Indian Journal of Natural Products and Resources
Vol. 11(4), December 2020, pp 295-306

# Pesticidal properties of *Anamirta cocculus*, *Cardiospermum halicacabum*, *Cocculus laurifolius* and *Strychnos nux-vomica* against *Spodoptera litura* (Lepidoptera: Noctuidae)

Alina Paul[1,2] and R. Jayaraj[1]*

[1]Division of Forest Ecology and Biodiversity Conservation, KSCSTE - Kerala Forest Research Institute, Peechi, Thrissur 680653, Kerala, India
[2]Cochin University of Science and Technology, Kochi 682022, Kerala, India

*Received 28 May 2020; Revised 24 September 2020*

*Spodoptera litura*, commonly known as taro caterpillar, is a major pest of several vegetables and economically important crops. The pest is reported to reduce the yield of the affected crop up to 10-30%. Hence, controlling this pest is one of the very crucial steps in increasing crop yield. The extensive use of broad-spectrum chemical pesticides to control *S. litura* has many negative impacts. The present study is an attempt to evaluate the efficacy of certain plants against *S. litura*. In this study, we investigated the anti-insect properties of leaf and bark extracts of *Anamirta cocculus*, *Cardiospermum halicacabum*, *Cocculus laurifolius* and *Strychnos nux-vomica*. All four plant extracts showed significant anti-feedant activity compared to control at different concentrations. The leaf extracts showed the activity in the order *S. nux-vomica* >*C. halicacabum* >*C. laurifolius* >*A. cocculus* at the exposure of maximum concentration. Anti-feedant activity of the bark extract was in the order *C. laurifolius* >*S. nux-vomica* >*C. halicacabum.* The leaf extracts of three plants *A. cocculus*, *C. halicacabum* and *S. nux-vomica* showed significant repellent activity. The repellent activity of the bark extracts was in the order, *C. laurifolius* > *C. halicacabum* >*S. nux-vomica* >*A. cocculus.* The GC-MS analysis of these plant extracts have shown many compounds with known anti-insect properties and specific molecule-based bio-assays might be required to ascertain the distinctive effects of these compounds.

**Keywords:** *Anamirta cocculus*, *Cardiospermum halicacabum*, *Cocculus laurifolius*, *Strychnos nux-vomica*, *Spodoptera litura*, Anti-insect activities.

**IPC code; Int. cl. (2015.01)-**A01N 25/00, A01N 25/02, A01N 65/00

## Introduction

*Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) is a poly-phytophagous insect damaging several vegetables and field crops in many Asian countries including India. It is commonly known as cotton cutworm, rice cutworm, taro caterpillar, tobacco budworm, cotton leafworm, cluster caterpillar, cotton worm, Egyptian cotton leafworm, tobacco caterpillar, tobacco cutworm, tobacco leaf caterpillar and common cutworm. *S. litura* has been reported from the south and south-east Asia, Australia and pacific islands[1]. This insect deteriorates leaves of many commercially important crops. Earlier it was identified as a random pest of tobacco, but over the years it has become a major pest in tobacco[2-4] as well as many other plants. Among the 44 families of plants, there are 150 cultivated food plants in the world[5] and 60 from India that come under the attack of this pest[6]. Some plants under its infestation include castor, cotton, sunflower, cabbage, pigeon pea, chili, cucumber, pumpkin, potato, banana, tomato, okra, etc[7,8]. This pest has caused yield reduction up to an extent of 30% in crops[9-15]. An average of 15% of crops worldwide is currently damaged by insects, so controlling pests is crucial in achieving the goal of increasing crop yield[16].

*S. litura* is one of the most damaging pest, which consumes up to 85.5% of the leaf area[17]. The assessment of an economic impact of this polyphagous pest in a range of crops and trees were studied well in India and abroad[18-21]. Recently, there were many incidences reported on the reduced qualitative and quantitative yield in soybean and cotton from Maharashtra. The larvae adversely affect flowers, flower buds and bolls by eating their contents. It was estimated that about 3-

*Correspondent author
Email: jayaraj@kfri.res.in
Phone: +91-487-2690147

4 buds per each day can be damaged by a single larva and 7-8 larvae can destroy one adult plant in a day[22].

Due to the extensive use of broad-spectrum pesticides to control *S. litura*, it has developed resistance to many of these chemical agents. Concurrently these chemical pesticides are harmful to the non-target organisms as well as humans[23]. The widespread usage of broad-spectrum synthetic pesticides during the last century has caused numerous environmental problems such as pest resistance, increased cost of agricultural production, retention of pesticide residues and non-target toxicity. Thus, there is a need for developing ecologically safe bio-agents, which could be used against these pests. In such a situation, new agents originating from plant products could be helpful in more environment-friendly integrated pest management and function as an effective alternative to chemical pesticides.

Botanical pesticides are often slow-acting and safer to non-target organisms and human health. Role of secondary metabolites in insect-plant interaction is under constant exploration. Plants produce a variety of natural products with highly diverse chemical natures and that protect them from pest attack[23]. These chemical substances function in many ways, such as repellents, anti-feedants, etc. Anti-feedants inhibit the feeding of insect on a treated food material without killing or repelling[24]. Repellents deter an insect from flying to, landing on or biting human or skin of an animal or eating a food material[25]. Many plants have these kinds of molecules and evaluating their properties may provide newer molecules with promising anti-insect properties.

This study was framed to evaluate the efficacy of *A. cocculus, C. halicacabum, C. laurifolius*, and *S. nux-vomica* plant extracts against *S. litura.* Different pesticidal effects such as anti-feedant activity, repellent activity, and contact toxicity against *S. litura* were evaluated along with the chemical composition of the extracts.

## Materials and Methods

### Plant materials and extraction

The leaves and bark of the plants, *A. cocculus*, *C. halicacabum*, *C. laurifolius*, and *S. nux-vomica* were collected from foothills of southern Western Ghats. Plant specimens were identified by plant taxonomist Dr P. Sujanapal, Kerala Forest Research Institute, Peechi, Kerala, India. Voucher specimens (*A. cocculus* -18024, *C. halicacabum* - 18025, *C. laurifolius* - 18026 and *S. nux-vomica* – 18027) were deposited in Kerala Forest Research Institute Herbarium (KFRI), Kerala, India.

The collected plant materials were thoroughly washed, shade dried and powdered with the help of a blender. The plant powder (10 g) was extracted with 200 mL methanol, in a flask of 500 mL capacity, using soxhlet apparatus. Four to five repeat refluxes were carried out for each plant sample (total time of 6–8 h). After extraction, the methanol extract was concentrated to near dryness under reduced pressure maintaining the temperature below 40 $^{o}$C using a rotary evaporator. The samples were stored at deep freezer (-20 $^{o}$C) until further use. The aqueous methanolic extract was used for the study. This was prepared by dissolving the dried extract powder in 0.01% of methanol and made up to the final volume with water. Methanol (0.01 %) in water was used as control.

### Rearing of insects

Different stages of *S. litura* were collected from banana fields of Ernakulam (Kerala), India and their subsequent generations were maintained at 25±1 $^{o}$C, 60±5% relative humidity. Plastic containers covered with muslin cloth were used for insect culture in the laboratory, and the larvae were reared on *Ricinus communis* (castor) leaves which were changed daily. During the pupation stage, it was shifted to jars containing moist sterilized sand covered with filter paper. Just after the adult emergence, they were transferred to oviposition jars and provide the honey solution with few drops of multivitamin to increase the rate of fecundity as food, which was soaked in cotton attached on the sides of the jars. To facilitate the egg-laying, the oviposition jars were lined with filter paper. Neonates, upon hatching from the eggs, were transferred to glass jars containing fresh thoroughly washed *R. communis* (castor) leaves. This process was repeated and the insect culture was maintained throughout the study period.

### Bio-assay of plant extracts against *S. litura*

#### *Anti-feedant and feeding activity*

Anti-feedant activity of plant extracts was studied using leaf disc no-choice bioassay method[26]. Fresh castor leaf discs (4.5 cm diameter) were dipped in 0.5, 1.0, 2.5, and 5.0% concentrations of crude aqueous methanolic extracts against *S. litura* in individual boxes. The leaf disc treated with methanol in water was used as the control. In each box, wet cotton was placed to avoid early drying of the leaf discs and

single third instar larva was introduced. Since the maximum feeding activity and leaf damage was observed in the third instar stage of the larvae, the assay was carried out using the third instar of the larvae. Progressive consumption of treated or control leaf area by the larvae after 24 hours was recorded using graph paper. Leaf area, eaten by larvae in treatment was corrected from the control and shrinkage percentage. Four replications were maintained for each treatment. The per cent of feeding and anti-feedant activity in the no-choice method was calculated based on the following formula[27].

$$\text{Per cent feeding} = \frac{\text{(Initial leaf disc area for feeding} - \text{area left over after feeding)}}{\text{Initial leaf disc area given for feeding}} \times 100$$

$$\text{Antifeedant activity}(\%) = \frac{\text{(\% protection in treatment} - \text{\% protection in control)}}{(100 - \text{\% protection in control})} \times 100$$

***Repellent activity***

The repellent of the insect was tested with choice bioassay[28]. The fresh castor leaf disc of 4.5 cm diameter was treated with plant extracts (100 mg/mL) on one piece and with control on another. Then the leaves were exposed to ten, 3rd instar larvae of *S. litura* by placing them in the middle of each box. After three hours, the number of larvae present at treated or control was counted. Repellent index (RI) was calculated as

$$\text{Repellent Index} = \frac{(C - T)}{(C + T)} \times 100$$

Where, C = Number of larvae in the control diet and T = Number of larvae in the treated diet. If RI >50, the extract is repellent and RI <50, the extract is non-repellent[29]. All the experiments were repeated four times.

***Contact toxicity***

This experiment tested the hypothesis that topically applied plant extract solutions exhibit contact toxicity to *S. litura* larvae. Contact toxicity of the plant extracts was evaluated using 1st instar larvae as the contact toxins show maximum effect in the younger stage. For each replicate, 10 larvae were transferred to a Whatman No. 1 filter paper disc in a 90 mm disposable plastic box. Three replicates of 10 larvae each were treated with each plant extract. Each larva was treated topically with aqueous-methanol plant extract using a 50 µL micropipette. In the control treatment, larvae were treated with methanol in water. After treatments, it was allowed to dry for 10 minutes at 25±1 ºC and were subsequently transferred individually into castor leaves containing plastic containers. Following treatment application, larvae were maintained at 25±1 ºC and mortality was assessed after 24 hours. The experiment was repeated four times.

**Gas chromatography-mass spectrometry analysis**

The chemical composition of the plant extracts in methanol was analyzed using GC–MS. The extracts were filtered through 0.22 µm syringe filter before the analysis. One microlitre of the filtered sample was analyzed using GC–MS (QP-2010-S Shimadzu) equipped with Rxi-5Sil MS column of 30 m in length, 0.25 mm in diameter, and 0.25 µm thickness. The GC-MS was employed with helium as the carrier gas at a constant flow of 1 mL/min. The oven temperature started at 80 °C and remained at this temperature for 4 minutes increasing to 280 °C at 5° C/min ramp rate. Injection port was adjusted at 260 °C and splitless injection mode was used. EI mode was at 70 eV, while a mass spectrum was recorded in the 50–500 amu range and ion source temperature was maintained at 200 °C. The components of the extracts were identified by comparing the retention times of chromatographic peaks using quadrapole detector with NIST and Wiley library.

**Statistical analysis**

Data were expressed as mean±SE from four replicates per each treatment. Data of anti-feedant and feeding activity were analyzed by one-way analysis of variance followed by Dunnet's test for comparison between respective control and treatment groups. For the experiments of contact toxicity and repellent activity, data were analyzed by one-way analysis of variance followed by Student- Newman-Keul's multiple mean comparison test. The level of significance was set at $p \leq 0.05$. Data of all the results in this study were obtained from at least three independent experiments with similar pattern.

## Results and Discussion

**Bio-assay of plant extracts against *S. litura***

***Anti-feedant and feeding activity***

The results of the anti-feedant activity of the leaf extracts were shown in Fig. 1a. The leaf extracts showed significant anti-feedant activity at higher concentrations, i.e., 2.5 and 5%. Among the concentrations of extracts tested, leaf extracts of *S. nux-vomica* showed the maximum anti-feedant

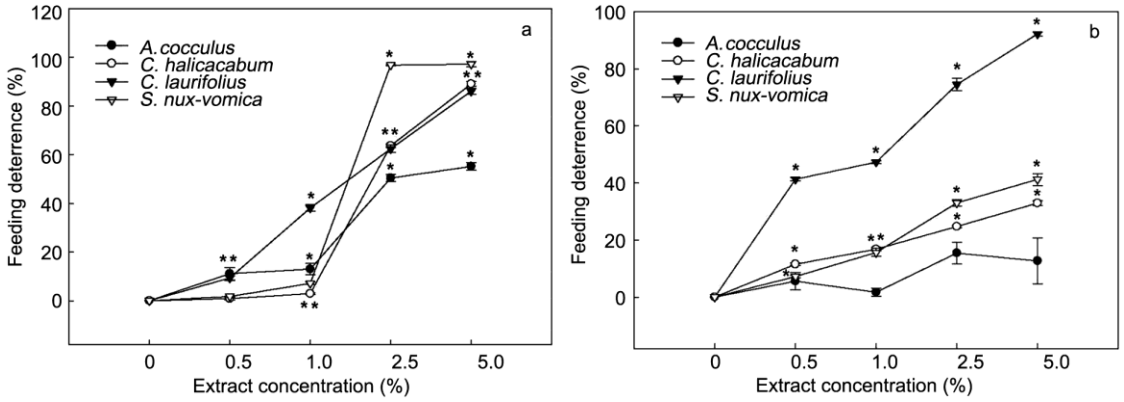


Fig. 1 — Anti-feedant activity of leaf (a) and bark (b) methanol extracts of *A. cocculus, C. halicacabum, C. laurifolius* and *S. nux-vomica* against *Spodoptera litura*. The values are expressed as mean ± SE of four replicates per experiment. * Significantly different from respective controls at $p \leq 0.05$ by Dunnet's test.

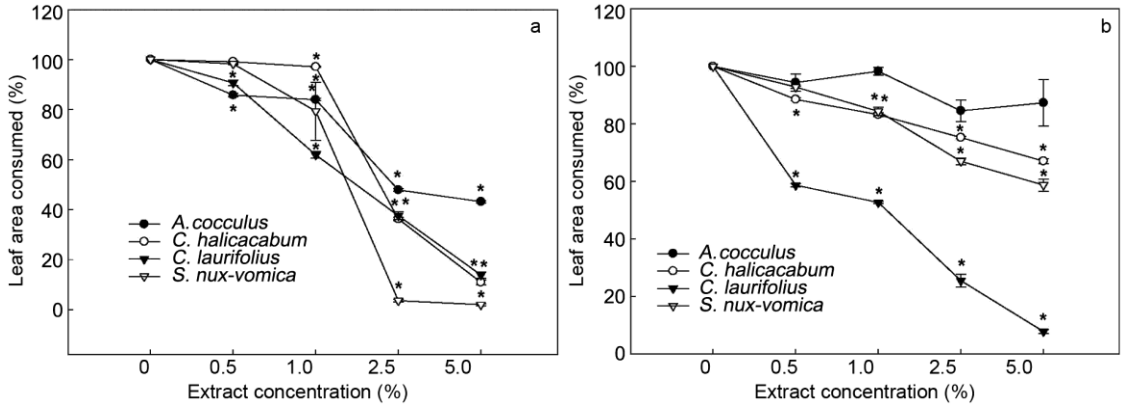


Fig. 2 — Feeding activity of leaf (a) and bark (b) methanol extracts of *A. cocculus, C. halicacabum, C. laurifolius* and *S. nux-vomica* against *Spodoptera litura*. The values are expressed as mean ± SE of four replicates per experiment. * Significantly different from respective controls at $p \leq 0.05$ by Dunnet's test.

activity at an exposure of 2.5% (96.8%) and 5% (97%) extracts. *C. laurifolius* extracts showed significant anti-feedant activity from 1% exposure onwards and maximum activity was observed at 5% exposure (86.11%). In *C. halicacabum* significant anti-feedant activity was observed from 1% exposure and the maximum anti-feedant activity was noted in 5% extract exposure (89.06%). A similar trend was noted in *A. cocculus* with maximum anti-feedant activity (55.2%) was seen in the highest dose of exposure.

However, a different pattern was noted in the assay of bark extracts. The maximum activity was noted in *C. laurifolius* extracts with 41.29% anti-feedant activity on the exposure of 0.5% extract followed by 47.29% in 1% exposure, 74.46% in 2.5% exposure and a maximum of 92.17% in 5% exposure. *C. halicacabum* and *S. nux-vomica* showed a similar trend with a maximum anti-feedant activity of 32.93% and 41.23% respectively at the exposure of 5% bark extracts. Even though *A. cocculus* extracts showed significant anti-feedant activity compared to control, it has the lowest anti-feedant activity (12.66%) even at an exposure of 5% extract. The results are shown in Fig. 1b. Similar to anti-feedant activity assay, feeding activity was also recorded on the exposure of leaf and bark extracts of *A. cocculus*, *C. halicacabum*, *C. laurifolius* and *S. nux-vomica.* In all the samples, 100 % feeding was recorded in untreated control samples. In leaf extracts (Fig. 2a), least feeding activity (1.98%) was noted in *S. nux-vomica* extracts at 5% extract exposure, followed by *C. halicacabum* (10.92%), *C. laurifolius* (13.87%) and *A. cocculus* (43.2%). In bark extracts, *C. laurifolius* has shown the maximum inhibition in all the concentrations, 58.69 % in 0.5%, 52.70% in 1%, 25.52% in 2.5% and 7.8% in 5% extracts. This was followed by *S. nux-vomica*, *C. halicacabum* and *A. cocculus* (Fig. 2b).

In the present study, *S. nux-vomica* leaf extract had shown up to 97% anti-feedant activity which is highest compared to all other extracts. *C. halicacabum* and *C. laurifolius* also showed a similar feeding inhibition at highest dose of exposure. In case of bark extracts, *C. laurifolius* had the maximum effect followed by *S. nux-vomica* and *C. halicacabum.* Anti-feedant activity of leaf extracts of *Catharanthus roseus* and *Ocimum sanctum* against the 4th instar larvae of *S. litura* had shown promising results[18]. On screening of different plant extracts against *S. litura*, varying degrees of anti-feedant activity was reported i.e., *Pedalium murex* (87.49%), *Lantana camara* (83.17%), *Gymnema sylestre* (63.08%), *Taxodum disticum* (56.24%) and *Ageratum vulgaris* (51.27%)[30]. Anti-feedant and growth inhibitory activities of *Syzygium lineare*[31] and flower extract of *Cassia fistula*[32] has been reported against *S. litura.* The crude acetone extracts of *Tamarindus indica, Tectona grandis, Madhuca indica, Jatropha curcas* and *Momordica charantia* showed significant anti-feedant activity against *S. litura*[33]. The results of the present study were well corroborated with many of the above-cited results. The extracts of *S. nux-vomica* and *C. laurifolius* showed better anti-feedant activity compared to many other plants reported earlier, this could be because of the presence of molecules with anti-feedant activities in them. Most potent insect anti-feedants are indole alkaloids, quinoline, diterpinoids, triterpinoids and sesquiterpene lactone molecules present in the plants[34].

***Repellent activity***

Repellent index (RI) of both leaf and bark extracts (100 mg/mL) of *A. cocculus, C. halicacabum, C. laurifolius* and *S. nux-vomica*were were tested in the 3rd instar larvae of *S. litura.* In leaf extracts (Fig. 3a), RI was almost similar in *A. cocculus* (45), *C. halicacabum* (50) and *S. nux-vomica* (50). No statistically significant difference was noted among these plants. However, the *C. laurifolius* had shown an attractant (-25) activity. In bark extracts (Fig. 3b), *A. cocculus* (30) and *S. nux-vomica* (30) were similar in their RI. Similarly, *C. halicacabum* (65*)* and *C. laurifolius* (70) falls into the same group. Among the extracts tested, bark extracts of *C. laurifolius* has shown the maximum RI. The study revealed that the crude plant extracts showed different levels of repellent activity against *S. litura. A. cocculus, S. nux-vomica* and *C. halicacabum* leaf extracts showed RI values not significantly different from each other. However, bark extracts *C. halicacabum* and *C. laurifolius*, have shown significantly higher values compared to other two plants. Repellent activity of *Caulerpa scalpelliformis* extracts and its formulations against *S. litura* has been reported earlier[35]. Arthropods show a differential response to volatile plants. At the same time, the same compound is attractive to some arthropods and repellent to others. The volatile compounds in orange fruit *Citrus aurantium* (L.) were attractive to *Anastrepha ludens* and repellent for *Culex pipiens*[36,37]. *C. halicacabum* crude extract showed protection against mosquito bites without any allergic reaction to the test person, and also, the repellent activity was dependent on the strength of the plant extracts. The tested plant extracts had exerted promising repellent activity against three mosquitoes *Culex quinquefasciatus, Aedes aegypti* and *Anopheles stephensi*[38]. Adulticidal properties of *C. halicacabum* plant extract against these three important vector mosquitoes have also been reported[39]. *C. halicacabum* leaf extracts (benzene, hexane, ethyl

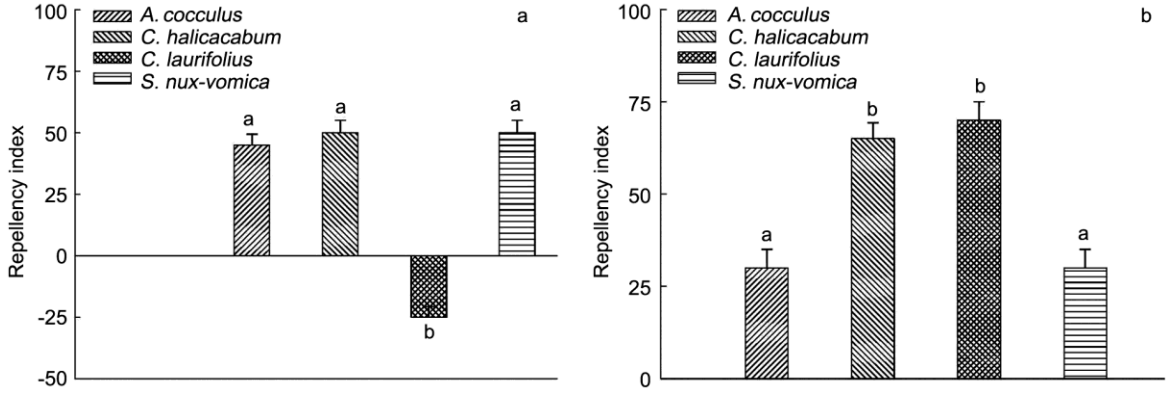


Fig. 3 — Repellent activity of leaf (a) and bark (b) methanol extracts of *A. cocculus, C. halicacabum, C. laurifolius* and *S. nux-vomica* against *Spodoptera litura.* The values are expressed as mean ± SE of four replicates per experiment. Means followed by different alphabets are significantly different at $p \leq 0.05$ by Student-Newman-Keul's multiple comparison test.

acetate, methanol, and chloroform) were found to have larvicidal and ovicidal activity against *C. quinquefasciatus* and *A. aegypti*. The ovicidal activity was maximum in methanol and benzene extracts. Complete mortality was shown by methanol and benzene extract against *C. quinquefasciatus*. The methanol extract showed complete ovicidal activity against *A. aegypti*[40].

***Contact toxicity***

The contact toxicity of leaf extracts was in the order *A. cocculus* (382.5 µg/mL), *C. halicacabum* (110 µg/mL), *C. laurifolius* (92.5 µg/mL) and *S. nux-vomica* (8.75 µg/mL) (Fig. 4a). In case of bark extracts, *S. nux-vomica* (137.5 µg/mL) had shown the maximum toxicity followed by *C. halicacabum* (87.5 µg/mL), *C. laurifolius* (15.25 µg/mL) and *A. cocculus* (11.25 µg/mL) (Fig. 4b). Acetone extracts of *Anamirta cocculus* fruit reported to show larvicidal activity against different instars of *Culex pipiens*[41]. Many of the compounds identified in the assessed plants have anti-insect activities. For example, sesquiterpenes like caryophyllene oxides are reported to have anti-termite activity[42]. This is in addition to the anti-inflammatory and cytotoxic activities exhibited by caryophyllene class of compounds[43,44].

**GC-MS analysis**

Identification of chemical constituents was established based on the molecular structure, molecular mass and calculated fragments. Explication on GC-MS spectrum was conducted using the database NIST and Wiley library. The name, retention time, area and the base m/z of the components of the test materials were ascertained. The correlative percentage amount of each component was calculated by comparing its average peak area in the total area. The spectrum of the unknown component was compared with the spectrum of the component in the library.

The identified phytochemical constituents in *A. cocculus* leaf extracts are neophytadiene, methylpalmitate, 4-nonenoic acid-methyl ester, T-phytol, stigmasterol, gamma-sitosterol, gamma-curcumene, methyl 8,11,14-eicosatrienoate, Urs-12-ene, lupeol, ethyl iso-allocholate, squalene, longifolenaldehyde, (+-)-trans-1-Isopropenyl-4-methyl-1,4-cyclohexanediol, (-)-Globulol and dodecanedioic acid. The bark extract contains coumarin, p-Vinylguaiacol, pyrogallol dimethylether, neophytadiene, methyl palmitate, linoleic acid- methyl ester, 9-Octadecenoic Acid (Z)-methyl ester, phytol, methyl stearate, myo-Inositol, L-serine-ethyl ester, galactopyranoside, 3,6,9,12,15-Pentaoxanonadecan- 1-ol, butyraldehyde-semicarbazone, levoglucosan, alpha-l-rhamnopyranose, 5-Methyl-2-hexanone oxime, N-Isoamylacetamide, methyl pentofuranoside, inositol, 1-deoxy, glycerol .beta.- palmitate, 1,2-enzenedicarboxylic Acid and methyl lignocerate (Table 1).

The leaf extract of *C. halicacabum* contains tridecyl acrylate, phytol acetate, hexahydrofarnesol, methyl palmitate, linolelaidic acid-methyl ester, 8,11,14-docosatrienoic acid methyl ester, phytol, methyl stearate, ethyl elaidate, ethyl 9,12-hexadecadienoate, eicosanoic acid -methyl ester, ethyl margarate, methyl melissicate, squalene, gamma-tocopherol and 3-bromocholest-5 ene. Phytochemical constituents in *C. halicacabum* bark methanol extracts are beta - caryophyllene epoxide, tridecyl acrylate, phytol acetate, 2-hydroxyhexadecyl butyrate, mome-inositol, methyl palmitate, linolelaidic acid-methyl ester, 2-methyltetracosane, phytol, eicosane, pentacosane and 2-methyloctacosane. Their retention time (RT), peak area in percentage, name and m/z ratio and chemical nature is shown in Table 2.

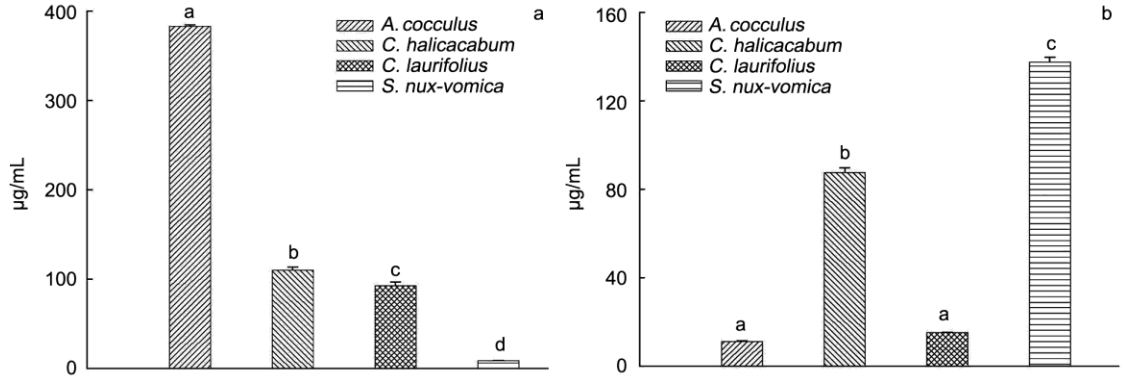


Fig. 4 — Contact toxicity of leaf (a) and bark (b) methanol extracts of *A. cocculus*, *C. halicacabum*, *C. laurifolius* and *S. nux-vomica* against *Spodoptera litura*. The values are expressed as mean ± SE of four replicates per experiment. Means followed by different alphabets are significantly different at $p \leq 0.05$ by Student-Newman-Keul's multiple comparison test.

Table 1 — Phytochemical constituents *A. cocculus* extracts

| No | Retention Time | Area (%) | Name | Base m/z | Chemical Nature |
|---|---|---|---|---|---|
| | | | Leaf | | |
| 1 | 26.542 | 12.80 | Neophytadiene | 68.10 | Sesquiterpeninoids |
| 2 | 28.765 | 14.88 | Methylpalmitate | 74.05 | Saturated fatty acids methyl ester |
| 3 | 31.875 | 1.29 | 4-Nonenoic acid, methyl ester | 96.05 | Fatty acids methyl ester |
| 4 | 32.042 | 8.42 | T-Phytol | 71.10 | Diterpene alcohol |
| 5 | 34.416 | 11.93 | Stigmasterol | 55.05 | Tetracyclictriterpinoids |
| 6 | 39.835 | 19.47 | Gamma-Sitosterol | 55.05 | Tetracyclictriterpinoids |
| 7 | 41.725 | 1.91 | Gamma-Curcumene | 77.00 | Sesquiterpene |
| 8 | 42.054 | 2.05 | Methyl 8,11,14-Eicosatrienoate | 82.10 | Methyl ester |
| 9 | 42.150 | 2.96 | Urs-12-ene | 218.20 | Diterpene |
| 10 | 42.322 | 3.10 | Lupeol | 94.10 | Pentacyclic terpenoids |
| 11 | 42.892 | 0.94 | Ethyl iso-allocholate | 59.95 | ---------- |
| 12 | 43.051 | 0.97 | Squalene | 69.10 | Pentacyclic triterpenoids |
| 13 | 44.209 | 6.00 | Longifolenaldehyde | 138.15 | Tricyclic sesquiterpene |
| 14 | 45.400 | 1.16 | (+-)-trans-1-Isopropenyl-4-methyl-1,4-cyclohexanediol | 108.10 | Diol |
| 15 | 45.501 | 3.89 | (-)-Globulol | 95.10 | Sesquiterpenoids |
| 16 | 45.617 | 0.76 | Dodecanedioic Acid | 52.95 | Saturated fatty acids/Carboxylic acid |
| | | | Bark | | |
| 1 | 12.300 | 0.48 | Coumaran | 120.10 | Phenylpropanoids |
| 2 | 14.209 | 1.31 | p-Vinylguaiacol | 150.05 | 2-Methoxy 4-Vinyl Phenol |
| 3 | 15.192 | 3.27 | Pyrogallol Dimethylether | 154.10 | --------- |
| 4 | 26.470 | 0.39 | Neophytadiene | 68.05 | Sesquiterpenoids |
| 5 | 28.290 | 0.89 | Methyl palmitate | 74.05 | Saturated fatty acids methyl ester |
| 6 | 31.487 | 0.35 | Linoleic Acid, Methyl Ester | 67.05 | Saturated fatty acids methyl ester |
| 7 | 31.615 | 0.81 | 9-Octadecenoic Acid (Z)-, Methyl Ester | 55.05 | Saturated fatty acids methyl ester |
| 8 | 31.823 | 0.40 | Phytol | 71.05 | Diterpene alcohol |
| 9 | 32.125 | 0.44 | Methyl stearate | 74.05 | Saturated fatty acids methyl ester |
| 10 | 32.302 | 0.50 | Myo-Inositol | 73.05 | Vitamin-B |
| 11 | 32.367 | 1.60 | L-Serine, Ethyl Ester | 60.00 | ------- |
| 12 | 32.417 | 2.56 | Galactopyranoside | 61.00 | Galactoside |
| 13 | 32.525 | 7.79 | 3,6,9,12,15-Pentaoxanonadecan-1-ol | 57.00 | ------- |
| 14 | 32.717 | 5.04 | Butyraldehyde, Semicarbazone | 60.00 | Aldehyde |
| 15 | 32.758 | 10.48 | Levoglucosan | 60.00 | Anhydrohexose |
| 16 | 32.908 | 17.40 | Alpha-l-rhamnopyranose | 60.00 | --------- |
| 17 | 33.117 | 5.59 | 5-Methyl-2-hexanone oxime | 73.05 | --------- |
| 18 | 33.308 | 0.70 | N-Isoamylacetamide | 73.05 | ---------- |
| 19 | 33.350 | 10.73 | Methyl pentofuranoside | 73.00 | ---------- |
| 20 | 33.547 | 25.61 | Inositol, 1-deoxy- | 73.05 | 1,2,3,4,5-Cyclohexanpentol |
| 21 | 38.700 | 2.54 | Glycerol .beta.- palmitate | 57.05 | Monoacylglyceride (Saturated fatty acids) |
| 22 | 38.900 | 0.55 | 1,2-enzenedicarboxylic Acid | 149.00 | Aromatic dicarboxylic acid (Phthalic Acid) |
| 23 | 41.862 | 0.59 | Methyl Lignocerate | 74.05 | Lignoceric acid Methyl ester |

Methanol extracts of *C. laurifolius* bark had shown the presence of 24 compounds, however, the leaf extract had shown only 10 compounds. The compounds in bark extract were methoxyeugenol, hexahydrofarnesol, 3,5-dimethoxy-4-hydroxyphenyl acetic acid, neophytadiene, cholesterol dimethylsilyl ether, methyl palmitate, inositol, 1- deoxy, methyl octadeca-9,12-dienoate, 9-octadecenoic acid (Z)-methyl ester, trans-13-octadecenoic acid-methyl ester, phytol, methyl stearate, ambrettolide, 4,8,12,16-tetramethylheptadecan-4-olide, 3,5,6-trimethyl-4-phenyl-2-pyridone, crinan-3-one, methyl docosanoate,

Table 2 — Phytochemical constituents *C. halicacabum* extracts

| No | Retention Time | Area (%) | Name | Base m/z | Chemical Nature |
|---|---|---|---|---|---|
| | | | Leaf | | |
| 1 | 23.585 | 7.24 | Tridecyl acrylate | 55.05 | Ester |
| 2 | 26.652 | 15.68 | Phytol, acetate | 68.10 | Diterpene alcohol |
| 3 | 26.772 | 3.35 | Hexahydrofarnesol | 70.10 | Sesquiterpenoids |
| 4 | 28.472 | 10.83 | Methyl Palmitate | 74.10 | Saturated fatty acids methyl ester |
| 5 | 31.674 | 3.40 | Linolelaidic Acid, Methyl Ester | 67.10 | Poly unsaturated fatty acid methyl ester |
| 6 | 31.797 | 12.08 | 8,11,14-Docosatrienoic Acid, Methyl Ester | 55.10 | Fatty acid Methyl ester |
| 7 | 32.021 | 17.58 | Phytol | 71.10 | Diterpene alcohol |
| 8 | 32.304 | 2.96 | Methyl stearate | 74.05 | Saturated fatty acids methyl ester |
| 9 | 33.147 | 1.17 | Ethyl elaidate | 55.10 | Elaidic acid ethyl ester |
| 10 | 34.631 | 3.39 | Ethyl 9,12-hexadecadienoate | 67.10 | Saturated Fatty acid methyl ester |
| 11 | 35.821 | 1.02 | Eicosanoic Acid, Methyl Ester | 74.10 | Saturated fatty acids methyl ester |
| 12 | 36.528 | 5.11 | Ethyl Margarate | 57.10 | Saturated fatty acids ethyl ester |
| 13 | 39.075 | 1.07 | Methyl Melissicate | 74.10 | Very long chain fatty acids |
| 14 | 43.223 | 6.94 | Squalene | 69.10 | Pentacyclic triterpenoids |
| 15 | 46.963 | 1.57 | Gamma-Tocopherol | 151.15 | Vitamin-E |
| 16 | 47.636 | 1.74 | 3-Bromocholest-5-ene | 57.10 | --------- |
| | | | Bark | | |
| 1 | 21.055 | 1.39 | Beta - Caryophyllene Epoxide | 79.10 | Bicyclic sesquiterpene |
| 2 | 23.518 | 3.41 | Tridecyl acrylate | 55.05 | -------- |
| 3 | 26.597 | 2.13 | Phytol acetate | 68.10 | Diterpene alcohol |
| 4 | 27.117 | 1.23 | 2-Hydroxyhexadecyl butyrate | 73.05 | ------ |
| 5 | 27.217 | 3.93 | Mome Inositol | 87.10 | ------- |
| 6 | 28.414 | 3.67 | Methyl Palmitate | 74.10 | Saturated fatty acids methyl ester |
| 7 | 31.613 | 2.57 | Linolelaidic Acid, Methyl Ester | 67.10 | Poly unsaturated fatty acid methyl ester |
| 8 | 31.764 | 5.33 | 2-Methyltetracosane | 57.10 | Alkane |
| 9 | 31.950 | 4.93 | Phytol | 71.10 | Diterpene alcohol |
| 10 | 35.308 | 8.95 | Eicosane | 57.10 | Alkane |
| 11 | 41.579 | 7.64 | Pentacosane | 57.10 | Hydrocarbon |
| 12 | 47.810 | 1.19 | 2-Methyloctacosane | 57.10 | Alkane |

benzoic acid, 4-(3-acetoxy-4-methoxybenzylidenamino)-1 methyl ester, 1H-naphtho[2,1-b]pyran-1-one,7,8-dimethoxy-2-methyl-,2-chloro-4,5methylenedioxymethamphet- amine, vinyl methyl ether, dibenz[d,f]cycloheptanone, 2,3,9-trimethoxy-, gamma-tocopherol and vitamin E. The leaf extracts contain, phytol-acetate, hexahydrofarnesylacetone, 3,7,11,15-tetramethyl-2-hexadecen-1-ol, methyl palmitate, methyl elaidate, phytol, 4,6-dimethyl-1,4,6-oxadiazocane-5-Thione, palmitaldehyde-diallyl acetal and pentacosane (Table 3).

The *S. nux-vomica* bark extracts contain methaqualone metabolite VI (hypnotic), chinasaure, methoxyeugenol, 5-ethyl-2-nonanol, methyl palmitate, mome inositol, 1,3-oxathiane, 5-isopropyl-2-methyl, ethyl pentofuranoside, 9,12-octadecadienoic acid - methyl ester, 9-octadecenoic Acid (Z)-methyl ester and gamma-sitosterol. The leaf extracts contain, methaqualone metabolite VI (hypnotic), neophytadiene, 3,7,11,15-tetramethyl-2-hexadecen-1-ol, phytol-acetate, methyl palmitate, mome inositol, phytol, glyoxal, 1H-purin-6-amine, [(2-Fluorophenyl) methyl] and strychnidin-10-one (Table 4).

The essential oil from the rhizomes of *Zingiber zerumbet* had shown contact and repellent activities because of the presence of caryophyllene and other molecules in the essential oils[45]. A study conducted on the essential oils from different genotypes of citrus from Brazil had shown the repellent activity against *Diaphorina citri* Kuwayama and the presence of phytol in these extracts were also confirmed by GC-MS analysis[46]. Essential oils of *Mentha longifolia*, *Pulicaria gnaphalodes* and *Achillea wilhelmsii* had shown insecticide activity against two stored product pests, the flour beetle, *Tribolium castaneum*, and the cowpea weevil, *Callosobruchus maculatus*. Further

Table 3 — Phytochemical constituents of *C. laurifolius* extracts

| No | Retention Time | Area (%) | Name | Base m/z | Chemical Nature |
|---|---|---|---|---|---|
| | | | Leaf | | |
| 1 | 26.486 | 27.85 | Phytol, acetate | 68.10 | Diterpene alcohol |
| 2 | 26.613 | 16.44 | Hexahydrofarnesylacetone | 58.05 | -------- |
| 3 | 27.365 | 8.35 | 3,7,11,15-Tetramethyl-2-hexadecen-1-ol | 82.10 | -------- |
| 4 | 28.357 | 6.88 | Methyl Palmitate | 74.05 | Saturated fatty acids Methyl esters |
| 5 | 31.652 | 6.04 | Methyl Elaidate | 85.05 | Unsaturated trans fatty acid |
| 6 | 31.849 | 11.31 | Phytol | 71.05 | Diterpene alcohol |
| 7 | 32.183 | 8.40 | 4,6-Dimethyl-1,4,6-Oxadiazocane-5-Thione | 174.15 | ------ |
| 8 | 32.409 | 2.83 | Palmitaldehyde, Diallyl Acetal | 84.10 | ------ |
| 9 | 44.243 | 3.65 | Pentacosane | 57.05 | Hydrocarbon |
| | | | Bark | | |
| 1 | 23.724 | 15.59 | Methoxyeugenol | 194.05 | ----- |
| 2 | 24.155 | 0.77 | Hexahydrofarnesol | 56.05 | Sesquiterpenoids |
| 3 | 25.251 | 4.84 | 3,5-Dimethoxy-4-hydroxyphenyl acetic acid | 167.05 | ----- |
| 4 | 26.473 | 0.60 | Neophytadiene | 68.05 | Sesquiterpenoids |
| 5 | 27.478 | 0.74 | Cholesterol Dimethylsilyl Ether | 75.05 | Sterol |
| 6 | 28.298 | 1.71 | Methyl palmitate | 74.05 | Saturated fatty acids Methyl ester |
| 7 | 29.592 | 0.54 | Inositol, 1- deoxy | 73.05 | ----- |
| 8 | 31.492 | 2.81 | Methyl Octadeca-9,12-dienoate | 67.05 | Fatty acid methyl ester |
| 9 | 31.617 | 2.04 | 9-Octadecenoic Acid (Z)-, Methyl Ester | 55.00 | Saturated fatty acids Methyl ester |
| 10 | 31.730 | 0.63 | Trans-13-Octadecenoic acid, methyl ester | 55.00 | Saturated fatty acids Methyl ester |
| 11 | 31.822 | 0.64 | Phytol | 71.05 | Diterpene alcohol |
| 12 | 32.117 | 0.42 | Methyl stearate | 74.05 | Saturated fatty acids methyl ester |
| 13 | 32.447 | 0.92 | Ambrettolide | 55.05 | ------ |
| 14 | 35.985 | 0.78 | 4,8,12,16-Tetramethylheptadecan-4-olide | 99.05 | ------ |
| 15 | 36.646 | 3.60 | 3,5,6-Trimethyl-4-Phenyl-2-Pyridone | 212.05 | ------ |
| 16 | 38.817 | 1.52 | Crinan-3-one | 271.10 | ------ |
| 17 | 38.877 | 1.56 | Methyl docosanoate | 74.05 | Saturated fatty acids |
| 18 | 40.316 | 6.76 | Benzoic acid, 4-(3-acetoxy-4-methoxybenzylidenamino)-1 methyl ester | 285.10 | ----- |
| 19 | 42.106 | 17.44 | 1H-Naphtho[2,1-b]pyran-1-one, 7,8-dimethoxy-2-methyl- | 270.05 | ----- |
| 20 | 42.192 | 16.59 | 2-chloro-4,5-methyleendioxymethamphetamine | 58.05 | ----- |
| 21 | 42.592 | 1.74 | Vinyl Methyl Ether | 58.05 | Enol ether |
| 22 | 44.736 | 14.35 | Dibenz[d,f]cycloheptanone, 2,3,9-trimethoxy- | 298.10 | ----- |
| 23 | 46.626 | 1.16 | gamma-Tocopherol | 151.10 | Tocopherol |
| 24 | 48.105 | 2.26 | Vitamin E | 165.10 | Tocopherol |

analysis of the oils had shown the presence of eicosane along with many other compounds[47]. n-Pentacosane is reported to act as both contact and volatile pheromone in the tea weevil, *Myllocerinus aurolineatus*[48]. It was reported in a recent study that squalene showed repellent against whitefly adults, whitefly nymphal toxicity and mite toxicity[49]. Insecticidal activity of *Jatropha curcas* against

Table 4 — Phytochemical constituents of *S. nux-vomica* extracts

| No | Retention Time | Area (%) | Name | Base m/z | Chemical Nature |
|---|---|---|---|---|---|
| | | | Leaf | | |
| 1 | 18.049 | 2.63 | Methaqualone Metabolite VI (Hypnotic) | 251.00 | Quinazolines |
| 2 | 26.476 | 14.05 | Neophytadiene | 68.05 | Sesquitepenoids |
| 3 | 26.984 | 3.08 | 3,7,11,15-Tetramethyl-2-hexadecen-1-ol | 82.05 | -------- |
| 4 | 27.357 | 5.54 | Phytol, acetate | 82.10 | Diterpene alcohol |
| 5 | 28.300 | 10.20 | Methyl palmitate | 74.05 | Saturated fatty acids methyl ester |
| 6 | 31.499 | 31.57 | Mome Inositol | 73.00 | ------- |
| 7 | 31.825 | 15.87 | Phytol | 71.05 | Diterpene alcohol |
| 8 | 32.678 | 3.08 | Glyoxal | 58.00 | Dialdehyde |
| 9 | 45.417 | 4.89 | 1H-Purin-6-Amine, [(2-Fluorophenyl)Methyl]- | 73.05 | ------ |
| 10 | 49.231 | 9.08 | Strychnidin-10-one | 334.10 | Alkaloid |
| | | | Bark | | |
| 1 | 18.043 | 0.79 | Methaqualone Metabolite VI (Hypnotic) | 251.05 | ----- |
| 2 | 23.233 | 4.97 | Chinasaure | 60.00 | Cyclitol,Cyclicpolyol, Cyclohexanecaboxylic acid |
| 3 | 23.867 | 6.53 | Methoxyeugenol | 194.05 | ----- |
| 4 | 24.142 | 5.31 | 5-Ethyl-2-Nonanol | 57.00 | ----- |
| 5 | 28.298 | 1.28 | Methyl palmitate | 74.05 | Saturated fatty acids Methyl esters |
| 6 | 29.643 | 4.24 | Mome Inositol | 73.05 | ------ |
| 7 | 29.733 | 4.73 | 1,3-Oxathiane, 5-isopropyl-2-methyl- | 75.05 | -------- |
| 8 | 29.875 | 10.01 | Ethyl pentofuranoside | 60.00 | -------- |
| 9 | 31.494 | 0.61 | 9,12-Octadecadienoic acid, methyl ester | 67.05 | Saturated fatty acids Methyl esters |
| 10 | 31.619 | 1.11 | 9-Octadecenoic Acid (Z)-, Methyl Ester | 55.05 | Saturated fatty acids Methyl esters |
| 11 | 39.826 | 1.83 | gamma-Sitosterol | 55.05 | Tetracyclic triterpenoids |

housefly, *Musca domestica* could be due to the presence of trans-phytol and squalene in the extracts[50]. Studies were shown that toxicity and larvicidal activity of the essential oil from *Acalypha segetalis* could be due to the presence of the major components alpha-pinene, neophytadiene, isomer II and neophytadiene, isomer III[51].

## Conclusion

*S. litura* being a pest which causes economic damage to many of the vegetables and important crops, effective mechanisms are required for controlling them. Due to the continuous and irrational use of chemical agents, the pest has become resistant to many of them and the incessant use of chemical agents are becoming more dangerous to non-target pests and other environmental factors. Through the present study, it was found that effective anti-feedant and repellent agents or formulations could be developed from *S. nux-vomica*, *C. halicacabum* and *C. laurifolius*, which containmany phytochemicals with proven anti-insect properties.

## Acknowledgement

The financial support from Kerala Biotechnology Commission, Kerala State Council for Science Technology and Environment (KSCSTE) and analytical service support from Centre for Analytical Instrumentation- Kerala (CAI-K) are highly acknowledged. Ms. Alina Paul is thankful to KSCSTE for the grant of Research Fellowship.

## Conflict of interest

The authors declare that they have no conflict of interest.

## References

1 Divya D, Management of *Spodoptera litura*, *Imp J Interdiscip Res*, 2016, **2**(5), 285-289.

2 Guan B B and Chen O J, Biology and ecology of *Spodoptera litura*, *Acta Entomol Eastern China*, 1999, **8**, 57-61.

3 Chunxian G, Yawei B, Tinghua C and Xiuhui G, On factors causing outbreak of *Spodoptera litura* (Fabricius), *Acta Agri Zhejiangensis*, 2004, **16**(5), 332-335.

4 Houguo Q, Zhengxiang Y, Shuijin H, Jian D and Renhua L, The correlation of the different host plants with preference level, life duration and survival rate of *Spodoptera litura* Fabricius, *Chin J Eco Agric*, 2004, **12**(2), 40-42.

5 Kranthi K R, Jadhav D R, Kranthi S, Wanjari R R, Ali S S, *et al.*, Insecticide resistance in five major insect pests of cotton in India, *Crop Prot*, 2002, **21**(6), 449-60.

6 Garad G P, Shivpuje P R and Bilapate G G, Life fecundity tables of *Spodoptera litura* (Fabricius) on different hosts, *Proc Anim Sci*, 1984, **93**(1), 29-33.

7 Armes N J, Wightman J A, Jadhav D R and Ranga Rao G V, Status of insecticide resistance in *Spodoptera litura* in Andhra Pradesh, India, *Pestic Sci*, 1997, **50**(3), 240-248.

8 Ahmad M, Ghaffar A and Rafiq M, Host plants of leaf worm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) in Pakistan, *Asian J Agric Biol*, 2013, **1**, 23-28.

9 Patel H K, Patel N G and Patel V C, Quantitative estimation of damage to tobacco caused by the leaf eating caterpillar, *Prodenia litura* F, *PANS*, 1971, **17**(2), 202-205.

10 Nakasuji F and Matsuzaki T, The control threshold density of the tobacco cutworm *Spodoptera litura* (Lepidoptera: Noctuidae) on eggplants and sweet peppers in vinyl-houses, *Appl Entomol Zool*, 1977, **12**(2), 184-189.

11 Dhir B C, Mohapatra H K and Senapati B, Assessment of crop loss in groundnut due to tobacco caterpillar, *Spodoptera litura* (F.), *Indian J Plant Prot*, 1992, **20**(2), 215-217.

12 Pillai K S, Palaniswami M S, Rajamma P, Mohandas C and Jayaprakas C A, Pest management in tuber crops, *Indian J Hortic*, 1993, **38**(3), 20-23.

13 Singh S P and Jalali S K, Management of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae), in *Proc Natl Sci* Forum *Spodoptera litura* (F.) (ICRISAT Asia), 1996, 27-65.

14 Patnaik H P, Pheromone trap catches of *Spodoptera litura* F. and extent of damage on hybrid tomato in Orissa, In Advances in IPM for horticultural crops, in *Proc 1st Natl Symposium Pest Management Horticultural Crops*: Environmental implications and thrusts held on 15-17 October 1997, Bangalore, India, Association for Advancement of Pest Management in Horticultural Ecosystems, Indian Institute of Horticultural Research, 1998, 68-72.

15 Ferry N, Edwards M G, Gatehouse J A and Gatehouse A M, Plant–insect interactions: Molecular approaches to insect resistance, *Curr Opin Biotechnol*, 2004, **15**(2), 155-161.

16 Maxmen A, Crop pests: Under attack, *Nature*, 2013, **501**(7468), S15-7.

17 Ram S, Patil B D and Purohit M L, Seasonal incidence of major insect pests of fodder cowpea (*Vigna unguiculata* L.) in Bundelkhand region, *Bull Entomol Res*, 1989, **30**(1), 44-47.

18 Chatterjee P B and Nayaky D K, Occurrence of *Spodoptera litura* (Fabr.) as a new pest of sugar-beet in West Bengal, *Pesticides*, 1987, **21**(10), 21-22.

19 Roychoudhury N, Kalia S and Joshi K C, Pest status and larval feeding preference of *Spodoptera litura* (Fabricius) Boursin (Lepidoptera: Noctuidae) on Teak, *Indian For*, 1995, **121**(6), 581-583.

20 Ranjith A M, Haseena B and Nambiar S S, *Spodoptera litura* causes brown flag syndrome in banana, *Insect Environ*, 1997, **3**(2), 44.

21 Balikai R A, Bagali A N and Ryagi Y H, Incidence of *Spodoptera litura* Fab. on grapevine, *Vitis vinifera* L, *Insect Environ*, 1999, **5**(1), 32.

22 Chattopadhyay N, Balasubramaniam R, Attri S D, Ray K, John G, *et al.*, Forewarning of incidence of *Spodoptera litura* (Tobacco caterpillar) in soybean and cotton using statistical and synoptic approach, *Ital J Agrometeorol*, 2019, **21**(1), 68-75.

23 Isman M B, Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world, *Annu Rev Entomol*, 2006, **51**, 45-66.

24 Summarwar S and Pandey J, Anti-feedant activity of leaf extracts of *Catharanthus roseus* and *Ocimum sanctum* against Fourth instar larvae of *Spodoptera litura*, *Int J Pure Appl Zool*, 2015, **3**(3), 259-262.

25 Blackwell A, Stuart A E and Estambale B B, The repellent and anti-feedant activity of *Myrica gale* oil against *Aedes aegypti* mosquitoes and its enhancement by the addition of salicyluric acid, *J R Coll Physicians Edinb*, 2003, **33**, 209-214.

26 Isman M B, Koul O, Luczynski A and Kaminski J, Insecticidal and anti-feedant bioactivities of neem oils and their relationship to azadirachtin content, *J Agric Food Chem*, 1990, **38**(6), 1406-1411.

27 Singh R P and Pant N C, *Hymenocallis littoralis* Salisb. as anti-feedant to desert locust *Schistocerca gregaria* Forsk, *Indian J Entomol*, 1980, **42**(3), 460-464.

28 Haouas D and Halima-Kamel M, Assessment of insecticidal effect of *chrysanthemum* sp. essential oils against *Tribolium confusum* du Val (Coleoptera, Tenebrionidae), *Afr J Plant Sci Biotechnol*, 2013, **7**(1), 79-82.

29 Pascual-Villalobos M J and Robledo A, Screening for anti-insect activity in mediterranean plants, *Ind Crop Prod*, 1998, **8**(3), 183-194.

30 Awasthi A and Avasthi S, Screening of some plant extracts against polyphagous pest *Spodoptera litura* (Lepidoptera: Noctuidae), *Int J Zool Stud*, 2018, **3**(1), 173-176.

31 Jeyasankar A, Raja N and Ignacimuthu S, Anti-feedant and growth inhibitory activities of "*Syzygium lineare*" wall (Myrtaceae) against "*Spodoptera litura*" fab (Lepidoptera: Noctuidae), *Curr Res J Biol Sci*, 2010, **2**(3), 173-177.

32 Duraipandiyan V, Ignacimuthu S and Paulraj M G, Anti-feedant and larvicidal activities of Rhein isolated from the flowers of *Cassia fistula* L, *Saudi J Biol Sci*, 2011, **18**(2), 129-133.

33 Devanand P and Rani P U, Biological potency of certain plant extracts in management of two lepidopteran pests of *Ricinus communis* L, *J Biopestic*, 2008, **1**(2), 170-176.

34 Schoonhoven L M, Biological aspects of anti-feedants, *Ent Exp Applicat*, 1982, **31**(1), 57-69.

35 Kombiah P and Sahayaraj K, Repellent activity of *Caulerpa scalpelliformis* extracts and its formulations against *Spodoptera litura* and *Dysdercus cingulatus* (Fab.), *J Biopest (Supplementary)*, 2012, **5**, 145-150.

36 Choi W S, Park B S, Ku S K and Lee S E, Repellent activities of essential oils and monoterpenes against *Culex pipiens* pallens, *J Am Mosq Control Assoc*, 2002, **18**(4), 348-351.

37 Rasgado M A, Malo E A, Cruz-López L, Rojas J C and Toledo J, Olfactory response of the mexican fruit fly (Diptera: Tephritidae) to *Citrus aurantium* volatiles, *J Econ Entomol*, 2009, **102**(2), 585-594.

38 Govindarajan M and Sivakumar R, Repellent properties of *Cardiospermum halicacabum* Linn.(Family: Sapindaceae) plant leaf extracts against three important vector mosquitoes, *Asian Pac J Trop Biomed*, 2012, **2**(8), 602-607.

39 Govindarajan M and Sivakumar R, Adulticidal properties of *Cardiospermum halicacabum* plant extracts against three important vector mosquitoes, *Eur Rev Med Pharmacol Sci*, 2012, **3**, 95-104.

40 Govindarajan M, Mosquito larvicidal and ovicidal activity of *Cardiospermum halicacabum* Linn. (family: Sapindaceae) leaf extract against *Culex quinquefasciatus* (Say.) and *Aedes*

*aegypti* (Linn.) (Diptera: Culicidae), *Eur Rev Med Pharmacol Sci*, 2011, **15**(7), 787-794.

41 Pushpalatha E, Najeeba M B and Santhini K P, Efficacy of *Anamirta cocculus* (Linn.) wight and arn and *Pogostemon paniculatus* (Wild) benth extract on *Culex pipiens*, *Int J Appl Biol Pharm*, 2014, **5**(3), 159-162.

42 Ashitani T, Kusumoto N, Borg-Karlson A K, Fujita K and Takahashi K, Antitermite activity of β-caryophyllene epoxide and episulfide, *Z Naturforsch C*, 2013, **68**(7-8), 302-306.

43 Usai M, Marchetti M, Culeddu N and Mulas M, Chemical composition of myrtle (*Myrtus communis* L.) berries essential oils as observed in a collection of genotypes, *Molecules*, 2018, **23**(10), 2502.

44 Figueiredo P L, Pinto L C, da Costa J S, da Silva A R, Mourão R H, *et al*, Composition, antioxidant capacity and cytotoxic activity of *Eugenia uniflora* L. chemotype-oils from the Amazon, *J Ethnopharmacol*, 2019, **232**, 30-38.

45 Wu Y, Guo S S, Huang D Y, Wang C F, Wei J Y, *et al*, Contact and repellant activities of zerumbone and its analogues from the essential oil of *Zingiber zerumbet* (L.) Smith against *Lasioderma serricorne*, *J Oleo Sci*, 2017, **66**(4), 399-405.

46 Andrade M D, Ribeiro L D, Borgoni P C, Silva M F, Forim M R, *et al*, Essential oil variation from twenty two genotypes of citrus in brazil-chemometric approach and repellency against *Diaphorina citri* Kuwayama, *Molecules*, 2016, **21**(6), 814.

47 Khani A and Asghari J, Insecticide activity of essential oils of *Mentha longifolia*, *Pulicaria gnaphalodes* and *Achillea wilhelmsii* against two stored product pests, the flour beetle, *Tribolium castaneum*, and the cowpea weevil, *Callosobruchus maculatus*, *J Insect Sci*, 2012, **12**(1), 73.

48 Sun X, Zhang X, Wu G, Li X, Liu F, *et al*., n-Pentacosane acts as both contact and volatile pheromone in the tea weevil, *Myllocerinus aurolineatus*, *J Chem Ecol*, 2017, **43**(6), 557-562.

49 Wagan T A, Cai W and Hua H, Repellency, toxicity, and anti-oviposition of essential oil of *Gardenia jasminoides* and its four major chemical components against whiteflies and mites, *Sci Rep*, 2018, **8**(1), 1-12.

50 Chauhan N, Kumar P, Mishra S, Verma S, Malik A, *et al*., Insecticidal activity of *Jatropha curcas* extracts against housefly, *Musca domestica*, *Environ Sci Pollut Res Int*, 2015, **22**(19), 14793-14800.

51 Aboaba S A, Aiyelaagbe O O and Ekundayo O, Chemical composition, toxicity and larvicidal activity of the essential oil from the whole plant of *Acalypha segetalis* from South-West Nigeria, *Nat Prod Commun*, 2010, **5**(3), 481-483.