RESEARCH ARTICLE

©2023 The Academy of Environmental Biology, India

Journal of Ecophysiology and Occupational Health, *Vol 25(3), DOI: 10.18311/jeoh/2025/48038, 399-406, September 2025*

ISSN (Online) : 0972-4397
ISSN (Online) : 0974-0805

Efficacy and Toxicity of Four Natural Plants Extracts as Botanical Pesticides Against Pulse Beetle *Callosobruchus chinensis* (L.) (*Coleoptera:Bruchidae*)

Dimpal Bharti and Bhuwan Bhaskar Mishra*

University Department of Zoology, B.N. Mandal University, Madhepura - 852113, Bihar, India; b2mishra123@gmail.com

Abstract

The plant extracts were extracted by water distillation method from four natural plants products, and its repellent activity and toxicity was investigated against the cowpea weevil, *Callosobruchus chinensis* F. (*Coleoptera: Bruchidae*), is an important pest of stored commodities. For repellency and toxicity assay, the plant extracts were applied on filter paper for testing their efficacy and toxicity against *C. chinensis* in laboratory condition. All four plant extracts were shows repellency with highest repellent activity was 94.4% ($\chi 2$ value=3.934) ($P<0.05$) against *Tridax procumbens* followed by *Citrus sinensis* (92.8 %), *Rauwolfia serpentine* (90.0 %) and *Curcuma longa* (84.8 %) at 0.20% concentration and minimum LC_{50} were recorded 10.35µl and 12.35 µl with *T. procumbens* against larvae and adults of *C. chinensis* after 48 hr. exposure. Therefore, from the present study it can be concluded that these essential oils can be suggested for controlling *C. chinensis* in storage systems. **Major Findings:** From the present investigation, it can be suggested that natural plant extracts in form of volatile essential oils could have greater potential compared to other insecticides. It could further reduce the application of synthetic pesticides.

Keywords: *C. chinensis*, Lethality, Plant Extracts, Repellency, Toxicity

1. Introduction

Storage of food grains started as a safeguard against poor harvests and famine with the beginning of agricultural practices[1,2]. Simultaneously, the grain pests cause significantly qualitative and quantitative harm to stored grain[3]. In recent years, the global concern is the impact of the activities of pests on the stored products and their production by farmers all over the world. It is estimated that the annual crop losses due to pests is 35 to 40 % world-wide during storage depending on traditional storage technologies and has created a major problem in grain storage[4-6]. Among the insect pests attacking stored pulses, the pulse beetle *Callosobruchus chinensis* L., frequently found in humid tropical region of the world majority in Asian country and notable pest for pulses, chick pea, green grams, cow pea that cause huge quantitative and qualitative losses and decrease the nutritional value of pulses[7-10]. Therefore, protection of stored-grain agricultural products from insect infestation is quite essential.

To mitigate the economic damage many insecticides have been used for managing stored-grain insect pests for a long time but many insects have acquired resistance against various synthetic pesticides[11,12]. The uncontrolled use of these synthetic pesticides caused negative effects owing to their repeated use in last decades that affects non-targeted animals like humans[13-15]. Hence, there is

*Author for correspondence

Article Received on: 03.01.2025 Revised on: 10.02.2025 Accepted on: 11.02.2025

urgent need to develop an of alternative of these synthetic chemical pesticides for safe with effective, biodegradable pesticides with no toxic effect on non-target organisms. Recently the researchers have focused towards the use of plant based pesticides for control of stored grain insect pests[8,16,17].

Many plants which constitute a rich source of bioactive chemicals are known to have different activity against stored grain insect pests[18-21]. From the last two decades, botanical pesticides as natural products that are largely free from adverse effects have been used for insecticidal activities against stored-grain insect pests. Many plants are known to have different activity against stored grain insect pests. The plant extracts in form of essential oils are secondary metabolites having insecticidal property reported by earlier researchers and these are non-hazardous to human being and safe for environment[22,23]. The insecticidal activity of essential oils against different stored-product pests has been evaluated and regarded as environmentally compatible[24,25].

In previous findings by different researchers tested insecticidal activity of *Rutaceae, Asteraceae, Zingiberaceae* and *Apocynaceae* family against different pests[26,27]. In the previous study, the insecticidal, antibacterial, antifungal activities of *Tridax procumbens, Citrus sinensis, Rauwolfia serpentina* and *Curcuma longa* plants have been evaluated with their medicinal value[28-31].

Keeping the above facts in view, the present study was undertaken to test the repellent and toxic activity of these natural plant products against the pulse beetle on black gram seeds that cause very high losses reaching 50% after 6 month storage without any mammalian toxicity.

2. Materials and Methods

2.1 Plant Collection and Isolation of Plants Extracts

The *T. procumbens, R. serpentina* and *C. longa* leaves as well as the *C. sinensis* peel had been collected from the local area of Madhepura district of Bihar situated in the Plains of River Koshi located in the Northeastern part of Bihar at latitude between 25°.34 to 26°.07 and longitude between 86°.19 to 87°.07 and identified by University Department of Botany, BNMU Madhepura for insecticidal activity (Table 1). After being allowed to dry at room temperature (30±5°C) without exposure to sunlight, leaves and peels had been crushed by a domestic mixer. The essential oils have been extracted by hydro-distillation method by using modified Clevenger equipment. 5 hours of continuous distillation had been conducted for extraction of essential oils. Water was removed utilizing anhydrous sodium sulphate. After being extracted from the condenser, they are placed in glass containers, the superior phase was kept at 5°C in an appendorff tube until it was needed for future investigation.

2.2 Insect Rearing

The stock cultures of *C. chinensis* have been kept in incubator at 30±2°C temperature, 75±5 per cent RH, as well as a photoperiod of 10:14 (L:D) without being exposed to any pesticides. Adult insects had been reared on *Vigna unguiculata* with a moisture level of 12-13 %. The unsexed adults of *C. chinensis* were used to determine the efficacy and toxicity of plant extracts.

2.3 Repellent Activity

Repellency assay was carried out in a Y-shaped glass tube (each arm with diameter of 20 cm and 25 cm length). 40 cowpea seeds with mixed different concentrations of leaf and peel of oils were placed in Y-tube-like paired arms in which one (experimental) arm and the other (control) arm contained only crushed rice. 40 numbers of insects of *C. chinensis* were introduced through the median arm of the Y-tube. The open ends of the median arm were plugged with cotton and the experimental set up was kept for observation.

The number of insects present in the experimental, control and median arms was counted after 4 h. Each concentration was replicated six times. Percent Repellency (PR) was calculated using formula: $PR = [(N_{UT} - N_T / N_{UT}+N_T] 100$,

where N_{UT}= number of insects in control and N_T= number of insects in experiment.

2.4 Larval and Adult Mortality

The essential oils of leaf and peels were used for testing their toxicity in a solution made in acetone. 25 adults and third instar larvae of *C. chinensis* collected from laboratory culture placed in a glass vials (15 cm height 10cm diameter) floored by Whatman filter paper No. 1. A paper strip (2 cm^2 diameter) treated with different concentrations was pasted on the inner surface of the glass

Table 1. Images and botanical description of selected plants parts

Sl. No.	Image	Botanical Description
1		Order- *Asterales* Family- *Asteraceae* Genus- *Tridax* Species- *T. procumbens* Parts used- Leaves
2		Order- *Sapindales* Family- *Rutaceae* Genus- *Citrus* Species-*C. sinensis* Parts used- Peels
3		Order- *Gentianales* Family- *Apocynaceae* Genus- *Rauwolfia* Species- *R. serpentine* Parts used- Leaves
4		Order- *Zingiberales* Family- *Zingiberaceae* Genus- *Curcuma* Species- *C. longa* Parts used- Leaves

cover of each glass vial. The treated filter was covered with wire mesh to avoid contact of the treated filter with the test. Finally, the glass vials were covered by a glass cover and sealed with parafilm. During 48 h of experiment the six replicates of each concentration of glass were kept in dark and after this the treated adults were transferred to a fresh glass jar of similar measurement. After 48 h of exposure, mortality in adults and larvae was recorded. In control, untreated filter paper was used.

2.5 Data Analysis

In accordance with Sokal and Rohlf, a chi-square test had been employed to determine essential oils repelling properties[32]. Robertson's computer software was utilized for determining g-value heterogeneity factor, Median Lethal Concentration (LC_{50}), t-ratio, LCL-UCL (Lower and Upper Confidence Limits), chi-square value, as well as slope value[33]. All dose-response associations had been defined utilizing correlation and linear regression

analysis. The equality of the regression coefficient was tested utilizing analysis of variance[32].

3. Results

In repellency assay, the repellent action of the *T. procumbens, C. sinensis, R. serpentina* and *C. longa* plant extracts was tested against *C. chinensis*. At highest concentration (0.20%) the *T. procumbens, C. sinensis, R. serpentina* and *C. longa* plant extracts showed 94.4, 92.8, 90.0, and 84.3 % repellency respectively after 4 hr against *C. chinensis* (Table 2).

Fumigant toxicity of the plant extracts from *T. procumbens, C. sinensis, R. serpentina* and *C. longa* against larvae and adults of *C. chinensis* gradually increased with increasing exposure time and concentration ($P<0.01$). The Median Lethal Concentration (LC_{50}) against larvae of *C. chinensis* was 10.35 µl against *T. procumbens* followed by *C. sinensis* (11.42 µl), *R. serpentine* (13.60 µl) and *C. longa* (14.39 µl) after 48 hr respectively (Table 3).

The medium Lethal Concentration (LC_{50}) against adults of *C. chinensis* was 12.32 µl against *T. procumbens* followed by *C. sinensis* (15.47 µl), *R. serpentine* (16.87 µl) and *C. longa* (18.33 µl) after 48 hr respectively (Table 3).

Each dose response line exhibited substantial regression when t-ratio values had been >1.96. Model matched the data because heterogeneity factor had been <1.0, indicating that log-dose-probit lines have been within 95 % confidence bounds. Mean had been within the limit at all 90, 95, as well as 95 % confidence levels when value of g had been <0.5.

Regression analysis revealed that *T. procumbens* ($F_{3,20}$=132.31, $F_{3,20}$=121.33) followed by ($F_{3,20}$=114.04, $F_{3,20}$=124.41),($F_{3,20}$=131.83, $F_{3,20}$=146.79), ($F_{3,20}$=109.25, $F_{3,20}$=106.32) with *C. sinensis, C. longa* and *R. serpentine* against *C. sinensis* had a concentration-dependent substantial positive correlation with ($P<0.001$) respect to adult and larval mortality at 48 hr. (Table 4).

Table 2. Repellency caused by *T. procumbens, C. sinensis, R. serpentina* and *C. longa* plant extracts against adults of *C. Chinensis* after four hours in filter paper test

Plant Extract	Concentration (%) Vol	Percent Repellency (PR)* Mean+SE	Preference Index (PI)**	P-Value	Chi-Square Value
T. procumbens	0.05 µl	61.2±0.66	-0.61	0.2242	1.477^{NS}
	0.10 µl	71.2±1.15	-0.71	0.0222	5.228^{S}
	0.15 µl	81.6±1.28	-0.81	0.0029	8.845^{S}
	0.20 µl	94.49±0.37	-0.94	0.0473	3.934^{S}
C. sinensis	0.05 µl	60.8±1.06	-0.60	0.0504	3.828^{NS}
	0.10 µl	70.4±1.20	-0.70	0.0188	5.521^{S}
	0.15 µl	83.2±0.24	-0.83	0.0034	8.604^{S}
	0.20 µl	92.08±0.58	-0.92	0.0436	4.072^{S}
R. serpentina	0.05 µl	64.8±0.86	-0.64	0.1071	2.597^{NS}
	0.10 µl	69.6±0.81	-0.69	0.1142	2.495^{NS}
	0.15 µl	82.4±0.87	-0.82	0.0407	4.190^{S}
	0.20 µl	90.0±0.80	-0.90	0.0322	4.587^{S}
C. longa	0.05 µl	53.6±0.81	-0.53	0.0140	2.124^{NS}
	0.10 µl	61.6±0.50	-0.61	0.3485	0.879^{NS}
	0.15 µl	73.6±1.12	-0.73	0.0227	5.189^{S}
	0.20 µl	84.8±0.96	-0.84	0.0157	5.835^{S}

The repellent activity was calculated by using formula:

$PR = [(N_{UT} - N_T / N_{UT} + N_T] 100$,

where N_{UT}=numberof insects in control area and N_T= numberof insects in experimental area.

NS: Not significant as the calculated values of χ^2 were less than the table values at probability levels 99%. S: Significant at probability levels 99%.

**Preference Index (PI)= (Percentage of insects in treated halves-percentage of insect in untreated halves)/(Percentage of insects in treated halves-percentage of insect in untreated halves).

Table 3. Summary of *T. procumbens, C. sinensis, R. serpentina* and *C. longa* plant extracts on toxicity assays against adult of *C. chinensis* after 48 hrs

Plant Extract	Parameters	Exposure period (hr)	[a]LC_{50} (µl)	LCL-UCL[b]	g-value[c]	t-ratio[c]	Heterogeneity[c]	Chi square
T. procumbens	Larval mortality	48 hr	10.35 µl	09.32-12.27	0.14	6.29	0.261	14.967
	Adult mortality	48 hr	12.35 µl	11.07-13.01	0.34	2.93	0.346	7.336
C. sinensis	Larval mortality	48 hr	11.42 µl	1.38-12.93	0.17	6.25	0.373	9.832
	Adult mortality	48 hr	15.47 µl	14.9-16.30	0.29	3.76	0.366	3.885
R. serpentine	Larval mortality	48 hr	13.6 µl	12.72-14.33	0.31	4.23	0.338	8.545
	Adult mortality	48 hr	16.87 µl	15.33-17.89	0.14	5.75.	0.311	5.442
C. longa	Larval mortality	48 hr	14.39 µl	13.22-16.56	0.63	6.01	0.292	.3578
	Adult mortality	48 hr	18.33 µl	14.73-21.33	0.23	4.03	0.249	5.639

[a]LC_{50} represent the median lethal concentration. [b]UCL and LCL represent upper confidence limit and lower confidence limit. [c]g-value, t-ratio and heterogeneity were significant at all probability levels (90%, 95%, 99%).

Table 4. Regression parameters of lethal activity on stored-grain insect pest *C. chinensis* with *T. procumbens, C. sinensis, R. serpentina* and *C. longa* plant extracts by fumigation method

Treatment	Mortality	Intercept	Slope	Regression Equation	Regression Coefficient	F-value
T. procumbens	Larval	-6.922	3.913	Y=-6.922+3.913X	0.922	132.31
	Adult	-9.459	4.032	Y=-9.459+4.032X	0.999	121.33
C. sinensis	Larval	-5.812	3.075	Y=-5.812+3.075X	0.966	114.04
	Adult	-9.976	4.893	Y=-9.976+4.893X	0.997	124.41
R. serpentina	Larval	-6.732	4.665	Y=-6.732+4.665X	0.995	131.83
	Adult	-4.535	4.137	Y=-4.535+4.137X	0.979	146.79
C. longa	Larval	-4.813	3.861	Y=-4.813+3.861X	0.933	109.25
	Adult	-3.184	4.478	Y=-3.184+4.478X	0.994	106.32

Regression analysis revealed that various concentrations of plant extracts and responses of the insect pest. *Significant at 99% probability level. *F values were significant (90, 95 and 99%) at all probability levels.

4. Discussion

Plants extracts as botanical pesticides have an insecticidal activity and play an important role in Insect Pest Management (IPM)[34]. They have considerable potential as stored product protectants.

The plant extracts are monoterpenoids having fumigant activity due to their volatile nature and play an important role for management of insect pests[35-38]. The repellent activity of plant extracts is generally attributed to some particular compound[39,40]. The results from previous works indicating that all constituents present in extracts have repellent activity with conferring bioactivity to natural mixture. Previous research by different workers demonstrated and corroborates the finding that plant extracts has insecticidal activity against insect pests[8,12,40]. The essential oils can vary in quality, quantity and in chemical composition according to the process of distillation climate, soil composition, plant organ, age[41,42].

In the present investigation the plant extracts of *T. procumbens, C. sinensis, R. serpentina* and *C. longa* were significantly (P<0.05) repellent at very low concentration after 4 hr exposure period against pulse beetle *C. chinensis*. The repellent effect of plant extract has an important contribution in the repelling of pests during storage after post-harvest of the crops. Due to its specification, it is an important candidate for the management of insects during storage of grains. This result was similar to earlier workers who found that the plant extracts have insecticidal activity against *C. chinensis*[43-46].

In the present study, leaf and peel oils repelled adults and caused acute toxicity in adults as well as larvae of *C. chinensis*. The repellent and rapid toxicity of the essential oils is caused due to vapour action showing their low persistence in the environment and probable nurotoxicity[47]. Several essential oils have been known for their neurotoxicity in insect pests[48].

The rapid action and toxicity of the plant extracts indicating that the response was concentration and time dependent due to increased toxicity with an increase in concentration at different grade exposure periods. All the above findings clearly support the result of the present study.

In conclusion, to reduce the negative effects of synthetic pesticides, there is a need to emphasize on the development and widespread use of natural pesticides and insects will not be able to develop resistance against these plant based pesticides. These botanical pesticides are biodegradable with no mammalian toxicity. Therefore, from the results of the present study it is concluded that the plant extracts used in this study play an important role as good alternative to pesticides against *C. chinensis*.

5. References

1. Jayas DS. Storing grains for food security and sustainability. Agric Res. 2012; 1:21-24. https://doi.org/10.1007/s40003-011-0004-4
2. Mobolade AJ, Bunindro N, Sahoo D, Rajashekar Y. Traditional methods of food grains preservation and storage in Nigeria and India. Ann Agric Sci. 2019; 64(2):196-205. https://doi.org/10.1016/j.aoas.2019.12.003
3. Stathas IG, Sakellaridis AC, Papadelli M, Kapolos J, Papadimitriou K, Stathas GJ. The effects of insect infestation on stored agricultural products and the quality of food. Foods. 2023; 12(10):2046. PMID: 37238864. PMCID: PMC10217422. https://doi.org/10.3390/foods12102046
4. Bouchelos KT. Insects of warehouses and food. Embryo Publications. 2018: pp. 133.
5. Perera AGWU, Karunaratne MMSC, Chinthaka SDM. Insecticidal activity of bis (methylthio) methane based volatile extract of *Olax zeylanica* (L.) against *Sitophilus zeamais* (L.) and *Corcyra cephalonica* (Stainton). Ind Crop Prod. 2021; 169:113635. https://doi.org/10.1016/j.indcrop.2021.113635
6. Kumar RR, Bhargava DV, Pandit K, Goswami S, Shankar SM, Singh SP, Rai GK. Satyavathi CT, Praveen S. Lipase-The fascinating dynamics of enzyme in seed storage and germination-A real challenge to pearl millet. Food Chem. 2021; 361:130031. https://doi.org/10.1016/j.foodchem.2021.130031
7. Ragul S, Manivannan N. Bruchid a serious pest on pulse crops: Its control measures and breeding advancements: A review. Agric Rev. 2024; 45(2):290-296. https://doi.org/10.18805/ag.R-2307
8. Singh D, Boopathi T. *Callosobruchus chinensis* (*Coleoptera: Chrysomelidae*): Biology, life table parameters, host preferences, and evaluation of green gram germplasm for resistance. J Stored Prod Res. 2022; 95:101912. https://doi.org/10.1016/j.jspr.2021.101912
9. Atwal AS. Insect pests of stored grain and other stored products. Agricultural pests of India and South East Asia. 1976: pp. 389-415.
10. Sharma P, Pandya P, Parikh P. Elucidating the host preference by the Pulse *Callosobruchus chinensis* (L). Indian J Entomol. 2023; 86(2):565-568. https://doi.org/10.55446/IJE.2023.778
11. Champ BR, Dyte CE. Report of the FAO global survey of pesticides susceptibility of stored grain pests. NSP. 1976; 5):257.
12. Zettler JL, Cuperus GW. Pesticide resistance in *Tribolium castaneum* (*Coleoptera*: *Tenebrionidae*) and *Rhyzopertha dominica* (*Coleoptera: Bostrichidae*) in wheat. Jof Econ Entomol. 1990; 83(5):1677-1681. https://doi.org/10.1093/jee/83.5.1677
13. Simoniello MF, Kleinsorge EC, Scagnetti JA, Grigolato RA, Poletta GL, Carballo MA. DNA damage in workers occupationally exposed to pesticide mixtures. J Appl Toxicol. 2008; 28(8):957-965. https://doi.org/10.1002/jat.1361
14. Pathak VM, Verma VK, Rawat BS, Kaur B, Babu N, Sharma A, Dewali S, Yadav M, Kumari R, Singh S, Mohapatra A, Pandey V, Rana N and Cunill JM. Current status of pesticide effects on environment, human health and it's eco-friendly management as bioremediation: A comprehensive review. Front Microbiol. 2022; 13:962619. https://doi.org/10.3389/fmicb.2022.962619

15. Ahmad MF, Ahmad FA, Alsayegh AA, *et al*. Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures. Heliyon. 2024; 10(7):e29128. https://doi.org/10.1016/j.heliyon.2024.e29128
16. Owolabi MS, Camberos EP, Ogundajo AL, Ogunwande IA, *et al*. Insecticidal activity and chemical composition of the *Morinda lucida* essential oil against pulse beetle *Callosobruchus maculatus*. Sci World J. 2014; 784613. PMID: 25143991. PMCID: PMC4131103. https://doi.org/10.1155/2014/784613
17. Pipariya G, Sharma P, Pandya N, Parikh P. Insecticidal activity of essential oils from Mint and Ajwain against Pulse Beetle *Callosobruchus chinensis* (L). Indian J Entomol. 2022; 85(1):229-233. https://doi.org/10.55446/IJE.2022.800
18. Mishra BB, Tripathi SP. Repellent activity of plant derived essential oils against *Sitophilus oryzae* (*Linnaeus*) and *Tribolium castaneum* (*Herbst*). SJSR. 2011; 1(2):173-178. https://doi.org/10.3923/sjsres.2011.173.178
19. Mishra BB, Tripathi SP, Tripathi CPM. Response of *Tribolium castaneum* (Coleoptera: Tenebrionidae) and Sitophilus oryzae (Coleoptera: Curculionidae) to potential insecticide derived from essential oil of *Mentha arvensis* leaves. Biol Agric Hortic. 2012; 28(1):34-40. https://doi.org/10.1080/01448765.2012.662792
20. Kumar R, Tiwari SN. Fumigant toxicity of essential oils against *Corcyra cephalonica* and *Sitotroga cerealella*. Environ Ecol. 2018; 36(1):33-37.
21. Akarca G, Sevik R. Biological activities of *Citrus limon* L. and *Citrus sinensis* L. peel essential oil. J Essent Oil-Bear Plants. 2021; 24(6):1415-1427. https://doi.org/10.1080/0972060x.2021.2022000
22. Twaij, BM, Hasan MN. Bioactive secondary metabolites from plant sources: Types, synthesis, and their therapeutic uses. *Int J Plant Biol. 2022;* 13(1):4-14. https://doi.org/10.3390/ijpb13010003
23. Divekar PA, Narayana S, Divekar BA, Kumar R, *et al*. Plant secondary metabolites as defense tools against herbivores for sustainable crop protection. Int J Mol Sci. 2022; 23(5):2690. PMID: 35269836. PMCID: PMC8910576. https://doi.org/10.3390/ijms23052690
24. Demeter S, Lebbe O, Hecq F, Nicolis SC, Kenne Kemene T, Martin H, Fauconnier ML, Hance T. Insecticidal activity of 25 essential oils on the stored product pest, *Sitophilus granarius*. Foods. 2021; 10(2):200. PMID: 33498233. PMCID: PMC7909281. https://doi.org/10.3390/foods10020200
25. Yang Y, Isman MB, Tak JH. Insecticidal activity of 28 essential oils and a commercial product containing *Cinnamomum cassia* bark essential oil against *Sitophilus zeamais* Motschulsky. 2020; 11(8):474. https://doi.org/10.3390/insects11080474
26. Khan S, Taning CNT, Bonneure E. *et al.* Insecticidal activity of plant-derived extracts against different economically important pest insects. Phytoparasitica. 2017; 45:113-124. https://doi.org/10.1007/s12600-017-0569-y
27. Sridhar PS, Prabhakaran VS, Ammar BA, Ramji K, Narayanaswamy R, Sengottayan SN, Kandasamy K, Nainarpandian C, Sengodan K, Raja G, *et al*. Bioactive molecules derived from plants in managing Dengue vector *Aedes aegypti* (Linn.). *Molecules. 2023;* 28(5):2386. https://doi.org/10.3390/molecules28052386
28. Etebu E, Nwauzoma AB. A review on sweet Orange (*Citrus Sinensis* Osbeck): Health, diseases, and management. AJRC. 2014; 2(2):33-70.
29. Ingole VV, Mhaske PC, Katade SR. Phytochemistry and pharmacological aspects of *Tridax procumbens* (L.): A systematic and comprehensive review. Phytomedicine Plus. 2022; 2(1):100199. https://doi.org/10.1016/j.phyplu.2021.100199
30. Alshahrani MY, Rafi Z, Alabdallah NM, Shoaib A, Ahmad I, Asiri M, Zaman GS, Wahab S, Saeed M, Khan S. A comparative antibacterial, antioxidant, and antineoplastic potential of *Rauwolfia serpentina* (L.) leaf extract with its biologically synthesized gold nanoparticles (R-AuNPs). Plants. 2021; 10(11):2278. PMID: 34834641. PMCID: PMC8617663. https://doi.org/10.3390/plants10112278
31. Emeka JI, Miracle EU, Emmanuel DD, Lotanna RE, *et al*. *Curcuma longa* (Turmeric): Ethnomedicinal uses, phytochemistry, pharmacological activities and toxicity profiles- A review. Pharmacol Res - Mod Chin Med. 2023; 6:100222. https://doi.org/10.1016/j.prmcm.2023.100222
32. Sokal RR, Rohlf FJ. Introduction to biostatistics. Dover Publications Inc. 1973.
33. Robertson JL, Russell RM, Preisler HK, Savin NE. Bioassay with arthropods POLO Computer programme for analysis of bioassay data. 2nd Edition. CRC Press, Talor and Francis; 2007. p. 1-224.
34. Lengai GMW, Muthomi W, Mbega ER. Phytochemical activity and role of botanical pesticides in pest management for sustainable agricultural crop production. Sci Afr. 2020; 7:e00239. https://doi.org/10.1016/j.sciaf.2019.e00239
35. Huang Y, Chen SX, Ho SH. Bioactivities of methyl allyl disulfide and diallyl trisulfide from essential oil of garlic to two species of stored-product pests, *Sitophilus zeamais* (Coleoptera: Curculionidae) and *Tribolium castaneum* (Coleoptera: Tenebrionidae). J Econ Entomol. 2000; 93(2):537-543. https://doi.org/10.1603/0022-0493-93.2.537
36. Batish DR, Singh HP, Kohli RK, Kaur S. Eucalyptus essential oil as a natural pesticide. For Ecol Manaage.

2008; 256(12):2166-2174. https://doi.org/10.1016/j.foreco.2008.08.008

37. Cosimi S, Rossi E, Cioni PL, Canale A. Bioactivity and qualitative analysis of some essential oils from Mediterranean plants against stored-product pests: Evaluation of repellency against *Sitophilus zeamais* Motschulsky, *Cryptolestes ferrugineus* (Stephens) and *Tenebrio molitor* (L.). J Stored Prod Res. 2009; 45(2):125-132. https://doi.org/10.1016/j.jspr.2008.10.002
38. Mishra BB, Tripathi SP, Tripathi CPM. Bioactivity of two plant derived essential oils against the Rice Weevils *Sitophilus oryzae* (L.) (*Coleoptera: Curculionidae*). Proc Natl Acad Sci India Sect B Biol Sci. 2023; 83(2):171-175. https://doi.org/10.1007/s40011-012-0123-0
39. Nerio LS, Verbel JO, Stashenko E. Repellent activity of essential oils: A review. Bioresour Technol. 2010; 101(1):372-378. https://doi.org/10.1016/j.biortech.2009.07.048
40. Asadollahi A, Khoobdel M, Ramazani AZ. *et al.* Effectiveness of plant-based repellents against different *Anopheles* species: A systematic review. Malaria J. 2019; 18:436. https://doi.org/10.1186/s12936-019-3064-8
41. Sousa DP, Damasceno ROS, Amorati R, Elshabrawy HA, Castro RD, Bezerra DP, Nunes VRV, Gomes RC, Lima TC. Essential oils: Chemistry and pharmacological activities. Biomol. 2023; 13(7):1144. PMID: 37509180. PMCID: PMC10377445. https://doi.org/10.3390/biom13071144
42. Fokou JBH, Dongmo PMJ, Boyom FF. Essential oil's chemical composition and pharmacological properties. Essential Oils - Oils of Nature. 2020. http://dx.doi.org/10.5772/intechopen.86573
43. Pandey AK, Palni UT, Tripathi NN. Repellent activity of some essential oils against two stored product beetles *Callosobruchus chinensis* L. and *C. maculatus* F. (*Coleoptera*: *Bruchidae*) with reference to *Chenopodium ambrosioides* L. oil for the safety of pigeon pea seeds. J Food Sci Technol. 2014; 51:4066-4071. https://doi.org/10.1007/s13197-012-0896-4
44. Swamy G, Wasley BJ. Bioefficacy of some botanicals as grain protechtants against *Callosobruchus maculates* (F.) infesting stored blackgram. India J Ecol. 2017; 446:663-666.
45. Kaur DK, Verma SC, Sharma PL. Efficacy of plant powders against Pulse Beetle, *Callosobruchus chinensis*. L. infesting pea seed. J Entomol Zool Stud. 2019; 7(1):737-741.
46. Jayaram CS, Chauhan N, Dolma SK, Reddy SGE. Chemical composition and insecticidal activities of essential oils against the Pulse Beetle. *Mol.* 2022; 27(2):568. https://doi.org/10.3390/molecules27020568
47. Agrahari P, Singh VK, Singh DK. Toxicity of snail attractant pellets containing eugenol with respect to abiotic factors against the vector snail *Lymnaea acuminata*· Biol Agric Hortic. 2012; 28(3):156-166. https://doi.org/10.1080/01448765.2012.712903
48. Priestley CM, Williamson EM, Wafford KA, Sattelle DB. Thymol a constituents of thyme essential oil is a positive allosteric modulator of human GABA receptors and a homo-oligomeric GABA receptors from *Drosophila melanogaster*. Braz J Pharmacol. 2003; 140(8):1363-1327. https://doi.org/10.1038/sj.bjp.0705542

Access this journal online	
Website: http://www.informaticsjournals.co.in/index.php/JEOH/index	**Quick Response Code**