RESEARCH ARTICLE

Production and evaluation of eco-friendly and non-toxic herbal pest repellent chalk

A.M. Ananda Kumar*, K. Kavipriya, R. Rakkimuthu, P. Sathishkumar, D. Sowmiya

Kumar AMA, Kavipriya R, Rakkimuthu R, et al. Production and evaluation of eco-friendly and non-toxic herbal pest repellent chalk. AGBIR.2025;41(5):1-7.

This study presents the development of an eco-friendly herbal chalk to repel pests in stored food grains, addressing significant economic and psychological losses caused by infestations in warehouses and homes. Various plant extracts, including *Vitex negundo, Ocimum tenuiflorum, Origanum vulgare, Chrysanthemum indicum* and *Eucalyptus* species, were combined to create five formulations, which were applied to chalks through repeated soaking. The repellent activity was tested using maze studies, where formulations F5 (12.5 cm) and F3 (12.1 cm) were most effective in repelling ants, with F5 and F3 repelling 80% and 76% of ants, respectively. Phytochemical analysis revealed the presence of terpenoids, flavonoids, saponins and other compounds, while ash content tests indicated high values in *Origanum vulgare* and *Chrysanthemum indicum* (14.54% and 12.16%, respectively). The formulations were stable, with minimal reaction to most solvents and demonstrated low toxicity to humans and animals. These herbal chalks, with long-lasting aroma and bitterness, provide a sustainable, cost-effective solution for pest control and are adaptable for use in various environments. The study suggests the potential for future commercial production of non-toxic insect repellent chalk for widespread applications in food storage.

Key Words: *Herbal chalk; Phytochemical; Ant repellent; Eco-friendly; Domestic medicinal plant*

INTRODUCTION

Pests are a persistent problem in households, schools and various environments, causing health risks and property damage. Traditional pest control methods often use harmful chemicals that endanger human health and the environment. In response, there is a growing demand for safer, eco-friendly alternatives, such as pest repellent chalk. Pest repellent chalk, also known as insecticidal chalk, provides a non-toxic way to repel household pests like ants, cockroaches and spiders. Formulated with natural, safe ingredients, it disrupts the sensory perception of pests, causing them to avoid treated areas [1].

Originating in Asia, particularly China, insecticidal chalk is easy to use, targeting specific areas such as doorways, windowsills and cracks in walls [2]. Unlike conventional insecticides, it leaves a residue that prevents pests from crossing into protected zones and is odorless, making it suitable for indoor use. Moreover, it poses minimal environmental risks, as it does not contain harmful chemicals that can contaminate soil or water [3]. However, chemical repellent chalks, such as those containing permethrin, have been linked to neurotoxicity and environmental damage [1,3].

Herbal pest repellent chalk offers a sustainable alternative by using botanical extracts like Neem oil, Citronella, Eucalyptus and Peppermint. These ingredients are known for their repellent properties and are biodegradable, reducing ecological impact [4,5]. Additionally, herbal chalk supports Integrated Pest Management (IPM) strategies, promoting ecological balance while minimizing pesticide use [6]. The current study aimed to develop an eco-friendly, less-toxic herbal chalk infused with flower and plant extracts, tested for its effectiveness against common pests while being completely safe for the environment.

MATERIALS AND METHODS

Collection of plant materials

For the present study the plant species, *Ocimum tenuiflorum, Origanum vulgare, Vitex negundo, Chrysanthumum indicum, Eucaluptus* sps were collected from nearby areas of Pollachi and Mayiladuthurai and preserved till the study was carried out. The plants and its parts were collected and finely powdered for the present study. The high-quality plant materials were dried, and grounded using pulverizer. The following plant and its part such as leaves, flowers were collected.

Preparation of plant powder

The clean and healthy plants were collected and shade dried. The dried plant materials were powdered using electrical blender. Then the powder was stored in a glass container.

Preparation of extracts

The powders were used to take hot extract by using Soxhlet apparatus. The powder was taken in the Whatman filter paper and packed. The solvent like ethanol were used to take extract. About 30 gms of plant powder of different parts such as leaves, flower was taken separately and extracted. The extract was collected stored in cool and dry place. The extract obtained was added into further analysis. The final volume was noted to estimate the extractive values parts of plants crude.

Preparation of herbal extract infused chalk

The herbal extract infused chalk will be made according to standard procedure with chalk powder as base material. The appropriate formulation will be made with extracts and added to the chalk powder. The chalk powder is converted to desired shape and form.

Herbal infused insect repellent chalk making

Mix appropriate parts of herbal infusions and diatomaceous earth in a bowl. Add enough gypsum powder to form a thick paste. Add water a little at a time until the paste is smooth and easy to work with. Pour the paste into a mold or ice tray and let it dry for several hours. Once the chalk is dry, remove it from the mold and cut it into pieces. Herbal-based ant chalk is safe for children and pets and it is biodegradable. It is also a good alternative

Department of Botany, Nallamuthu Gounder Mahalingam College, Pollachi, Tamil Nadu, India

Correspondence: *A.M. Ananda Kumar, Department of Botany Nallamuthu Gounder Mahalingam College, Pollachi, Tamil Nadu, India; E-mail: anandbiotech2010@gmail.com*

Received: *27-Apr-2025, Manuscript No. AGBIR-25-164942;* **Editor assigned:** *01-May-2025, PreQC No. AGBIR-25-164942 (PQ);* **Reviewed:** *15-May-2025, QC No. AGBIR-25-164942;* **Revised:** *09-Sep-2025, Manuscript No. AGBIR-25-164942 (R);* **Published:** *16-Sep-2025, DOI: 10.37532/0970-1907.25.41(2)51-7*

to chemical pesticides, which can be harmful to humans and the environment [7].

Evaluation of herbal chalk

The prepared herbal chalks will be evaluated against standard domestic ants and other pests according to the standard procedures followed by Raphael.

Organoleptic studies

Macroscopic observation of the study chalk was carried out like shape, size and physical characters like appearance, texture, colour, odour, taste, smell etc., was noted according to Aji, et al. [8].

Preliminary phytochemical analysis

Test for alkaloids-Mayer's reagent: About 1 ml of extract, 2 ml of Mayer's reagent is added formation of dull white precipitate indicates the presence of alkaloids [9,10].

Test for steroids-Salkowski's test: About 2 ml of extract was dissolved in 2 ml of chloroform and 2 ml of conc. H_2SO_4 red colour formation indicates the presence of steroids [11].

Test for terpenoids-Salkowski test: About 1 ml of extract 2 ml of chloroform was added and mixed well. Then conc. H_2SO_4 was added carefully along the sides of the tube to form a layer. A reddish brown colouration indicates the presence of terpenoids.

Test for flavonoids-lead acetate test: About 1 ml of extract, lead acetate solution is added. Formation of yellow precipitate confirms the presences of flavonoids.

Saponins-foam test: About 1 ml of extract is shaken vigorously with 20 ml of distilled water for 5-10 minutes in graduated cylinders. Formation of 1 ml layer of foam indicates the presence of saponins.

Test for glycosides-Borntrager's test: About 1 ml of extract, 1 ml of benzene and 0.5 ml of dil. Ammonia solution is added. A reddish pink colour indicates the presence of glycosides [12].

Test for tannins-ferric chloride test: About 1 ml of extract, 1 ml of 5%$Fecl_2$ (prepared in ethanol) solution was added. Blue black (or) dark green colour confirms the presence of tannins.

Phenols-ferric chloride test: About 1 ml of extract, 1 ml of 5% $Fecl_2$ (prepared in ethanol) solution was added. Blue black (or) dark green colour confirms the presence of tannins [13].

Determination of total ash: The powdered plant material 5 g was accurately weighted and placed in crucible. The material was spread in even at the temperature of 550˚C unit it was until it was white indicating the absence of carbon [14].

$$\text{Ash contents} = \frac{\text{Final weight of dish with ash - weight of empty dish}}{\text{Weight of sample}}$$

Determination of water insoluble ash: The residual ash was allowed to cool and the weight was taken and the materials was filtered by water using Whatman filter paper and then it is dried.

$$\text{Water insoluble Ash} = \frac{\text{Total ash weight-water insoluble residue of total ash}}{\text{Weight of Sample}} \times 100$$

Determination of acid insoluble ash: The dried power is then filtered using concentrated hydrochloric acid and the substance that can extract from the acids are removed for the further process for the indication of heavy metals.

$$\textbf{Acid insoluble ash} = \frac{\textbf{weight of filter paper with ash-weight of filter paper}}{\textbf{Sample}} \times 100$$

Reaction of formulated powders with chemicals: To determine the change in colour and behaviour of powders like floating or sinking according to the methods described.

Methodology for maze studies

The ants are specifically meant for territorial in nature. They have their own boundaries and to feed and crawl. For the present study the prepared herbal extract formulation infused chalk was assessed using maze studies. Based on the Dany et al., ant repellent study was made with some modifications. A maze of about 1.5 ft ×1.0 ft and wrapped on four side by using cardboard paper to avoid ants completely escape from the maze, was prepared and a straight line has been drawn as boundary as territorial marking using the various formulated chalk with thickness of about of 0.5 mm to 1.0 cm. A known number of ants were allowed to crawl freely on the prepared maze (Figures 1 and 2). The evalution made by the behaviour of ants like distance repelled by ants, lethality and the time taken for the repellency were calculated according to standard procedure. The results were tabulated and interpreted among the five herbal extract infused chalk. The best of five formulations was selected using this method.

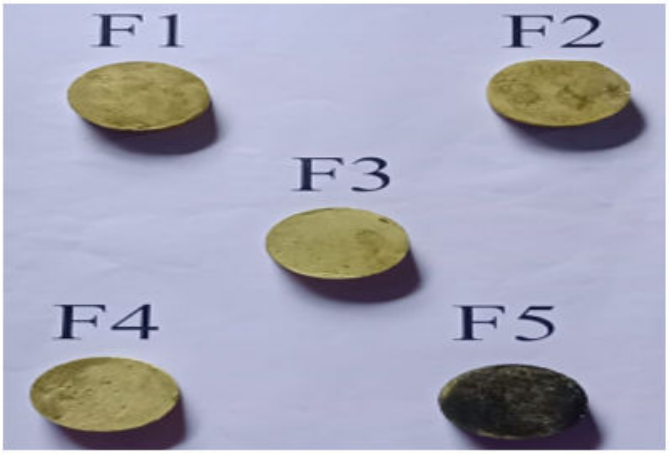

Figure 1) *The final product of herbal extract infused ant repellent chalk made on five different formulations*

Figure 2) *The maze studies taken for the present study to assess the effect of ant repellent chalk on domestic ants*

RESULTS AND DISCUSSION

Pests are one of the biotic invaders on many areas including ware houses, homes and other long term storing places. They are group of harmful insects which may cause considerable loss on stored food grains. The loss on food grains also affects the farmers considerably both economically and psychologically. The pests are also responsible for the dispersal many fungal and bacterial infection. It also acts as one of the important vector to communicate many diseases. The microbial infections which decay the food grains in the stored area and leads to desist from using. Hence to overcome the above problem many repellent chemicals are available throughout the world which may be applied in various modes like sprays, chalks, powders etc., the chemical repellents are highly toxic and ecologically it affects the environment drastically. For the present study, a eco-friendly herbal chalk was prepared by using different extracts of herbal extracts. The herbal extracts are confirmed to have good pest repellent activity based on many available published literatures. Those extracts were combined at a definite ratio and used for the present study. The parts of various plants were taken *viz., Vitex negundo, Ocimum tenuiflorum, Origanum vulgare, Chrysanthemum indicum, Eucalyptus* sps. Cleaned using standard methods with water and ethanol. The cleaned parts were dried under shade condition to keep the phytochemicals intact (Table 1). The present study successfully formulated and evaluated an eco-friendly herbal chalk for ant repellent activity using a combination of plant extracts including *Vitex negundo, Ocimum tenuiflorum, Origanum vulgare, Chrysanthemum indicum*, and *Eucalyptus* spp. The promising results observed, particularly in formulations F3 and F5, validate the insect-repelling potential of these phytochemicals.

TABLE 1
List of selected plants for herbal chalk preparation

S. no	Binomial name	Parts used
1	*Vitex negundo*	Leaves
2	*Ocimum tenuiflorum*	Leaves
3	*Origanum vulgare*	Leaves
4	*Chrysanthemum indicum*	Flower
5	*Eucalyptus* sps.	Leaves

Five different formulations were prepared based on the properties of plants and mixed to prepare a five different formulations at definite ratios (Table 2) and eucalyptus oil was added for aroma with some 2 to 5 drops (Table 2). The formulation was infused on chalk by soaking in respective formulation repeatedly for more than 20 times. The chalks were allowed to imbibe sufficient herbal extracts and dried considerably in a hot air over at standard temperature.

TABLE 2
Five different formulation for making herbal chalk

S. no	Plants	F1 (µl)	F2 (µl)	F3 (µl)	F4 (µl)	F5 (µl)
1	*Chrysanthemum indicum*	2	1.5	0.7	1	0
2	*Ocimum tenuiflorum*	0	0.2	0.2	0.5	2
3	*Origanum vulgare*	0.5	0.2	0.5	0	1
4	*Vitex negundo*	0.5	0	0.6	0.2	0.2
5	*Eucalyptus* sps.	2 drops	2 drops	2 drops	2 drops	2 drops

The chalks were assessed for its physical and chemical properties. The chalks were evaluated for its stability, appearance, odour, colour and taste. Each and every formulation has specific odour and it is long lasting for more than two to three hours. All the chalk material was stable with enough stable for the application of chalk. The taste was bitter in all the formulation.

The repellent chalk was evaluated by using maze studies as per the Tables 3 and 4. The prepared chalk was used to make a line mark as shown in the plate no 7. The ants of definite number was taken and involved in the present study. The time taken by the ant repelled by the herbal chalk was noted and tabulated. Out of five different formulations the F5 (12.5 cm) and followed by F3 (12.1 cm) on 30 cm 30 deviated the ants from line of

repellent (Table 4). The Table 3 shows the F3 and F5 formulation showed the good results and about 76 and 80 ants of 100 ants respectively. The F3 and F5 formulation also shows the lethality in about 6 and 19 ants respectively. Some of the ants are also normal and it is not affected by the herbal and behaved normally and it was active throughout the test. About 20 and 32 insects of the formulation F5 and F3 were noticed respectively. The others are less active and moved from the place. The other formulations are also showed considerable repellent activity. The other ants completely moved from the place. The repellent activity observed in the maze studies is consistent with previously reported insecticidal properties of these plants. For example, *Vitex negundo* and *Ocimum tenuiflorum* are known for their strong repellent action against various pests due to the presence of active constituents such as flavonoids, terpenoids and essential oils Sukumar, Dharmagadda et al. [15,16]. *Origanum vulgare* and *Chrysanthemum indicum*, which showed higher ash values, also contribute to the formulation's effectiveness possibly due to their high content of phenolic compounds and oxygenated monoterpenes known for insecticidal properties [17,18].

TABLE 3
Average distance deviated from the territorial border drawn using the herbal ant repellent chalk

S. no	Formulation	No. of ants	Distance deviated from chalk line		Time difference
			Range	Average	
1	F1	100	9.5-22 cm	13.6 cm	20 minutes
2	F2	100	2-16.5 cm	7.6 cm	54 minutes
3	F3	100	4.5-21.5 cm	12.1 cm	62 minutes
4	F4	100	5.5-20 cm	11.9 cm	47 minutes
5	F5	100	7-19.5 cm	12.5 cm	61 minutes

TABLE 4
The organoleptic characters of prepared chalk

S. no	Characters	F1	F2	F3	F4	F5
1	Appearance	Fine	Fine	Fine	Fine	Fine
2	Colour	Pale green	Pale green	Pale green	Pale yellow green	Dark green
3	Aroma	Characteristic	Characteristic	Characteristic	Characteristic	Characteristic
4	Taste	Bitter	Bitter	Bitter	Bitter	Bitter
5	Texture	Viscous	Viscous	Viscous	Viscous	Viscous
6	Odour	Pleasant	Pleasant	Pleasant	Pleasant	Pleasant
7	Overall	Good	Good	Good	Good	Good

The phytochemical screening indicated the presence of flavonoids, terpenoids and saponins in major plant components. These compounds are known to disrupt the nervous system of insects and interfere with their foraging behavior [19]. Terpenoids, in particular, have demonstrated fumigant and contact toxicity against storage pests [20].

With the above results the formulation was tested for its phytochemical contents except alkaloids, glycosides, tannins and phenols all other important phytochemicals such as terpenoids, flavonoids were present in plant extracts *Vitex negundo, Ocimum tenuiflorum, Origanum vulgare* and *Chrysanthemum indicum*. The steroids were absent in *Ocimum tenuiflorum* and *Saponins* was reported in *Vitex negundo* and *Ocimum tenuiflorum* (Tables 5 and 6).

TABLE 5
Qualitative phytochemical analysis of the herbal extract used in the formulation

S. no	Phytochemicals	Plant materials			
		Vitex negundo	***Ocimum tenuiflorum***	***Origanum vulgare***	***Chrysanthemum indicum***
1	Alkaloids	-	-	-	-
2	Steroids	+	-	+	+
3	Terpenoids	+	+	+	+
4	Flavonoids	+	+	+	+
5	Saponins	+	+	-	-
6	Glycosides	-	-	-	-
7	Tannins	-	-	-	-

8	Phenols	-	-	-	-

Note: '+' Present '-'Absent

TABLE 6
The ash content of various parts in study plants (leaves, flower)

S. no	Ash type	% of ash content			
		Chrysanthemum indicum	***Vitex negundo***	***Ocimum tenuiflorum***	***Origanum vulgare***
1	Total ash value of powder	12.16 ± 0.030	6.54 ± 0.09	11.28 ± 0.06	14.54 ± 0.070
2	Water insoluble ash	7.16 ± 0.030	0.04 ± 0.01	2.12 ± 0.01	2.16 ± 0.02
3	Acid insoluble ash	0.4 ± 0.1	3.28 ± 0.03	0.16 ± 0.04	6.36 ± 0.02

The ash values were calculated for the presence of metal elements in plant powders to test its ash content. Out of four different plants the plant *Origanum vulgare* and *Chrysanthemum* has highest ash values with 14.54% and 12.16% respectively. Followed by the water insoluble ash was calculated it is also noted that about 7.16% and 2.16% of ash was found in *Chrysanthemum indicum* and *Origanum vulgare* (Table 7). The acid insoluble ash was calculated and *Origanum vulgare* reported the highest value with 6.36% and 3.28% was calculated values.

TABLE 7
Reaction of studied plant powders with various chemical reagents

	Treatment	Before	After	Inference
F1	H_2So_4	Pale yellow	Brown	Persistent froth
F2		Pale green	Brown dots	Persistent froth
F3		Pale green	Light pink	Persistent froth
F4		Light yellow	Pale brown	Persistent froth
F5		Dark green	Light brown	Persistent froth
F1	Hcl	Pale yellow	Yellow	Persistent froth
F2		Pale green	Yellow	Persistent froth
F3		Pale green	Yellow	Persistent froth
F4		Light yellow	Yellow	Persistent froth
F5		Dark green	Yellow	Persistent froth
F1	NaOH	Pale yellow	Pale yellow	No reaction
F2		Pale green	Pale yellow	No reaction
F3		Pale green	Pale yellow	No reaction
F4		Light yellow	Pale yellow	No reaction
F5		Dark green	Pale yellow	No reaction
F1	KOH	Pale yellow	Pale yellow	No reaction
F2		Pale green	Pale yellow	No reaction
F3		Pale green	Pale yellow	No reaction
F4		Light yellow	Pale yellow	No reaction
F5		Dark green	Pale yellow	No reaction
F1	CH_3COOH	Pale yellow	Pale green	Persistent froth
F2		Pale green	Pale green	Persistent froth
F3		Pale green	Pale green	Persistent froth
F4		Light yellow	Cream white	Persistent froth
F5		Dark green	Green	Persistent froth

F1	Pet ether	Pale yellow	Green	No reaction
F2		Pale green	Green	No reaction
F3		Pale green	Green	No reaction
F4		Light yellow	Green	No reaction
F5		Dark green	Green	No reaction
F1	Ethanol	Pale yellow	Pale yellow	Colloidal
F2		Pale green	Pale yellow	Colloidal
F3		Pale green	Pale yellow	Colloidal
F4		Light yellow	Pale yellow	Colloidal
F5		Dark green	Pale yellow	Colloidal
F1	Methanol	Pale yellow	Pale yellow	No reaction
F2		Pale green	Pale yellow	No reaction
F3		Pale green	Pale yellow	No reaction
F4		Light yellow	Pale yellow	No reaction
F5		Dark green	Pale yellow	No reaction
F1	Chloroform	Pale yellow	Light yellow	Effervesence
F2		Pale green	Light yellow	Effervesence
F3		Pale green	Light yellow	Effervesence
F4		Light yellow	Light yellow	Effervesence
F5		Dark green	Light yellow	Effervesence
F1	Ethyl acetate	Pale yellow	Pale green	No reaction
F2		Pale yellow	Pale green	No reaction
F3		Pale green	Pale green	No reaction
F4		Light green	Pale green	No reaction
F5		Dark green	Pale green	No reaction

The observed frothing and effervescence when formulations were treated with strong acids and some organic solvents further confirm the presence of saponins and other active constituents. This chemical stability indicates the chalk formulations are structurally resilient and could withstand varied environmental conditions during application, supporting their potential for real-world use in households and warehouses.

The reaction with bases and organic solvents such as petroleum ether and methanol ensures that the formulation maintains its integrity under normal environmental exposure. This adds a significant advantage for long-term storage and usability without chemical degradation. The formulations did not exhibit harmful residual effects, indicating safety for humans and non-target organisms. This is a crucial advantage over synthetic pesticides, which are often associated with toxicity, environmental pollution and pest resistance [21]. The herbal chalk thus aligns with Integrated Pest Management (IPM) strategies focused on sustainable and safe pest control methods.

The five different formulations were evaluated with various chemicals to understand the reaction with solvents, strong acids, bases and other liquid solvents. All the five formulation which reacted with strong acids with sulphuric acid and hydrochloric acid showed persistent froth for some minutes. Similarly, the persistent froth like appearence was noted. It is also inferred that all the five formulation showed persistent froth in acetic acid. There is no reaction with bases like NaOH and in the solvents like petroleum ether, ethyl acetate and methanol. It is also noted a brisk effervescence was noted in the when formulation was treated with chloroform and methanol.

CONCLUSION

The present study clearly shows the prepared herbal infused ant repellent chalk with good qualities and with less side effects. The chalk was well evaluated on various parameters phytochemically, organoleptically, pharmacogenistically and chemically. All the above study showed the positive results. There are no residual effects and also a complete ecofriendly. The chalk if it is produced commercially which will very cost effective and with less toxic from human to animals. This may also use as powders and applied for the domestic ants. The repellent chalk is also working well on various places too in muds, cemented floor, walls etc.

In future the commercial possibilities of making toxic less insect repellent herbal chalk for all insects which affects the store houses will be formulated. The chalk of different colours and aroma were also under progress to work on wide range insects and to control it from consuming valuable food grains and cooked foods. The work was towards the hygiene approach for the betterment of healthy society.

REFERENCES

1. Wang K, Hu Q. Formulation and efficacy evaluation of insecticidal chalk for controlling *Blattella germanica*. Insects. 2012;3(2):593-601.

2. Tang J, Zhang M, Zheng J. Study on the development and application of pest repellent chalk. J Anhui Agric Sci. 2018;46(24):234-237.
3. Gao Z, Tian R. Preparation and application of insect repellent chalk. Mod Chem Ind. 2015;35(4):142-144.
4. Isman MB. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu Rev Entomol. 2006;51:45-66.
5. Pavela R. Essential oils for the development of eco-friendly mosquito larvicides: A review. Ind Crops Prod. 2016;76:174-187.
6. Regnault-Roger C, Vincent C, Arnason JT. Essential oils in insect control: Low-risk products in a high-stakes world. Annu Rev Entomol. 2012;57:405-424.
7. Raphel. Development of chalk from selected herbs as cockroach (*Periplaneta americana)* repellents. JPAIR Multidiscip Res. 2019; 35:128-143.
8. Aji A, Ajantha A, Shashirekha K. Soxhlet alcoholic extraction of varuna (*Crateva nurvala*) and its phytochemical analysis. Int Ayurvedic Med J. 2016;4(9):2728-2732.
9. Edeoga H, Okwu D, Mbaebie B. Phytochemical constituents of some Nigerian medicinal plants. Afr J Biotechnol. 2005;4:685-688.
10. Harborne J. Phytochemical Methods. Chapman and Hall. 1973;188.
11. Yadav M, Chatterji S, Gupta S, et al. Preliminary phytochemical screening of six medicinal plants used in traditional medicine. Int J Pharm Pharm Sci. 2014;6(5):539-542.
12. Mandal S, Parta JA, Samanta A, et al. Analysis of phytochemical profile of *Terminalia arjuna* bark extract with antioxidative and antimicrobial properties. Asian Pac J Trop Biomed. 2013;3(12):960-966.
13. Kokate C. Practical pharmacognosy. Vallabh Prakashan. 2000;107-111.
14. Madhubala M, Santhi G. Phytochemical and GC-MS analysis on leaves of selected medicinal plants in *Boraginaceae* family *Cordia dichotoma*. Pramana Res J. 2019;9(3):668-707.
15. Sukumar K. Structure-activity relationships of insect repellents: A review. J Med Entomol. 1991;28(6):723-739.
16. Dharmagadda VSS, Naik SN, Mittal PK. Larvicidal activity of essential oils of *Vitex negundo* against three mosquito species. Bioresour Technol. 2005;96(16):1749-1757.
17. Isman MB. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu Rev Entomol. 2006;51:45-66.
18. Abdelgaleil SA, Mohamed MI, Badawy MEI, et al. Fumigant and contact toxicities of monoterpenes to *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst). J Pest Sci. 2010;79(6):93-102.
19. Koul O, Walia S, Dhaliwal GS. Essential oils as green pesticides: Potential and constraints. Biopesticides Int. 2008;4(1):63-84.
20. Nerio LS, Olivero-Verbel J, Stashenko E. Repellent activity of essential oils: A review. Bioresour Technol. 2010;101(1):372-378.
21. Aktar W, Sengupta D, Chowdhury A. Impact of pesticide use in agriculture: Their benefits and hazards. Interdiscip Toxicol. 2009;2(1): 1-12.