal activity of some plant extracts against seed-borne pathogens," IOSR J. Agriculture Veterinary Sci., vol. 10, no. 4, pp. 49–57, Apr. 2017.
- [45] M. Z. Hossain, M. I. Waly, V. Singh, V. Sequeira, and M. S. Rahman, "Chemical composition of date-pits and its potential for developing value-added product-a review," Polish J. Food Nutrition Sci., vol. 64, no. 4, pp. 215–226, Dec. 2014.
- [46] M. Samuel, S. V. Oliver, M. Coetzee, and B. D. Brooke, "The larvicidal effects of black pepper (*Piper nigrum* L.) and piperine against insecticide resistant and susceptible strains of *Anopheles* malaria vector mosquitoes," Parasit Vectors, vol. 9, no. p. 238, Apr. 2016.
- [47] M. Adnan *et al.*, "Proximate and nutrient composition of medicinal plants of humid and sub-humid regions in North-West Pakistan," J. Medicinal Plants Res., vol. 4, no. 4, pp. 339–345, Feb. 2010.
- [48] M. R. Hasan, M. N. Islam, and M. R. Islam, "Phytochemistry, pharmacological activities and traditional uses of *Embolia officinalis*: a review," Int. Current Pharmaceutical J., vol. 5, no. 2, pp. 14–21, Jan. 2016.
- [49] M. Carini, G. Aldini, M. Orioli, and R. M. Facino, "Antioxidant and photoprotective activity of a lipophilic extract containing neolignans from *Krameria triandra* roots," Planta Medica, vol. 68, no. 3, pp. 193–197, Mar. 2002.
- [50] E. Scholz and H. Rimpler, "Proanthocyanidins from *Krameria triandra* root," Planta Medica, vol. 55, no. 4, pp. 379–384, Aug. 1989.
- [51] G. A. F. Dadi, J. L. Tamesse, and F. Boyom, "Adulticidal effects of essential oils extracts from *Capsicum annum* (Solanaceae) *Piper nigrum* (Piperaceae) and *Zingiber officinale* (Zingiberaceae) on *Anopheles gambiae* (Diptera-Culicidae), vector of malaria," J. Entomology, vol. 8, no. 2, pp. 152–163, Feb. 2011.
- [52] N. Kishore, B. B. Mishra, V. K. Tiwari, V. Tripathi, and N. Lall, "Natural products as leads to potential mosquitocides," Phytochemistry Rev., vol. 13, no. 3, pp. 587–627, Sep. 2014.
- [53] M. S. Ahmedani, M. Haque, S. N. Afzal, M. Aslam, and S. Naz, "Varietal changes in nutritional composition of wheat kernel (*Triticum aestivum* L.) caused by Khapra beetle infestation," Pakistan J. Botany, vol. 41, no. 3, pp. 1511–1519, Jun. 2009.
- [54] L. G. Butler, "Effects of condensed tannin on animal nutrition," in Chemistry and Significance of Condensed, R. W. Hemingway and J. J. Karchesy, Eds. New York, NY: Plenum Press, 1988, p. 553.
- [55] S. M. Colegate and R. J. Molyneux, Bioactive Natural Products: Detection, Isolation, and Structural Determination. Boca Raton, FL: CRC Press, 2008.
- [56] P. M. Dewick, Medicinal Natural Products: A Biosynthetic Approach. West Sussex, UK: John Wiley & Son, 2002.