Phytochemical Screening, Ftir and Insecticidal Effect of Sapindus Mukrossi Against Callosobruchus Analis (Chrysomelidae: Coleoptera) Infesting Stored Vigna Radiata

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PHYTOCHEMICAL SCREENING, FTIR AND INSECTICIDAL EFFECT OF *SAPINDUS MUKROSSI* AGAINST *CALLOSOBRUCHUS ANALIS* (CHRYSOMELIDAE: COLEOPTERA) INFESTING STORED *VIGNA RADIATA*

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ABSTRACT

The *Callosobruchus analis* (F.) is one of the major pests of genus *Callosobruchus* belonging to the family Bruchidae. It exclusively attacks seeds of the family Leguminosae in stores and is hence responsible for great economic loss to farmers. To protect stored grains against *C. analis* pest populations, farmers use a variety of chemical pesticides and insecticides. These chemical insecticides are not safe for human consumption as they cause serious health hazards and also pose a serious threat to the environment. Therefore, to avoid the negative effects of chemical pesticides, it is necessary to adopt more efficient alternatives that are nonhazardous and environment friendly. One of the alternatives is the use of naturally derived insecticides, such as plant extracts. These plant extracts are also beneficial in preventing the development of pest resistance due to the presence of bioactive compounds. Hence, in the present study, the laboratory experiments were conducted to test the efficacy of four extracts of *Sapindus mukrossi,* namely, petroleum ether, chloroform, ethanol, and aqueous, against *C. analis* infesting the seeds of *Vigna radiata.* These results suggest that *S. mukrossi* fruit contains bioactive compounds with insecticidal properties, as confirmed by phytochemical screening of extracts and FTIR analysis of powder. The studies on the insecticidal effects of these extracts reveal that these plant extracts show a significant level of adult mortality, reduced oviposition by female adult *C. analis*, and reduced F1 adult emergence from infested seeds of *V. radiata*.

Keywords: Chemical insecticide, Plant extracts, *Callosobruchus*, Adult mortality, Botanicals

INTRODUCTION

Pulses belonging to the genus *Vigna* are the main source of protein for the majority of Indian populations. Due to uncontrolled environmental conditions and inadequate warehousing storage facilities, a large number of stored grain insect pests infest the food grains in farmer stores, domestic storage, and public warehouses. Improper storage practices over a prolonged duration of pulses lead to the infestation of many species of stored grain insects. Among stored grain insects, the bruchids, also known as pulse beetles, are a major category of insect pests that infest pulses in both the field and storage (Ramzan *et al.,* 1990)

Bruchids are small insects (1-6 mm) belonging to the sub-family Bruchinae (Chrysomelidae: Coleoptera), comprising approximately 1700 species which have been categorized into 62 genera. Out of these, 20 species are recognized as devastating storage pests in different pulse crops (Southgate, 1979, Pajni and Gupta 2012, and Mishra *et. al,* 2017). In India, 108 bruchid species, belonging to 11 genera have been reported so far. Out of these, the species of genus *Callosobruchus* are considered the most common and destructive pest of stored grains (Pajni and Gupta 2012, Bhalla *et.al* 2006).

Among the three major store pest species of *Callosobruchus*, *Callosobruchus analis* is widespread in distribution and infests the seeds belonging to 15 different genera, including soya beans, peanuts, chickpeas, beans, peas, pulses, and cowpeas (Pajni and Gupta, 2012).

To control the effect of these pests, the insect pest control strategies in stores rely heavily on the use of chemical insecticides and fumigants, as it is more effective than other alternatives (Dent, 1991). However, the continuous use of chemical insecticides for control of stored insect pests has led to problems such as environmental pollution, pest resurgence, insect resistance, and lethal effects on non-target organisms in addition to posing health risks to the users (Rajendra S., 2003; Prasanthi *et al*., 2017). Therefore, over the last few decades, the use of plant material for grain preservation has been considered as a promising alternative to synthetic insecticides (Boeke *et al*., 2004).

In several regions of the world, using naturally available plant materials to protect agricultural products from various insect pests is an ancient tradition. Furthermore, as botanicals are biodegradable and do not cause health hazards, therefore, they are favored as an alternative technique for the management of insect pests in both big and small storage spaces.

The researchers have assessed the efficacy of these plant-based products on various parameters like insect mortality, repellency, oviposition deterrence, larvicidal, and pupaecidal activity on the stored grain pests. A number of plant products have been successfully tried as protectants against various stored grain insect pests by various workers (Gill *et al*., 1971; Pandey *et al*., 1986; Dixit *et al*., 1990; Kumari *et al*., 1998; Verma *et al*., 1999; Kim *et al*., 2003 and Airi *et.al,* 2024).

Therefore, in light of the above observations, the present study has been designed with the aim of assessing the efficacy of the fruits of *S. mukrossi*. Additionally, the phytochemicals present in *S. mukrossi* have been screened from the extracts of fruit powder using various solvents. To have a clear understanding of the functional groups and secondary metabolites present in these extracts, the Fourier transform infrared (FTIR) analysis has been performed.

MATERIAL AND METHODS

Preparation of plant material

The fruits of *S. mukrossi* used for the study were collected and shade-dried for 2-3 weeks. The dried fruit (excluding the seed) was ground into a fine powder using a mixer grinder and then stored in a transparent zip-lock bag.

Preparation of plant extract

The extract was prepared with the Maceration extraction method given by Abubakar and Haque (2020). The extracts were prepared using four different solvents, namely, petroleum ether, chloroform, ethanol, and water. 20g of test plant material was mixed with 100 ml of each solvent in a flask. The powder of *S. mukorossi* fruits was extracted four times with petroleum ether, chloroform, ethanol, and water. The flask was tightly capped for 72 hours at room temperature. The flask was shaken at least twice and thrice a day to dissolve the plant material and to release the plant constituents in the solvent. The extracts of different solvents were filtered with the help of a muslin cloth, and the filtrate was evaporated at room temperature. After complete evaporation of solvents, crude extracts were weighed and preserved in cellophane bags at 5 ^{0}C until used for further investigation.

Experimental design for contact toxicity test

The plant extract at 3 % concentration was coated on the inner surface and the inner surface of cap of the jar. The other jar was kept as a control in which no extract treatment was given. The solvents were allowed to evaporate for 5 minutes. Five pairs of bruchids were introduced into the jar, and the cap was tightened. The jars were incubated for 24 hours, and five pairs of bruchids were shifted to fresh jars containing 100 grams of moong seeds. The experiment was performed in five replicates, with each extract at 3 % concentration. These experimental jars were kept in BOD under controlled conditions of temperature and humidity.

Characterization

FTIR spectra of the material were recorded on a Fourier Transform Infrared Spectroscope (FTIR Nicolet 5700, Thermo Corp.). The scanning range for the sample was 400–4000 cm–1.

RESULTS

I. Efficacy of plant extracts

The data collected for the effect of plant extracts on the adult mortality of bruchids was subjected to **Two-way Analysis of Variance ANOVA (univariate and multivariate**) and the mean differences were compared by **Duncan's Multiple Range Test (DMRT**), using SPSS software.

The percentage of adult mortality was calculated using the formula: -

$$\textbf{\%age of mortality} = \frac{\textbf{Number of dead bruchids}}{\textbf{Total number of bruchids}} \textbf{ x 100}$$

a) Effect of plant extracts on the mortality of *C. analis* adults:

The results for the insecticidal activity of *S. mukrossi* fruit extract on the mortality of *C. analis* infested *V. radiata* seeds were recorded at different time intervals, i.e., after 2, 4, 6, and 7th days after infestation (DAI). Table 1 indicates that petroleum ether extracts proved to be most effective, as it caused 100 % mortality followed by chloroform, ethanol, and aqueous extracts that caused 94%, 90%, and 84% mortality of bruchids, respectively, at 7th DAI. In the control group, where no extract treatment was applied to grains, there was only 28% mortality on the last day after infestation. All the tested extracts show a highly significant level ($p<0.05$) of adult mortality on the 2nd, 6^{th,} and 7th day after infestation as compared to the control. From the table, it was observed that as the treatment time increases, the mortality rate also increases.

Table 1: Mortality after infestation of *C. analis* treated with *S. mukrossi* fruit extracts on seeds

Extract (*S. mukrossi*)	**Mean and %age of adult mortality**							
	Day 2		**Day 4**		**Day 6**		**Day 7**	
	Mean ± SD	**% age**	**Mean ± SD**	**% age**	**Mean ± SD**	**% age**	**Mean ± SD**	**% age**
Control	0.2^{a}±0.44	2%	1.6 ^{a} ±0.89	18%	0.4 ^{a} ±0.54	22%	0.6 ^{a} ±0.89	28%
Pet. Ether	3.2 ^{b} ±0.44	32%	3.0 ^{b} ±0.70	62%	2.2 ^{b} ±0.44	84%	1.6 ^{b} ±0.54	100%
Chloroform	3.0 ^{b} ±0.70	30%	3.0 ^{b} ±0.44	60%	2.0 ^{b} ±0.70	80%	1.4 $^{a\,b}$ ±0.44	94%
Ethanol	3.0 ^{b} ±0.70	320	2.2 ^{a} ±0.44	52%	2.0 ^{b} ±0.70	72%	1.8 ^{b} ±0.54	90%
Aqueous	2.6 ^{b} ±0.54	26%	2.0 ^{a} ±0	46%	2.2 ^{b} ±0.44	68%	1.6 ^{b} ±0.70	84%

Data based on the mean number of dead insects in 10 replicates. Mean mortality in the column differs significantly at the indicated significant level of DMRT ($P< 0.05$). Means followed by same superscript letter **(a-f)** indicate no significant difference at 5% level.

b) Effect of plant extracts on oviposition by adult female *C. analis*:

The data presented in table 2 reveals that by the end of 7th day, the average number of eggs laid were only 25.2 when treated with a 3 % dose of petroleum ether extract of *S. mukrossi* while in control, the average number of eggs laid was 60.8, which is significantly higher ($p<0.05$). The oviposition deterrence was found to be maximum in petroleum ether followed by chloroform, ethanol, and then aqueous.

Table 2: Oviposition by female adult *C. analis* treated with *S. mukrossi* fruit extracts

Extract at dose 3%	**Mean Oviposition by adult female *C. analis***
Petroleum ether	25.2 ^{a} ±2.77
Chloroform	27.8 $^{a\,b}$ ±1.30
Ethanol	29.4 ^{b} ±1.51
Aqueous	29.8 ^{b} ±2.38

Control	60.8 ^{c}±2.01

Data based on the mean number of dead insects in 10 replicates. Mean mortality in the column differs significantly at the indicated significant level of DMRT (P< 0.05). Means followed by the same superscript letter **(a-f)** indicate no significant difference at 5% level.

c) Effect of plant extracts on adult emergence of *C. analis*:

The emergence of adult F1 progeny was noted after the emergence of bruchids. The emergence of F1 progeny was significantly reduced after the treatments of all plant extracts. The mean adult emergence was lowest in petroleum ether (12.8), followed by chloroform (17), ethanol (19.4), and aqueous (20.6), as compared to the control, where the highest mean number of 50.8 emergence of adults was observed. It has also been observed that the highest inhibition rate of F1 progeny was recorded after the treatment of *V. radiata* seeds with petroleum ether extracts.

The inhibition rate of F1 progeny (%IR) was calculated as-

$$\% IR = \frac{\mathrm{Cn-Tn}}{Cn}$$

Where, C_n= Number of newly emerged adults in control

Tn = Number of newly emerged adults in treated jars

T

Table 3: F1 progeny emergence of *C. analis* treated with *S. mukrossi* fruit extracts

Extract at dose 3%	**Mean adult emergence of *C. analis***	**Inhibition rate of F1 progeny (% IR)**
Petroleum ether	12.8^{a}±1.72	74.80%
Chloroform	17^{b}±1.20	66.53%
Ethanol	19.4^{bc}±1.81	61.81%
Aqueous	20.6^{c}±2.87	59.44%
Control	50.8^{d}±2.63	

Data based on the mean number of dead insects in 10 replicates. Mean mortality in the column differs significantly at the indicated significant level of DMRT (P< 0.05). Means followed by the same superscript letter **(a-f)** indicate no significant difference at 5% level.

The results of all three parameters mentioned above indicate that the fruit extracts of *S. mukrossi* can be used to control the population of *C. analis* in stores, as it has ovicidal, larvicidal, and adulticidal properties.

Therefore, to identify the different secondary metabolites present in the fruit pericarp of *S. mukrossi* that are responsible for the insecticidal activity, the phytochemical screening and FTIR analysis were carried out on the extracts of the plant.

II. Phytochemical screening of the extract

For the detection of various bioactive constituents, the phytochemical screening of the fruit extracts of *S. mukrossi* was performed. These extracts were subjected to qualitative analysis for the detection of major phytochemicals, namely alkaloids, steroids, phenolic compounds, tannins, flavonoids, and saponins. To have the authentic results, a minimum of two standard tests were performed for the analysis of each phytochemical component, as indicated in Table 4.

Table 4: List of tests performed for analysis of phytochemical constituents

S.NO.	PHYTOCHEMICAL CONSTITUENT	PHYTOCHEMICAL TEST
1	**Alkaloids**	Dragendroff's test, Mayer's test
2	**Glycosides**	Kellar kelane, Concentrated Sulphuric acid test
3	**Steroids**	Salkowski's test, Libermann-Bruchard test
4	**Tannins**	Ferric chloride test, KOH test
5	**Phenols**	$FeCl_3$ test, Alkaline reagent test
6	**Terpenoids**	Salkowski test
7	**Flavonoids**	Lead acetate test, Alkaline reagent test
8	**Saponins**	Foam test, Forth test

The results of the tests performed, as shown in Table 5 indicate the presence of alkaloids in petroleum ether and ethanol extract of *S. mukrossi,* while glycosides are present in petroleum ether and aqueous extracts. Tannins, terpenoids, phenols, and saponins are present in all extracts of *S. mukrossi,* whereas, quinones are absent in all extracts. Except in aqueous extract, flavonoids are present in all three other extracts while steroids are also present in all extracts except the chloroform extract.

Table 5: Phytochemical constituents found in extracts of *S. mukrossi* fruit

S.NO.	PLANT CONSTITUENT	PETROLEUM ETHER EXTRACT	CHLOROFORM EXTRACT	ETHANOL EXTRACT	AQUEOUS EXTRACT
1	Alkaloids	+	-	+	-
2	Glycosides	+	-	-	+
3	Tannins	+	+	+	+
4	Phenols	+	+	+	+
5	Terpenoids	+	+	+	+
6	Steroids	+	-	+	+
7	Flavonoids	+	+	+	-
8	Quinones	-	-	-	-
9	Saponins	+	+	+	+

III. Fourier transform infrared spectroscopy analysis

FTIR of the fruit extract of *S. mukrossi* has been done to identify the chemical structure of secondary plant metabolites.

To determine the infrared spectrum of any solid, liquid, or gas, FTIR operates on the basis of the absorption and emission of infrared light. It was employed to determine the functional groups found in the plant powder (Nandiyanto *et. al.,* 2019). The scanning range for the sample was 400–4000 cm^{-1}. The FTIR's peak values were noted. The *S. mukrossi* fruit powder showed a mid-IR spectrum (4000–400 cm^{-1}) based on transmission versus wavenumber as shown in Figure 1.

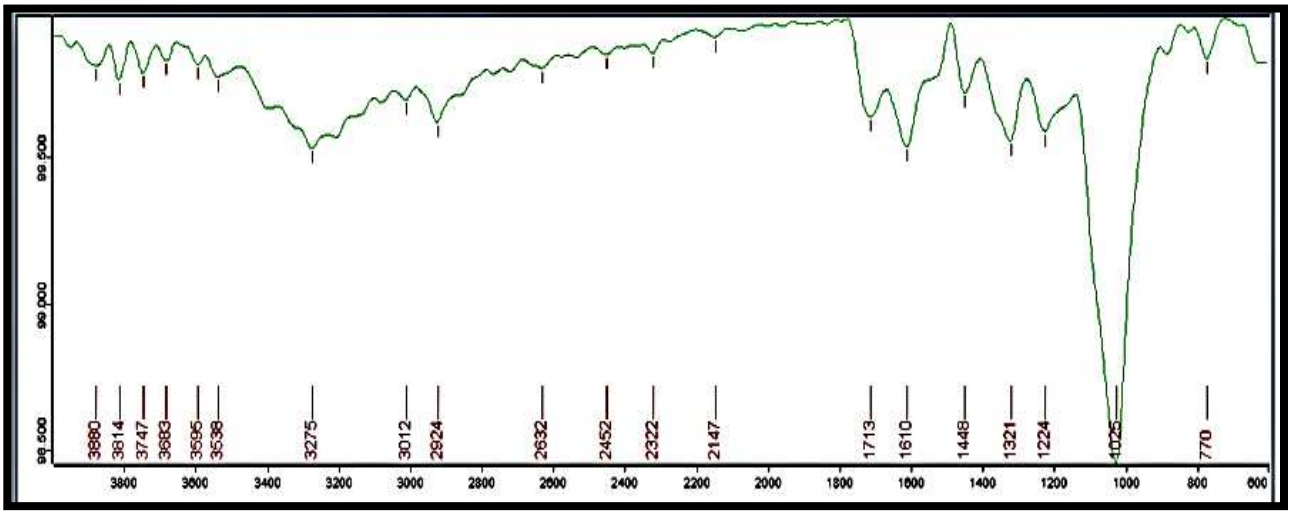

Figure 1: FTIR spectra of extracts of *S. mukrtossi*

The results of FTIR spectroscopy depict that the spectrum shows the O-H of alcohols and phenols stretching by the presence of a broad peak at 3275 cm^{-1}. The peak obtained at 1025 cm^{-1} is due to the C-O stretch of the carbinol group. The peak at 1713 cm^{-1} shows the C=O functional group of carboxylic acids or ketones. The 2924 cm^{-1} peak shows the aliphatic CH_2 stretching. The peak obtained at 1608 cm^{-1} may be due to the C=C bond present in saponins. The peak obtained at 770 cm^{-1} indicated the presence of a weak aromatic -CH group.

DISCUSSION

The findings from the above study demonstrate the effectiveness of *S. mukrossi* fruit in causing the mortality of *C. analis* adults infesting moong seeds. These results are in conformity with earlier reports by Yadava and Bhatnagar (1987), who used six different plants against *C. maculatus* and found *Sapindus trifoliatus* fruit and seed powder to be most effective. Suryaningsih *et. al* (2017) also reported that *Sapindus rarak* was effective in providing repellence and adult mortality against *C. maculatus.* Bajad *et. al* (2019) also tested the efficacy of *Sapindus emarginatus* for the control of protein loss in *Phaseolus aconitifolius* grains due to *C. chinensis.* In their study, they found that after exposure to ethanol, methanol, and aqueous extracts, the loss of the seed was highly reduced. It was concluded in their studies that the saponins are the major phytochemical constituent in *S. emarginatus* that controls the protein loss in grains due to the attack of bruchids**.**

The phytochemical screening tests showed that all four extracts of *S. mukrossi* contain major phytochemical constituents such as tannins, phenols, terpenoids, saponins, etc. These plant-derived compounds are a better substitute for synthetic insecticides as they are less hazardous to the environment and human health (Haddi *et. al,* 2020). Various phytochemical compounds-such as alkaloids, phenols, terpenoids, tannins, steroids, saponins, and flavonoids, exhibit antifeedant, repellent, metamorphosis-inhibiting, ovicidal, larvicidal, adulticidal, and oviposition deterrent activities against bruchids (Saha *et. al* 2024). The presence of these phytochemical constituents greatly depends on the polarity of the solvent used.

In our study, the petroleum ether proved the most efficient extract as it enhanced adult mortality of bruchids, reduced oviposition, and adult emergence as compared to the other three extracts.

The saponins are natural, secondary phytochemical constituents found in many species of the *Sapindus* genus, namely, *S. trifoliatus*, *S. mukrossi*, *S. laurifolia*, and *S. oahuensis* (Singh and Sharma 2019). These are the important phytochemical components present in plants that affect the development and survival of insects. It is also evident from the research of various workers who reported the defensive role of saponins synthesized by plants against insect attack to minimize store grain damage and loss due to these pests (Taylor, Field, and Sutherland 2004). The present investigation shows the presence of saponin in all four extracts, therefore, it can be considered an important insecticidal component present in *S. mukrossi.* This study is in line with Adel *et al*. (2000), who concluded that Saponins directly affect the growth and reproduction of insect pests due to their repellent or deterrent activity. They increase the mortality levels by lowering food intake and affecting the movement of food in the insect gut due to toxicity and less

digestibility. The other phytochemical constituent, tannin, is also found in all extracts, which could be responsible for the higher mortality of bruchids. From the literature review, it was found that plant tannins greatly impact the metabolic activity of insects. Tannins oxidize in high-PH guts, generating complexes with semiquinone radicals, quinones, and other reactive oxygen species, leading to insect mortality over time (Barbehn and Peter 2011). As a result, tannins inhibited the digestion and function of proteins by crosslinking them. Tannins operate as bioinsecticides and growth regulators by precipitating and inactivating adhesion enzymes and cell development proteins, which have the impact of antifeedant properties and ultimately result in death for phytophagous insects (Cowmann 1999). Alkaloids are well-known potent insecticides that show effectiveness in association with tannins and saponins as antifeedants and repellents to prevent insect pests and their negative consequences. As neurotoxins, alkaloids target the insect's acetylcholinesterase receptor site, changing the permeability of the neuromuscular junction and producing new nerve impulses that cause spasmodic contractions, delay larval development, convulsions, and ultimately the nymphs' and adults' death (Emam *et. al* 2009). The percentage of inhibition (%IR) could be attributed to the presence of terpenoids, which are important for controlling insect molting as they inhibit the process by which insects and arthropods produce the juvenile hormone (hydroxy ecdysone), controlling larval moults, the commencement of pupa formation, and metamorphosis. Salunke *et. al* 2005 also concluded that due to the chemical toxicity or physical properties of flavonoids, it causes a change in surface tension within the egg that causes oviposition deterrence.

The result of FTIR is also in conformity with the earlier reports of various researchers who found that *S. mukrossi* contains various bioactive agents that have insecticidal, fungicidal, and bactericidal properties (Pooja *et. al,* 2022, George and Shanmugam, 2014). Therefore, the use of fruit pericarp of *S. mukrossi* extracts as an insecticide of plant origin in postharvest protection should be encouraged in stored products management because of its great toxicant potential against *C. analis* in storage.

CONCLUSION

The current study provides strong proof of the insecticidal capacity of *S. mukrossi* that confirms its usefulness as a "bio-insecticide," a better alternative to chemical insecticides for the protection of stored grains. The FTIR Spectroscopy results confirmed the presence of various functional groups or bioactive chemical groups, such as hydroxyl groups, carboxylates, phenols, and polyphenols, that are known for their insecticidal properties, present in reetha. Therefore, the continued search for an efficient insect pest management under storage conditions has given rise to the possibility of using *S. mukrossi* as a sustainable and environmentally benign option.

STATEMENTS AND DECLARATIONS

The authors declare that the manuscript is original and has not been published or submitted elsewhere. All authors have read and approved the manuscript for publication.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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REFERENCES

Abubakar AR, Haque M (2020) Preparation of medicinal plants: Basic extraction and fractionation procedures for experimental purposes. J. Pharm. Bio Allied Sci 12: 1-10.

Adel MM, Sehnal F, Jurzysta M (2000) Effects of alfalfa saponins on the moth *Spodoptera littoralis***.** J. Chem. Ecol 26: 1065-1078.

Airi M, Khera P, Sekhon CK (2024) Studies on the effectiveness of various plant oils in suppression of store grain pest *Callosobruchus analis* (Fab.) (Coleoptera: Bruchidae). Int. J. Entomol. Res 9(6): 135-137.

Saha A., Choudhury SR, and Bhadra K (2024) A review on insecticidal efficacy of phytochemicals on stored grain insect pests. Notulae Scientia Biologicae 16(3):.11939-11939.

Bajad PN, Pardeshi AB, Pagore, VP 2019 Extraction, isolation and quantification of saponin from *Dodonaea viscosa* JACQ. Pharma Innov J 8(5): 41-44.

Bhalla S, Kapur ML, Gupta K, Lal B, and Khetarpal RK (2006) Check-list of bruchids associated with different plant genera. National Bureau of Plant Genetic Resources, New Delhi, India.

Barbehen RV, Constabel CP (2011) Tannins in plant–herbivore interactions. Phytochemistry 72(13): 1551-1565.

Boeke SJ, Boersma MG, Alink GM, Van Loon JJ, Van Huis A, Dicke M, Rietjens IM (2004) Safety evaluation of neem (*Azadirachta indica*) derived pesticides. J. Ethnopharmacol 94(1): 25-41.

Cowan MM (1999) Plant products as antimicrobial agents. CMR 12(4): 564-582.

Dent D (1991) Insect Pest Management, pp. 32–135. Wallingford, UK: CAB International.

Dixit OP and Saxena RC, 1990. Insecticidal action of *Premnaintegri folia* against *Callosobruchus chinensis*. *Pesticides* 24: 29-31.

Emam A, Eweis M, Elbadry M (2010) A new furoquinoline alkaloid with antifungal activity from the leaves of *Ruta chalepensis* L. Drug Discov Ther 4(6): 399-404.

George B, Shanmugam S (2014) Phytochemical screening and antimicrobial activity of fruit extract of *Sapindus mukorossi*. Int J Curr Microbiol Appl Sci 3: 604–611.

Gill JS, Lewis CT (1971) Systemic action of an insect feeding deterrent. *Nature*, 232: 402-403.

Haddi, K., Turchen, L.M., Viteri Jumbo, L.O., Guedes, R.N., Pereira, E.J., Aguiar, R.W. and Oliveira, E.E., 2020. Rethinking biorational insecticides for pest management: Unintended effects and consequences. *Pest management science*, *76*(7), pp.2286-2293.

Kim SI, Roh JY, Kim DH, Lee HS, Ahn YJ. (2003) Insecticidal activities of aromatic plant extracts and essential oils against *Sitophilus oryzae* and *Callosobruchus chinensis*. J. Stored Prod. Res 39: 293- 303.

Kumari K, Singh SN (1998). Evaluation of the efficacy of botanicals as insecticides against pulse beetle, *Callosobruchus chinensis.* J Appl Biol Biotechnol 8:138-140.

Mishra SN, Jena BC, Guru, BC (2017) Study of Impact of Edible and Non-Edible Oils on Grain Damage and Weight Loss of Green Gram in Storage Condition Infested with Pulse Beetle *Callosobruchus chinensis*. Int J Sci Res 4(10): 1021-1025.

Pajni HR, Gupta IJ (2012) Biology of bruchidae: Structure, development and control. Indian Council of Agricultural Research, New Delhi, pp 1-221

Pandey ND, Mathur KK, Pandey S, Tripathi RA (1986) Effect of some plant extracts against pulse beetle *Callosobruchus chinensis*. Indian J Entomol 38: 110-113.

Pooja R, Varsha SL, Aliya MS, Kumar C, Damini BM, Divya HK (2022) Phytochemical screening, GC-MS, UV-VIS and FTIR analysis of leaf methanolic extract of *Sapindus mukorossi* L. Int. J. Progress. Res. Sci. Eng. 3: 97–104.
Prasanthi SJ, Kumar R, Chakravarty MK (2017). Non-chemical methods for the management of pulse beetle: A Review. J. Entomol. Zool. Stud.5(5): 1526-1533.

Rajendra S (2003) Environment and health aspects of pesticide use in Indian agriculture. In: Martin J. Bunch, V. Madha Suresh and T. Vasantha Kumaran, (Eds), Proceedings of the Third International Conference on Environment and Health, Chennai: Dept. of Geography, University of Madras and faculty of Environmental studies. York University, 353-373

Ramzan M (1990) Efficacy of edible oils against pulse beetle, *Callosobruchus maculatus* (Fab). J. Insect Sci 7(1): 37-39.

Salunke BK, Kotkar HM, Mendki PS, Upasani SM, and Maheshwari VL (2005) Efficacy of flavonoids in controlling *Callosobruchus chinensis* (L.) (Coleoptera: Bruchidae), a post-harvest pest of grain legumes. Crop Prot. 24(10): 888-893.

Singh R, Sharma B, Singh R, Sharma B (2019) Phytochemical analysis and pharmaceutical development from *Sapindus* spp. *Biotechnological Advances, Phytochemical Analysis and Ethnomedical Implications of Sapindus species* 1st ed.; Springer: Singapore, 55-88.

Southgate BJ (1978) The importance of the Bruchidae as pests of grain legumes, their distribution and control. In: S. R. Singh, H. F. Van Emden and T. A. Taylor (Eds.), Pests of Grain Legumes: Ecology and Control. London: Academic Press, 1978, 219-229.

Suryaningsi S, Rochman N, Adi S (2017) Repellent ability of lerak (*Sapindus rarak* dc) fruit extract and kirinyuh (*Chromolaena odorata* L.) leaf extract on *Callosobruchus maculatus* F. warehouse pests. *JAG* 3(1): 36-45.

Taylor WG, Fields PG, Sutherland DH (2004) Insecticidal Components from Field Pea Extracts: Soyasaponins and Lysolecithins. J Agric Food Chem 52(25): 7484-7490.

Verma J, Dubey NK (1999) Prospective of botanical and microbial products as pesticides of tomorrow. Curr. Sci. 76(2): 172-179.

Yadava SRS, Bhatnagar KN (1987) A preliminary study on the protection of stored cowpea grains against pulse beetle, by indigenous plant products. *Pesticides* 21: 25-29.