Journal of Coastal Life Medicine

journal homepage: www.jclmm.com

Review article https://doi.org/10.12980/jclm.4.2016J6-173

Role of plants and plant based products towards the control of insect pests and vectors: A novel review

Elumalai Kuppusamy*, Kasinathan Irukatla Dhamodharan, Saranya Jayakumar

Unit of Entomotoxicity, Department of Advanced Zoology and Biotechnology, Govt. Arts College for Men (Autonomous), Chennai, 600035, Tamil Nadu India

ARTICLE INFO

Article history:
Received 2 Sep 2016
Received in revised form 21 Sep 2016
Accepted 8 Oct 2016
Available online 12 Oct 2016

Keywords:
Insecticidal
Phytochemicals
Compound
Fraction
Essential oil
Extracts

ABSTRACT

Insect pests bear harmful effects causing great loss to the agricultural crops, stored agricultural products and vector mosquitoes can cause diseases to human. Plants possess an array of vast repository of phytochemicals and have been used to cure many diseases and to control the infestation of insect pests from time immemorial. Plants are easily biodegradable and ecologically safe for treating on the stored or on the field crops against pests to prevent from further damage or loss of stored products or preventing human from mosquito bites, thus preventing the spreading of dreadful diseases such as chikungunya and malaria. Hence, this review can give a clear insecticidal, pesticidal and mosquitocidal property of several plants against the insect pests and vectors.

1. Introduction

Phyllum Arthropoda comprises of the biggest class in the animal kingdom known as the class Insecta or otherwise known as Hexapoda. Insects belonging to the class Insecta are found everywhere in the environment and they have been always closely associated with us. They are considered as economically important to humans. Some insects are considered as beneficial and some of them are considered as serious pests to the humans as well as cultivable crops. Being an agro-based country with agriculture as a major source of work in more than 80% of population, these insect pests bring about monetary loss in the agricultural productivity both quantitatively and qualitatively and severe damage to stored agriculture products, too[1]. Therefore, the total loss throughout the world is up to 10%–40% annually[2]. Hence, these pests are considered as a great nuisance to man and prevention of these pests has become a serious issue and thrown more light in the field of entomology.

The protection of stored products, agricultural filed crops, against pests is primarily dependent on liquid, gaseous insecticides[3] and synthetic insecticides. On advent of these, chemical insecticides coming into effect result in increased risk to non-target animals, toxicity to consumers and development of genetic resistance in the pests[4]. These findings result in developing a eco-friendly plant based formulation considering human safety and environmental damage. Furthermore, plants as a rich source of bioactive phytochemicals and compounds are used as insecticides and pesticides against phytophagous insects[5]. Numerous inventions have started to develop in this regard. Also, the insecticidal constituents are present in the plant extracts and in the essential oil. So far, 2 121 species of plants possessing pest management properties, 1 005 plant species showing insecticidal activites, 384 plant species showing antifeedant activities, 297 plant species showing repellent properties, 27 plant species showing attractant

*Corresponding author: Elumalai Kuppusamy, Unit of Entomotoxicity, Department of Advanced Zoology and Biotechnology, Govt. Arts College for Men (Autonomous), Chennai, 600035, Tamil Nadu, India.
E-mail: professorelumalai@gmail.com
Foundation Project: Supported by University Grants Commission, New Delhi [Reference No. 42-583/2013 (SR)].
The journal implements double-blind peer review practiced by specially invited international editorial board members.

properties and 31 plant species having growth inhibiting property have been identified[6].

Similarly, vector mosquitoes are momentarily important in view of public health importance, since they are responsible for the spreading of several disease-causing pathogens among humans and then causing dreadful diseases such as malaria, filariasis, Japanese encephalitis, dengue, chikungunya, West Nile fever, human arbo virus, *etc.*

The present review gives more emphasis on the utilization of plants and plant based products towards the control of agricultural and vector insect pests. This review article is prepared with more than 100 research papers to determine the bio-efficacy of the essential oil and extracts of plants to identify its property of insecticidal, pesticidal and vectoricidal activities against the stored pests, field pests and vector mosquitoes.

2. Roles of plants and plant based products towards the control of agricultural pests

Aslan *et al.*[7] reported that *Tetranychus urticae* (*T. urticae*) and *Bemisia tabaci* (*B. tabaci*) could be controlled by the essential oil vapours of *Satureja hortensis*, *Ocimum basilicum* (*O. basilicum*) and *Thymus vulgaris* (*T. vulgaris*). From their experiments, it was revealed that though essential oil of the three plants can act as an control agent against *T. urticae* and *B. tabaci*, it was found that *Satureja hortensis* was more powerful than the others two. Luo *et al.*[8] analyzed the compounds presenting in the ethanol extract of the root bark of *Tripterygium wilfordii* and also determined the insecticidal and antifeedant activities of the compounds. In their experiment, the compounds were characterized as triptolide, triptonide and euonine by bioassay-guided fractionation of the extract. Their experiment evaluated its antifeedant activity after 24 h of treatment of the pest and EC_{50} and KD50 values were recorded. Moreover, this was the first report on these three compounds for its insecticidal activity.

Çalmaşur *et al.*,[9] studied the essential oil vapours of *Micromeria fruticosa* and *Origanum vulgare* to determine its insecticidal and acaricidal effect on the nymphs and the adult stage of the pests, *T. urticae* and *B.tabaci*, and found that the essential oil from all the plants could be used for the management of pests *T. urticae* and *B.tabaci* in greenhouse condition. Mishra *et al*.[10] determined the solvent extracted essential oil from the seeds of *Momordica charentia*, *Momordica dioica*, *Lagenaria siseraria* and *Luffa acutangula* were tested for its insecticidal activity against *Lipaphis erysimi*. They have observed 100% mortality in all the vegetable oils at 6% concentration. Further, no infestation was found in the vegetable oil treated crop.

Oigiangbe *et al.*[11] analyzed *Alstonia boonei* (*A. boonei*) for its insecticidal activity against *Sesamia calamistis*. They observed a significant reduction in larval survival and weight due to the incorporation of the leaf and stem bark extracts of *A. boonei* in to the diet. Hence, it was concluded that the growth of *Sesamia calamistis* is inhibited by using the leaf and stem bark extracts of *A. boonei*. Kamaraj *et al.*[12] made the study on *Citrus sinensis* (*C. sinensis*), *Ocimum canum* (*O. canum*), *Ocimum sanctum* (*O. sanctum*) and *Rhinacanthus nasutus* to test their antifeedant and larvicidal activities against the gram pod borer, cotton leaf roller and malaria vector by using the extracts of acetone, chloroform, ethyl acetate, hexane and methanol. Their resuls suggested that in order to control the agricultural pests and vectors, ethyl acetate extract of *O. canum*, methanol and chloroform extract of *C. sinensis* and acetone extract of *O. sanctum* will be an ideal eco-friendly method.

Ramya *et al*.[13] analyzed the leaf aqueous extract of ten selected plants against the larvae of *Helicoverpa armigera* (*H. armigera*). Their results revealed the considerable amount of mortality in the decreasing order of *Andrographis paniculata* (*A. paniculata*), *Catharanthus roseus* (*C. roseus*), *Datura metal* (*D. metal*), *Albiziz amara, Cardiospermum halicacabum, Abutilon indicum, Cassia tora, Tribulus terrestris, Achyranthus aspera and Aerva lanata*. Thus, *A. paniculata*, *C. roseus* and *D. metal* can be used as the best source to control gram pod borer. Mikami and Ventura[14] investigated the potency of the oil of *Azadirachta indica* (*A. indica*) by conducting multiple and no-choice feeding preference assays. Their study clearly revealed that males were repelled and feeding deterrency was noted. Therefore, neem oil could be used in pest management.

Ramya and Jayakumararaj[15] studied the insecticidal activity of 25 medicinal plants against *H. armigera*. The larval mortality at 1 000 ppm concentration. The results showed the mortality rate in the following order: *Melia azedarach, A. indica, Solanum trilobatum, A. paniculata, Aegle marmelos* (*A. marmelos*), *Andrographis lineata, Solanum surattrense, C. roseus, Adhatoda zeylanica, Acalypha fruticosa, D. metal, Solanum nigrum, O. canum, Plectranthus coleoides, O. sanctum, Pergularia daemia, Albiziza amara, Gymnema sylvestre, Cardiospermum halicacabum, Vitex negundo, Abutilon indicum, Cassia tora, Tribulus terrestris, Achyranthus aspera* and *Aerva lanata*. Gökce *et al.*[16] suggested that the toxicity and antifeedant activities of *Bifora radians, Arctium lappa, Xanthium strumarium, Humulus lupulus* and *Verbascum songaricum* were against *Choristoneura rosaceana*. The researchers observed that there was a decrease in the pupal weight also due to the treated diet and also showed deterred larval feeding when it was treated in the diet. Furthermore, in each of the bioassay tests with extracts of *Humulus lupulus* and *Arctium lappa* showed the deleterious effects to the larvae. In another study, *Acalypha fruticosa* showed the maximum antifeedant activity against *Plutella xylostella* (*P. xylostella*). TLC fraction showed 7 fractions of which fraction 7 showed the presence of terpenoids, tannins, coumarins, anthraquinones and saponins were observed in the fraction on preliminary phytochemical analysis[17]. The leaf extracts of *Phyllanthus amarus*, *Acassia albida* and *Tithonia diversifolia* were evaluated for their insecticidal activities[18].

Jeyasankar *et al*.[19] studied the seed extracts of *Solanum pseudocapsicum* to investigate on antifeedant, insecticidal and growth inhibition against *H. armigera* and *Spodoptera litura* (*S. litura*). From their experiments, the ethyl acetate extract of *Solanum pseudocapsicum* showed deformed larvae, pupae and adults on *H. armigera* and *S. litura*. Praveena *et al.*[20] investigated the plants of *Clausena dentate*, *Dodonea viscose*, *Anacardium occidentale* (*A. occidentale*) and *Nicotiana tobacum* to study its antifeedant activity against *Earias vittella*. They found that, the maximum antifeedant activity was observed in petroleum ether extracts and still greater significant antifeedant activity was observed in the seed oil of *A. occidentale*.

Krishnappa and Elumalai[21] obtained essential oil from the leaves of *Chloroxylon swietenia* and ascertained its larvicidal and ovicidal activities. The essential oil showed 100% mortality, the highest ovicidal activity in geierene, no hatchability was recorded at 200 ppm concentration. Yang *et al*.[22] examined the insecticidal activity in the ethanol extract of *Cynanchi auriculati* against *Plutella xylostella* (*P. xylostella*), *Mythimna separata*, *Pieris rapae* (*P. rapae*), aphids and *Homona coffearia* (*H. coffearia*). From their experiments, results revealed that *P. xylostella,* aphids and *H. coffearia* exhibited stronger insecticidal activities in 95% of ethanol extract of *Cynanchi auriculati*. Whereas, *P. rapae* exhibited weaker insecticidal activity and no such activity was exhibited by *Mythimna separata*. From their results, the mortality of the pests were in order of aphis, *H. coffearia*, *P. xylostella*, *P. rapae*. Also, in their experiments, *P. xylostella* mortality was calculated with the five different polar extracts.

Packiam *et al*.[23] analyzed the different plant oil formulation against *H. armigera* and *S. litura*. From their experiment, it was concluded that the extreme ovicidal activity was exhibited by plant oil formulation 3 – PONNEEM. Furthermore, this was the first experiment on PONNEEM for its ovicidal activity against these two pests, *H. armigera* and *S. litura*. Gokulakrishnan *et al.*[24] studied the repellent activity in the essential oil of ten different plants against three pests *S. litura*, *H. armigera* and *Earias vitella*. From their results, it revealed that more than 50% of repellency activity was observed in lime, calamus, lemon and tagetes oil. Therefore, these essential oil and its formulation could be used for obtaining considerable remarkable repellent activities against the Lepidopteran species – E*arias* vitella, *H. armigera* and *S. litura*. Baskaran *et al*.[25] tested the antifeedant activity in the essential oil of the leaves of *Acorus calamus* (*A. calamus*), *O. sanctum*, *Eucalyptus globules*, *Rosmarinus officinalis* (*R. officinalis*) and *Cymbopogon citrates* (*C. citrates*) against the larvae of *S. litura* by leaf disc bioassay method. From their experiment, it was suggested that the remarkable antifeedant activity was showed by *A. calamus*, followed by *Eucalyptus globules*, *R. officinalis*, *O. sanctum* and *C. citrates* against fourth instar larvae of *S. litura* at 1 000 ppm concentration. Therefore, from the above findings, it was concluded that essential oil of these plants could be used to control against the agricultural pest armyworm – *S. litura*.

Gokulkrishnan *et al*.[26] studied 20 kinds of different plant essential oils against *S. litura*, *H. armigera* and *Achaea janata* for determining their antifeedant activities and found that remarkable activities were noted at 1 000 ppm concentration. Hence, it was concluded that the essential oils used in this experiment could be the best way to control the Lepidopteran species – *S. litura*, *H. armigera* and *Achaea janata*. Sharma *et al.*[27] analyzed the insecticidal activity of the seed extract of *Spilanthes acmella* against *P. xylostella*. Their results provided a significant insecticidal activity in spilanthol and in the crude seed extract of methanol, hexane, deltamethrin for the control of *P. xylostella.*

Degri *et al*.[28] conducted an experiment in order to control pod-sucking bugs with aqueous leaf extract of *A. indica*, *Chromolaena odorata* (*C. odorata*) and *Ricinus communis* (*R. communis*) and one synthetic insecticide – Uppercot 500 EC. They proposed that these leaf extracts of *A. indica* and *C. odorata* can be used to control pod-sucking bugs instead of synthetic insecticide. Sougui *et al*.[29] investigated the fumigant activity of the essential oils from *Foeniculum vulgare* (*F. vulgare*), *Coriandrum sativum* (*C. sativum*), *Daucus carota*, *Pelargonium graveolens*, *Origanum majorana* (*O. majorana*) and *Salvia officinalis* against third instar larvae of *S. littoralis*. From their experiment it was observed that the highest mortality was seen in *Salvia officinalis*, *F. vulgare*, *C. sativum*, *O. majorana* and *Daucus carota*. Mwine *et al*.[30] analyzed the extracts of *Euphorbia tirucalli*, *Jatropha curcas* and *Phytolacca dodecandra* to determine its pesticidal activity against *Brevicoryne brassicae* (*B. brassicae*) and *P. xylostella*. From their results, it was confirmed that *Euphorbia tirucalli* latex could be used against *B. brassicae* and for management of *P. xylostella*.

Maheswari *et al*.[31] investigated the compound presenting in the *Alangium salvifolium* to determine its insecticidal activity against *M. separate*. Jeyasankar *et al.*[32] investigated the crude extracts, fractions and compounds A and B in the leaves of *Syzigium lineare* in which compound A showed highest oviposition deterrent and compound B showed highest ovicidal activity. Further, on spectral analysis identified the compound presenting in A as 7-hydroxy-undec-1en-3-one and in B as 3-[3-hydroxy-hexyl]-tetrahydro-pyran-4-one. Arivoli and Tennyson[33] analysed the ovicidal activity in 25 plants with different extracts hexane, diethyl ether, dichloromethane and ethyl acetate against *S. litura*. From their observations, the maximum ovicidal activity was exhibited by hexane extract of *Cleistanthus collinus*, diethyl ether extract of *Murraya koeingii* and ethyl acetate extract of *A. marmelos*. Acheuk and Doumandji-Mitiche[34] analyzed the insecticidal activity of crude alkaloid extract of aerial part of *Pergularia tomentosa* against newly emerged fifth instar larvae of *Locusta migratoria*. And it was reported that *Pergularia tomentosa* is an eco-friendly approach acting as an bioinsecticides against *Locusta migratoria*.

Abbaszadeh *et al*.[35] studied the insecticidal and antifeedant activites of *Clerodendron infortunatum* against the *H. armigera*.

Jeyasankar *et al.*[36] analyzed the insecticidal and antifeedant activities in six plant against the fourth instar larvae of *Henosepilachna vigintioctopunctata*. From their findings, it was noticed that the significant levels of insecticidal activity and antifeedant index were recorded in the ethyl acetate extract of *Achyranthes aspera* on the fourth instar larvae. Selvam and Ramakrishnan[37] evaluated the *Tinospora cardifolia* to determine its antifeedant and ovicidal activities against the fourth instar larvae of *S. litura* and *H. armigera*. The maximum ovicidal activity can be reported in the methanol leaf extract of *Tinospora cardifolia* and followed by ethylacetate, dichloromethane, diethylether and hexane. Huang *et al*.[38] investigated the insecticidal activities of *Pogostemon cablin* against the two harmful insects – *S. litura* and *Spodoptera exigua*. Devi *et al*.[39] synthesized the silver nanopartilce from *Euphorbia hirta* (*E. hirta*) and analysed the larvicidal and pupicidal potential of SNPs against the first to fourth instar larvae and pupae of *H. armigera*. They reported that silver nanoparticle affected the gut physiology of the test insects. Lall *et al*.[40] reported that the pesticidal activity of *Argimone maxicana* and *Calotropis procera* against the fourth instar larvae of *S. litura*. The pesticidal activity of *A. paniculata*, *Anethum graveolens*, *A. Indica*, *Cassia fistula*, *Cuscuta reflexa*, *Dendropthoe falcate*, *Lantana camara*, *Melia azedarach* and *Vitex negundo* were tested on the 3rd and 6th day old larvae of *S. litura*[41].

Vattikonda *et al.*[42] studied the antifeedant activity of *Coleus forskohlii* on *Papilio demoleus*. Arumugam *et al*.[43] evaluated benzene, dichloromethane, diethylether, ethylacetate and methanol extracts of *Rivina humilis* to determine its antifeedant, oviposition deterrent, ovicidal and larvicidal activites against *S. litura*. Motazedian *et al*.[44] analyzed essential oils extracted from the leaves and stem of *Zataria multiflora* (*Z. multiflora*), *Nepeta cataria*, *Tagetes minuta*, *Artemisia sieberi* and *Trachyspermum ammi* by using gas chromatography-mass spectrometer (GC-MS). The major compounds present in all the plants were 4a-α, 7-β, 7a-α-nepetalactone, carvacrol γ-terpinene, limonene and artemisia ketone. The toxicity of these compounds was studied against *B. brassicae* and found significantly controlled the infestation. Santiago *et al*.[45] extracted the oils of *Chenopodium ambrosioides* and *Philodendron bipinnatifidum* and noticed that there was a decrease in feeding activity and increase in mortality of the adult *Diabrotica speciosa*. Teixeira *et al.*[46] determined the antioxidant and insecticidal activites in the essential oil of the leaves of *Lippia origanoides* and *Mentha spicata* (*M. spicata*) and identified by GC-MS. The major compounds of *Lippia origanoides* were carvacrol, *p*-cymene, γ-terpinene and thymol and *M. spicata* were piperitona, piperitenone and limonene. Therefore, these essential oils could be the useful agent in the integrated pest management of *Myzus persicae*.

Baskar *et al*.[47] analyzed that the larvicidal and pupicidal activites of various crude extracts, several methanolic fractions of *Couroupita guianensis* and tested it against *S. litura*. They also noticed, fraction 8 influenced the reduced protein in midgut and hemolymph. Nia *et al.*[48] analyzed the various extracts of *Artemisia herbaalba*, *Eucalyptus camaldulensi* and *R. officinalis* for their insecticidal activity against 3–4 days old *Myzus persicae*.

Muthusamy *et al*.[49] analyzed the benzene, diethylether, ethyl acetate, dichloromethane and methanol extracts of *Caesalpinia bonducella* for their antifeedant, oviposition deterrent, larvicidal and ovicidal activities against the field pest, *H. armigera*. Different extracts of *Tinospora crispa* and *Psidium guajava* were estimated for their larvicidal, oviposition deterrent and ovicidal activities against *H. armigera* and it was reported that the methanol extracts of these plants exhibited 100% oviposition deterrency against *H. armigera*[50]. Similarly, different solvent extracts of *Balanites aegytiaca*, *Paederia foetida*, *Limonia acididssima* and *Polyanthia longifolia* were tested for their antifeedant activities against *Lipaphis erysimi* and *S. litura*. The maximum potecncy was noted in the chloroform and petroleum ether extracts[51].

Recently, Kuhns *et al.*[52] suggested that essential oils played a major role against *Citrus psyllid* and *Diaphorina citri* under field condition. Jiang *et al*.[53] investigated the chemical composition, repellent and insecticidal activities in *Cinnamomum camphora* (*C. camphora*) leaves, twigs and seeds. Twigs and seeds showed good record of insecticidal activity on cotton aphids *Aphis gossypii*. Pan *et al*.[54] analyzed the *Ginkgo biloba* extracts which contained ginkgo flavonoids, ginkgolide and bilobalide and tested against *Hyphantria cunea*. Among the three secondary metabolites, ginkgolide was found to exhibit the highest antifeedant activity and significant effect on the detoxifying enzymes.

Tampe *et al*.[55] extracted the essential oil by steam distillation and its components were characterized by GC-MS to evaluate the repellent effect against *Aegorhinus superciliosus* (*A. superciliosus*) by using four-arm olfactometric bioassays. From their experiment, the major compounds presenting in the essential oil of *A. superciliosus* were 2-nonanone and 2-undecanone. In their results, it was identified that both male and female *A. superciliosus* were found greatly deterred by the essential oil treatment. Therefore, the essential oil of rue could be used as an potent source for repellent against *A. superciliosus*.

3. Roles of plants and plant based products towards the control of stored product pests

El Nadi *et al*.[56] analyzed the three plant species – *Rhazya stritcta*, *A. indica* and *Heliotropium bacciferum* for their insecticidal activities with the aqueous, methanolic and acetonic extracts against *Trogoderma granarium* (*T. granarium*). Their results suggested that acetone extracts exhibited remarkable toxicity on *T. granarium*. Kim *et al*.[57] analyzed the insecticidal activity of methanol extracts from 30 aromatic plants and 5 essential oils against *Sitophilus oryzae* (*S. oryzae*) and *Callosobruchus chinensis* (*C. chinensis*) for their insecticidal and fumigant toxicity. Insecticidal activities of the oils used in this invention were more significant to fumigant action since the oils used were showed remarkable effectiveness in the closed container than in open container.

Sanna Passino *et al*.[58] examined the insecticidal activity of microencapsulated essential oil obtained from *R. officinalis* and *T. vulgaris* against the indian meal moth, *Plodia interpunctella* (*P. interpunctella*). It was observed that even a lower concentration brings over 50% of mortalities. Saljoqi *et al*.[59] investigated the insecticidal activity in 6 plants, *Melia azdarach*, *Myrtus communis*, *Mentha longifolia*, *Pegnum harmala* and *C. citrates* against *S. oryzae*. Similarly, the methanol extracts of *Peganum harmala*, *Ajuga iva*, *Aristolochia baetica* and *Raphanus raphanistrum* inhibited the infestation of *Tribolium castaneum* (*T. castaneum*)[60]. Moreira *et al*.[61] analyzed *Ocimum selloi*, *Ruta graveolens*, *Leonotis nepetifolia*, *Datura stramonium*, *Cordia verbenacea*, *Mentha piperita* (*M. piperita*), *Mormodica charantia* and *Ageratum conyzoides* for their insecticidal active compounds against the stored pest *Rhyzopertha dominica* (*R. dominica*), *Sitophilus zeamais* (*S. zeamais*) and *Oryzaephilus surinamensis* (*O. surinamensis*). Their results revealed that the highest insecticidal activity was apparent in hexane extract of *Ageratum conyzoides* and the compounds presenting in it was fractionated and identified as 5,6,7,8,3',4',5'-heptamethoxyflavone, 5,6,7,8,3'-pentamethoxy-4',5'-methilenedioxyflavone and coumarin.

Jovanović *et al*.[62] reported that *Acanthoscelides obtectus* was greatly controlled by methanolic extracts of *Urtica dioica*, *Taraxacum officinale*, *Achillea millefolium*, *Sambucus nigra* and *Juglans regia*. *Piper nigrum* (*P. nigrum*), *Carum carvi* and *Sesamum indicum* were analysed for their insecticidal activities with different doses of plant extracts against *S. oryzae* by Bodroža-Solarov *et al*.[63]. In 2009, Pugazhvendan *et al*.[64] reported about the insecticidal activities of *Argemonem mexicana*, *Prosopis juliflora* and *Tephrosia purpurea* (*T. purpurea*) on *T. castaneum*. Moharramipour *et al*.[65] evaluated the essential oil of *Prangos acaulis* for its repellency and insecticidal activity against *T. castaneum*, *S. oryzae* and *Callosobruchus maculatus* (*C. maculatus*).

Ayvaz *et al*.[66] reported the insecticidal activities of three essential oils, *Origanum onites*, *Satureja thymbra* and *Myrtus communis* against the adult stages of stored pests, *Ephestia kuehniella* (*E. kuehniella*), *P. interpunctella* and *Acanthoscelides obtectus*. Ashouri and Shayesteh[67] made an experiment on *P. nigrum* and *Capsicum annuum* for their insecticidal activities against stored pests, *R. dominica* and *Sitophilus granarius*. Ebadollahi *et al*.[68] reported phytochemical components presenting in the *Agastache foeniculum* showed increase mortality rate with the period of time exposure and with the increased doses. Therefore, the detrimental effects of *E. kuehniella* and *P. interpunctella* can be decreased by using the essential oil of *Agastache foeniculum* as a fumigant.

Yankanchi and Gadache[69] investigated the insecticidal activity of *Clerodendrum inerme*, *Withania somnifera*, *Gliricidia sepia*, *Cassia tora* and *Eupatorium odoratum* on *S. oryzae*. The mortality activity was recorded in a dose-dependent manner and there was a drastic suppression in F1 progeny. Ebadollahi and Mahboubi[70] studied the insecticidal activity of *Azilia eryngioides* essential oil against *S. granaries* and *T. castaneum*. The major constituent of oil presenting in the plant were α-pinene and bornyl acetate which was identified by GC-MS. Jemâa *et al*.[71] analyzed that the essential oils of *Laurus nobilis* collected from Tunisia, Algeria and Morocoo were tested against *R. dominica* and *T. castaneum*. Remarkable repellent activity and toxicity were observed in the filter paper test against the two major stored pests when they werre treated with the essential oils of *Laurus nobilis* from Morocoo as compared to those from Tunisia and Algeria.

Chaubey[72] reported that the essential oil extracted from *Cuminum cyminum* and *P. nigrum* showed repellent activities, fumigant toxicity and effect of acetylcholinestease enzyme on rice weevil. Mahmoudvand *et al*.[73] investigated the essential oils of *R. officinalis*, *Mentha pulegium*, *Z. multiflora* and *C. sinensis* for the fumigant toxicity on *T. castaneum*, *Sitophilus granarius*, *C. maculatus*, and *P. interpunctella*. Younes *et al*.[74] evaluated the essential oil of 7 plants against the 4th instar larvae of *T. granarium*. On their evaluation, they observed that the inhibition of adult fecundity was seen between 0.025 and 1.000 mL per 10 gm of wheat. Their results also revealed that in the treated larvae glucose, lipid content and alkaline phosphatase were less and cholinesterase and protein content were higher. These biochemical studies proposed the best way to control *T. granarium*. Lü *et al*.[75] investigated the essential oil of *Artemisia argyi* to identify the repellent, fumigant effect and contact toxicity against *O. surinamensis*. Khani and Rahdari[76] analyzed the compounds presenting in the essential oil of *C. sativum* seed as a source of insecticidal activity against *Tribolium confusum* (*T. confusum*) and *C. maculatus*. The predominant compounds in *C. sativum* were linalool and geranyl acetate which was identified by GC-MS. The insecticidal activity increases with concentrations and the *C. maculatus* was more influenced than *T. confusum*. *Euphorbia prostrate* silver nanoparticles were synthesized to determine the pesticidal activity on *S. oryzae*. In their study, spectral analysis was used to study the silver nanoparticles. Then, with different concentrations, pesticidal bioassay tests were performed and the results suggested that the silver nanoparticles synthesized from the aqueous leaves extract of *Euphorbia prostrate* can be used as an control agent against *S. oryzae*[77].

The insecticidal activities of these plants, *Zingiber officinale* (*Z. officinale*), *Elettaria cardamomum* and *F. vulgare,* were analyzed against *O. surinamensis*. The experimental results revealed that *Z. officinale* followed by *Elettaria cardamomum* and *F. vulgare* showed considerable insecticidal activities. Further, under polyacrylamide gel electrophoresis for protein analysis of *O. surinamensis*, there observed a significant alteration in the protein configuration[78]. Essential oils of *Pinus longifolia*, *Eucalyptus oblique* and *C.*

sativum were tested for their fumigant toxicity against *S. oryzae*, *C. chinensis* and *Corcyra cephalonica*[79]. They found that the exposure of the pest with pine oil for 72 h exhibited 90% mortality. Pugazhvendan *et al*.[80] investigated the insecticidal activities of different solvent extracts of *Artemisia vulgaris*, *Sphaeranthus indicus* (*S. indicus*), *T. purpurea* and *Prosopis juliflora* against *T. castaneum*. From their results, choloroform extract of *S. indicus*, hexane extract of *Artemisia vulgaris* and ethyl acetate extract of *T. purpurea* exhibited the highest mortality activity. Therefore, these extracts could be used as an insecticidal agent against *T. castaneum*. Satti and Elamin[81] analyzed *Khaya senegalensis* and *A. indica* for their insecticidal activities against *T. granarium*.

Padin *et al*.[82] studied 9 medicinal plants for their insecticidal and repellent activities against *T. castaneum*. The significant mortality of *T. castaneum* was noticed by the researchers in *Viola arvensis* on grain, followed by *Matricaria chamomilla*, *Brassica campestris* and *Jacaranda mimosifolia*. Similary, the significant repellent activity was detected in the *Jacaranda mimosifolia*, *Matricaria chamomilla* and *Tagetes minuta*. Extracts of *Capsicum frutescens*, *Cymbopogon citratus*, *Moringa oleifera* and *A. occidentale* showed significant insecticidal activities against *Sitotroga cerealella* (*S. cerealella*). Consequently, when the moths from egg to adult were exposed to the plant powders, the highest mortality rate showed. These extracts also prevented the hatchings of the egg of Angoumois grain moths[83].

Sümer Ercan *et al*.[84] studied the insecticidal activity against different stages of *E. kuehniella* and egg parasitoid of *Trichogramma embryophagum* by extracting the essential oil from *Prangos ferulacea* and identified the major compound as 2,3,6-trimethyl benzaldehyde, minor compound as heneicosane through GC-MS. The essential oil was lethal showing 100% mortality to both the pests. Therefore, the results suggested that the essential oil can be used as an control agent. Obembe and Kayode *et al.*[85] reported that *Crotaria retusa*, *Hyptis suaveolens*, *R. communis* and *Tithonia diversifolia* showed strong insecticidal, ovipositional deterrence and supressed infestation rate of *C. maculatus*. Zandi-Sohani *et al*.[86] extracted the essential oil of leaves of *Callistemon citrinus* and reported that the plant essential oil has strong insecticidal activity against *C. maculatus*. Also, its repellent activity was observed in the filter paper arena test. Ali and Mohammed[87] studied the toxicity effect of the methanol extracts of *Anethum graveolens*, *Eucalyptus glauca*, *Apium graveolens*, *Malva parviflora*, *Z. officinale* and *Mentha longifolia* against *T. confusum*.

Utono *et al*.[88] evaluated the powdered dried leaves of *O. basilicum* and *Cymbopogon nardus* (*C. nardus*) for their repellent activities against *T. castaneum* and *R. dominica*. Jaya et al.[89] reported that *T. castaneum* showed 100% mortality with essential oils of *Hyptis suaveolens* at 250 ppm concentration while *Coleus aromaticus* was effective at 350 ppm concentration. Further, no adverse result on seed germination as well as non-phytotoxic nature of the oils were observed on the seedling growth of the seeds treated with the essential oils. Adjalian *et al.*[90] showed that the essential oils of *Dennettia tripetala* and *Uvariodendron angustifolium* showed insecticidal activities. In their study, the essential oils isolated from these plants were analyzed under GC-MS to determine the major components presenting in it. Then, by the fumigation method the level of toxicity of the essential oils was observed by the researcher in a closed glass jar by setting up a suitable temperature and relative humidity.

Pandey *et al*.[91] investigated the study of the essential oils of 35 plants to determine its repellent activity against *C. chinensis* and *C. maculatus*. *In vivo* evaluation showed reduced seed damage, increased feeding deterrence, weight loss of fumigated seeds and up to 6 months of storage. Sani[92] investigated the ethanol and petroleum extracts of seeds of *Parkia biglobosa* to show its antifeedant activity on *C. maculatus*. They concluded that the secondary metabolites of *Parkia biglobosa* seed extracts may be associated with antifeedant property to protect the cowpea bean against *C. maculatus*. Khan *et al*.[93] reported that the pest *T. castaneum* showed significant mortality when they were expose to a triterpenoid compound, 2α,3β,21β,23,28-pentahydroxyl 12-oleanene which was isolated from the roots of *Laportea crenulata*. It was observed that significant mortality of about 80% and 86% was recorded for 24 h. Hence, researchers concluded that this compound triterpenoid 2α,3β,21β,23,28-pentahydroxyl 12-oleanene exhibits pesticidal and pest repellency property so it could be used in controlling the pest of grain-based product.

Benzi *et al*.[94] evaluated the essential oils of two plants, *Aloysia polystachya* and Aloysia citriodora, to study its bioactivity on *T. castaneum* and *T. confusum*. The results from their experiments revealed that the highest repellent activity in both beetles. Abd El-Razik and Zayed[95] evaluated the toxicity of essential oil of *Helianthus annus* and *Sesamum indicum* at different mixing ratios of it with pyridalyl, abamectin, spinosad and malathion against *Callosobruchus maculatus* through residual film bioassay. Their results revealed that the synergistic effect on combination of the plant essential oils with pyridalyl and abamectin where evoked antagonistic effect. Fumigation and contact toxicity effects of methanol extract of leaves of *Lantana camara* against *S. oryzae*, *C. chinensis* and molecules presenting in the extract were identified by GC-MS[96].

Wang *et al.*[97] analyzed the essential oils in the leaves of *Citrus limonum* (*C. limonum*), *Litsea cubeba*, *Cinnamomum cassia* and *Allium sativum* (*A. sativum*) for fumigant, contact, and repellent activities against 6th instars and adults of *Alphitobius diaperinus*. The strongest AchE activity was exhibited by *A. sativum* against the 6th instars of *Alphitobius diaperinus* followed by of *C. limonum*, *Litsea cubeba*, *Cinnamomum cassia*. Emamjomeh *et al*.[98] obtained the essential oil and evaluated for its toxicity against the adults and larvae of *E. kuehniella* by fumigation method under dark condition. Their results suggested that *Z. multiflora* has a potential to use in integrated pest management of *E. kuehniella.* Najafabadi *et al.*[99] analyzed the ethanolic extract leaves of *A. indica*, *Mentha longifolia* and *Datura stramonium* for their insecticidal activities against *O. surinamensis* and *T. castaneum*. From their results revealed that the highest mortality rate was seen in the mint extract against *O. surinamensis* followed by *Datura* and neem extracts. However, neem, mint and *Datura* exhibited the effective mortality activity against *T. castaneum*. Whereas the repellency activity was maximum in *Datura* against *O. surinamensis* and maximum in mint against *T. castaneum*.

Adjalian *et al.*[100] assessed the insecticidal and repellent activity of *Premna angolensis* (*P. angolensis*) and *Premna quadrifolia* (*P. quadrifolia*) against *S. cerealella*. In their findings, essential oil of *P. angolensis* and *P. quadrifolia* displayed 29 compounds which corresponded to 96.1% of the essential oil of *P. angolensis* and 42 compounds which corresponded to 91% of the essential oil of *P. quadrifolia*. Results of their findings suggested that these two plants have insecticidal and repellent effects on the targeted pest. Oil extracted from *Dendranthema indicum* was identified by GC-MS and 31 components corresponded to 92.44% of the oil. Out of it, the major components are chamazulene, β-caryophyllene, germacrene D, and b-cis-farnesene[101]. Furthermore, the insecticidal and repellent activities were shown by the essential oil and chamazulene on targeted pests, *T. castaneum* and *Stegobium paniceu*.

Adebisi[102] investigated the insecticidal activity of the essential oil of *Citrus aurantifolia* against *C. maculates*. They have also identified 37 components and the major components of terpenoids were limonene, β-myceme, cymene, and thymol. Nattudurai *et al.*[103] reported that the fumigant and repellent activities of *Toddalia asiatica* were studied on *C. maculates*, *S. oryzae* and *T. castaneum*. From their findings, it was clearly revealed that *Toddalia asiatica* showed 100% repellency against *C. maculates*, *S. oryzae* and 92% repellency against *T. castaneum*.

Wu *et al.*[104] characterized the essential oil of the rhizome of *Alpinia kwangsiensis* by GC-MS and reported that 92.45% of the oil were identified and 31 components were present in it. Among the 31 compounds, the four major compounds camphor, eucalyptol, β-pinene, and α-pinene exhibited contact and fumigant activity against *Lasioderma serricorne*. Wang *et al.*[105] studied *Zingiber purpureum* against two stored pests *T. castaneum* and *Lasioderma serricorne*. In their study, essential oil of the rhizome of *Zingiber purpureum* showed contact and fumigant toxicity against the grain storage pest. Also, major compounds sabinene, terpinen-4-ol, γ-terpinene, α-terpinene, β-thujene and α-phellandrene presenting in the essential oil were characterized by GC-MS. Eliopoulos *et al.*[106] analyzed the essential oil of *O. basilicum* and *M. spicata* against *E. kuehniella* and *P. interpunctella*.

Cansian *et al.*[107] analyzed the essential oil of *Cinnamomum camphora* var. *linaloolifera* and *Cinnamomum camphora* var. *hosyo* for their insecticidal and repellent activities against *S. zeamais*. Shahab-Ghayoor and Saeidi[108] analyzed the essential oil of *Sature jahortensis* and *Fumaria parviflora* for its antifeedant activity against *P. interpunctella*.

Recently, Jeyasankar *et al.*[109] evaluated the larvicidal and repellent activity in 5 essential oils against *T. castaneum*. The 5 essential oils used in the study were *Corymbia citriodora*, *C. nardus*, *Syzygium aromaticum*, *Gaultheria* oil and *C. citrates*. Their study suggested that *Corymbia citriodora* oil showed high larval mortality and high repellent activity against *T. castaneum*. Pinto *et al.*[110] analyzed that the powder and essential oil extracted from *Crytocarya alba* showed the insecticidal properties against *S. zeamais* which showed 80% of mortality and 100% of reduction in the emergence of *S. zeamais*. Onaolapo Akinneye and Oyeniyi[111] studied the insecticidal activity of stem and bark of *Cleistoholis patens* against *S. cerealella*. Their experiment showed a significant reduce in the adult emergence of *S. cerealella*.

Guo *et al.*[112] reported that the contact and repellent activities of the essential oil distilled from the leaves of *Juniperus formosana*. From their results, among the main compounds, the compound 4-terpineol showed the strongest contact activity. Also, *T. castaneum* showed strong repellency when treated with the essential oil and the three isolated compounds. The essential oil of *Ajania fruticulosa* was assessed for its insecticidal activity against *T. castaneum* and *Liposcelis bostrychophila*[113]. Pandir and Baş[114] extracted the essential oil of *O. basilicum*, *Capsicum annuum*, *M. piperita* and *R. officinalis* and identified the major components linalool, capsaicin, menthol and cineole by GC-MS. One hundred percent of toxicity was exhibited by all the essential oil to the adult stages of *E. kuehniella*.

4. Roles of plants and plant based products towards the control of vector mosquitoes

Choi *et al.*[115] evaluated the repellent activities in the essential oil of *Eulcalyptus globulus*, *Lovender officinalis*, *R. officinalis* and *T. vulgaris* on *Culex pipiens* pallens. Mello *et al.*[116] analyzed the essential oil extracted from *Pilocarpus spicatus* against the fifth instar nymphae of *Rhodnius prolixus*. From their findings, it was revealed that discrete moulting inhibition by topical application, partial phagoinhibition, prolonged intermoutling period, high number of paralyzed insects were observed after oral treatment. Bagavan *et al.*[117] reported that the vectors and cotton pests can be controlled by using the followeing extracts such as *C. sinensis, O. canum, O. sanctum* and *Rhinacanthus nasutus* as they have larvicidal and nymphicidal actvities against the vectors and cotton pests. *Anopheles subpictus*, *Culex tritaeniorhynchus* and *Aphis gossypii*. *Anisomeles malabarica*, *E. hirta*, *O. basilicum*, *R. communis*, *Solanum trilobatum*, *Tridax procumbens* and seeds of *Gloriosa superba* extracts were determined for their adulticidal activities against *Anopheles stephensi* (*A. stephensi*) by Zahir *et al.*[118].

Elango *et al.*[119] studied the hexane and chloroform extracts of *A. marmelos*, *Andrographis lineata*, *A. paniculata*, *Cocculus* *hirsutus*, *Eclipta prostrata* and *Tagetes erecta* against the important vector mosquitoes. Kumar *et al*.[120] investigated the study on the larvicidal and repellent activity in *M. piperita* against the fourth instar larvae and adults of *Aedes aegypti* (*A. aegypti*). Consequently, this experiment showed an extraordinary larvicidal and repellent activity against the vector, *A. aegypti*. Further, it also suggested that 100% of protection was seen till 150 min and of late, only 1–2 bites were noticed as compared to the control. Govindarajan *et al*.[121] reported that the crude extracts of *Ervatamia coronaria* and *Caesalpinia pulcherrima* could be used to control vectors, *Culex quinquefasciatus* (*C. quinquefasciatus*), *A. aegypti* and *A. stephensi*. From their results, the 100% egg mortality was recorded from the crude extracts of *E. coronaria* and *C. pulcherrima, w*hereas the significant repellent activity was seen more in *E. coronaria* than *C. pulcherrima*.

Govindarajan and Sivakumar[122] analyzed the different solvent extracts (benzene, hexane, ethyl acetate, methanol and chloroform) of *Eclipta alba* and *A. paniculata* against 5–6 days old adult female mosquito *A. stephensi*. From their study, the results revealed that the highest significant repellent activity was exhibited by the methanol extract of *Eclipta alba* and *A. paniculata* against *A. stephensi*. Tedeschi *et al.*[123] determined the insecticidal activities of *Armoracia rusticana* and *A. sativum* against *Aedes albopictus*. Similarly, Tennyson *et al*.[124] analyzed the ovicidal activity in the solvent crude extract of 25 plants against *C. quinquefasciatus*.

Manimaran *et al*.[125] studied the larvicidal activity and knockdown effects of 25 essential oils against *C. quinquefasciatus*, *A. aegypti* and *A. stephensi*. *Calamus* oil showed its promising larvicidal activity against *C. quinquefasciatus*. A significant knockdown effect was observed in the orange oil against the three vectors. Adebajo *et al.*[126] studied the larvicidal activity of the methanol extract of *Euphorbia macrophylla* and stem barks of *Markhamia tomentosa* and *Newboldia laevi*. They have noticed that the extracts of *Blighia sapida* stem and bark, root of *Costus specious* and seed of *Xylopia aethiopica* showed the significant larvicidal activities to control dengue and yellow fever and vectors. The repellent activity of *C. sinensis*, *C. limonum*, *Citrus aurantifolia*, *Citrus reticulata* and *Citrus vitis* were tested against the important human vector mosquitoes by Effiom *et al.*[127].

Elumalai *et al.*[128] evaluated the larvicidal, ovicidal and pupicidal activities of the extract from *Eranthemum roseum* against *A. stephensi*. From their studies, it was revealed that methanol extracts of *Eranthemum roseum* had more toxicity for these larvicidal, ovicidal and pupicidal activites than acetone extracts. Kovendan *et al*.[129] studied the different extracts of *Morinda citrifolia* for its larvicidal and pupicidal activity against three vectors, *A. stephensi*, *A. aegypti* and *C. quinquefasciatus*.

Kovendan *et al*.[130] studied that *Plasmodium falciparum* can be controlled by the ethanolic leaf extracts of *Carica papaya* tested against larvae and pupae. Krishnappa *et al*.[131] studied the larvicidal, ovicidal and pupicidal activities in *Gliricidia sepium* against third instar larvae of *A. stephensi*. Their results revealed that the ethanolic extracts showed considerable mosquitocidal activity against *A. stephensi*. Therefore, it is concluded that the vector, *A. stephensi*, could be controlled by using the crude extract of *Gliricidia sepium*. Sarah *et al.*[132] synthesized the silver nanoparticles from the aqueous leaf extract of *Hibiscus rosasinensis* on the larvae of mosquito *Aedes albopictus*. In their experiment, the mortality activity was recorded for different concentrations and the significant larvicidal activity was seen in the synthesized nanoparticles.

Krishnappa *et al.*[133] investigated *Adansonia digitata* for its larvicidal and repellent activities by using the different sovent extracts against *A. stephensi*. Further, they have also analyzed the presence of phytochemicals, triterpenoids and saponins. Hence, from their results, methanol extract exhibited the highest repellent activity and the same 100% protection was also seen in the other extracts at higher concentration. Krishnappa and Elumalai[134] ascertained the methanol extract of *Aristolochia bracteata* for its larvicidal, ovicidal and repellent activities against three vector mosquitoes, *A. stephensi*, *A. aegypti* and *C. quinquefasciatus*. Samidurai[135] analyzed *Pemphis acidula* for its larvicidal and ovicidal potential by using the crude methanol, acetone and benzene extracts against the third instar of *Culex tritaeniorhynchus* and *A. subpictus*. Trindade *et al*.[136] evaluated *Piper alatabaccum* and *Piper tuberculatum* for their insecticidal activities against *Anopheles darlingi*. Their experiment clearly exhibited the larvicidal activity with the compounds 3,4,5-trimetoxy-dihydrocinamic acid, dihydropiplartine, piplartine, piplartine-dihydropiplartine and 5,5',7-trimetoxy and 3',4'-metilenodioxiflavone with *Piper alatabaccum* and *Piper tuberculatum*.

Murugan *et al*.[137] analyzed the larvicidal and pupicidal properties of the leaf extract of *Acalypha alnifolia* against *A. stephensi*. From their experiment, they have observed that the highest larvicidal and pupicidal mortality was exhibited in the leaf extract of ethanol against the larvae and pupae of *A. stephensi*. Therefore, this leaf extract exhibited a good larvicidal and puicidal activity to control the vector. Further, this was the first report on the leaves extract and fungal pathogen to control the vector. Allison *et al*.[138] investigated the phytochemical composition and larvicidal activity of the plant extracts of *A. indica*, *C. sinensis*, *C. citrates* and *Annona squamosa* on *Anopheles gambiense* and *C. quinquefasciatus*. Further, it was also observed by the researchers that *C. sinensis* and *C. citrates* showed the highest mortality potential on *Anopheles gambiense* at 20 mg/mL after 72 h. Similarly, *C. sinensis* showed its larvicidal potential against *C. quinquefasciatus*.

Panneerselvam *et al*.[140] evaluated *E. hirta* for its larvicidal and pupicidal activities against the malarial vector *A, stephensi*. In their experiments, the bioactivity of larvicidal and pupicidal were determined with different concentrations ranging from 75–375 ppm by probit analysis. The LC_{50} and LC_{90} values were calculated in the leaf extract of *E. hirta*. de Lima *et al*.[141] evaluated the essential oil of *Lippia sidoides* and *Croton* species for its insecticidal activity against *A. aegypti* mosquito. The oviposition of female gravid mosquitoes was inhibited by *Lippia sidoides*, *Croton zehntneri* and *Croton argyrophylloide* and OD_{50} values were calculated by them. El-Akhal *et al*.[142] reported that the essential oil from *O. majorana* in Morocco showed significant larvicidal activity and also studied the chemical composition presenting in it. In their experiments, the essential oil was analyzed by GC-MS and the major compounds presenting in it was identified for the study of larvicidal activity. Bakhshi *et al*.[143] carried out the study to establish the larvicidal activity of *Lawsonia inermis* on *A. stephensi* on the early larval and late larval stages.

Suganya *et al*.[144] compared the larvicidal activity of *Leucas aspera* (*L. aspera*) with the solvent leaf extracts and with the synthesized silver nanoparticles against fourth instar larvae of *A. aegypti*. Therefore, with these results, it was revealed that synthesized nanoparticles showed the most significant larvicidal activity when compared to crude extracts and hence *A. aegypti* can be controlled effectively by this way. Naik *et al*.[145] investigated synthesized silver nanoparticles from the leaf extracts of *Pongamia pinnata* and studied its larvicidal activity and they analysed and identified two phytochemical compounds, 9-octadecenoic acid and *n*-hexadecanoic acid. Ramesh *et al*.[146] studied the insecticidal activity in leaves extact and silver nanoparticles synthesized from *Morinda tinctoria* against the third instar larvae of *A. aegypti*. The silver nanoparticles were characterized with fourier transform infrared radiation spectroscopy, UV-Vis spectroscopy and atomic force microscopy. LC_{50} value was noticed in both the leaf extract and synthesized nanoparticles on the *A. aegypti*. Mavundza *et al*.[147] determined the adulticidal activity in the dichloromethane extract and ethanol extract of 10 different plants which were traditionally used as mosquito replellents in South Africa. It was observed by the researchers that the dichloromethane extract and ethanol extract of leaves of *Aloe ferox* leaves showed the highest mosquito mortality.

Aruna *et al*.[148] investigated *Gaultheria* oil to determine its larvicidal, pupicidal and repellent activities against the first to fourth instar larvae and pupae of *C. quinquefasciatus*. The major component present in *Gaultheria* is methyl salicylate which showed 100% repellency. Therefore, this result revealed that *Gaultheria* oil can be used to control *C. quinquefasciatus*. Thangarasu *et al*.[149] evaluated *Clausena excavata* for its larvicidal and ovicidal activities against *S. litura*, *A. aegypti*, *A. stephensi* and *C. quinquefasciatus* at different concentrations. From their experiment, they suggested that *Clausena excavata* can be used as an potent source for controlling the ovicidal activities against *S. litura*, *A. aegypti*, *A. stephensi* and *C. quinquefasciatus*.

Reegan *et al*.[150] analyzed the hexane extract of *Limonia acidissima* (*L. acidissima*) leaves on the fractions and compounds of it to determine its mosquitocidal activity against eggs, larvae and pupae of *A. aegypti*. In their experiment, eggs, larvae and pupae of *A. aegypti* were exposed to different concentrations and the active phytochemical compound niloticin was identified and exhibited good ovicidal, larvicidal and pupicidal activities. Priya *et al*.[151] synthesized silver nanoparticles from the aqueous extract of *Calotropis gigantean* to determine its mosquitocidal activity against *A. aegypti* and *A. stephensi*. Their results revealed that the plant mediated silver nanoparticles played a key role to control *A. aegypti* and *A. stephensi*.

Ramar *et al*.[152] tested the ovicidal and oviposition response in the essential oil of *Pimpinella anisum*, *A. calamus*, *Cinnamomum verum*, *C. nardus*, *Myrtus caryophyllus*, *Citrus limon*, *C. sinensis*, *T. vulgaris*, *O. sanctum* and *Vetiveria zizanioides* against *C. quinquefasciatus*. Their experiment was carried out against the vectors with different concentrations and they noted that the highest ovicidal activity was exhibited by the essential oils of clove, aniseed and cinnamom. Followed by these essential oils, the highest ovicidal activity was also exhibited by lemon and tulsi. Whereas, clove oil showed the maximum oviposition response activity. Theefore, these essential oils are the best source for controlling the vectors. Sivapriyajothi *et al*.[153] synthesized the silver nanoparticles from the leaf extract of *L. aspera* to estimate its lethal concentration against first to fourth instar larvae and pupae of *A. aegypti* and *A. stephensi*. The synthesized silver nanoparticles were characterized by various spectral analyses.

Alayo *et al*.[154] examined the larvicidal activity of the petroleum spirit, ethanol, water and dichloromethane extracts of leaves and pods of *Cassia mimosoides* (*C. mimosoides*) against *Anopheles gambiae*. In their studies, phytochemical examination showed the presence of saponins, anthraquinones, flavonoids steroids and tannins and absence of alkaloids and cardiac glycosides in a powdered *C. mimosoides*. One hundred percent of larvicidal efficiency was observed in the petroleum ether and dichloromethane extracts at 2 mg/mL. Furthermore, their research revealed that the petroleum ether were prepared in the aqueous cream based form. It was observed in their studies that 100% repellency was viewed against the vector. Hence, it was confirmed by them that the larvicidal and repellent activity against the vector can be achieved by using the crude extracts of *C. mimosoides*. Reegan *et al*.[155] investigated hexane, ethyl acetate and methanol leaves extract of *A. marmelos*, *L. acidissima*, *S. indicus*, *Sphaeranthus amaranthoides* and *C. odorata* for its ovicidal and oviposition deterrent activities against *C. quinquefasciatus* and *A. aegypti* mosquitoes. In their experiment, among the five different plant extracts screened, significantly highest ovicidal activity and 100% oviposition deterrent were noted in the hexane extract of *L. acidissima* against the vectors. Hence, hexane extract of *L. acidissima* could be used for controlling these vectors.

Kamakshi *et al.*[156] reported that *A. aegypti* could be controlled by using the cladodes extract of *Cereus hildmannianus*. Bhuvaneswari *et al.*[157] studied the larvicidal property of the silver nanoparticles synthesized from the leaf extract of *Belosynapsis kewensis* against

A. stephensi and *A. aegypti*. Shanthosh *et al*.[158] evaluated the *Annona muricata* aqueous crude extract and silver nanoparticles synthesized from the leaves to study its larvicidal activites against fourth instar larvae of three important mosquitoes under different concentrations. Silver nanoparticles synthesized from the plant were characterized by spectral analysis for confirmation.

Poopathi *et al*.[159] assessed the larvicidal activity of the silver nanoparticles synthesized from the aqueous leaf extract of *A. indica* against *A. aegypti* and *C. quinquefasciatus*. Futhermore, their results revealed that the mosquito can be controlled by the biosynthesis of silver nanopartilces from neem. Araujo *et al*.[160] evaluated the essential oil of *S. aromaticum* and *C. sinensis* alone or with combination of temephos for determining the larvicidal activity against *A. aegyti*. Further, the number of eggs decreased in the vector which were exposed to oil with that compared to tap water. Anuradha *et al*.[161] studied the repellent and adulticidal activities in the ethanol extract of *H. ovalis* on female adults of *C. quinquefasciatus*. Further, they have observed the highest adulticidal and repellent activities against *C. quinquefasciatus*.

Carvalho Kda *et al*.[162] investigated the insecticidal activity and chemical composition from the essential oil of *Croton tetradenius* against the larvae and adults of *A. aegypti* and *Mus musculus*. In their study, the significant component presenting in the essential oil was analyzed by GC-MS and flame ionization detection and it was declared as camphor. From the experiments, the toxicity level was recorded on larvae and adults of the vector. Ajaegbu *et al*.[163] investigated the bioactive compounds, leaf methanol extract and fractions of *n*-hexane, dichloromethane and ethyl acetate of *Spondias mombin* to determine its adulticidal activities against *A. aegypti*. Elumalai *et al*.[164] studied the larvicidal activity of fractions and compounds in the methanolic extracts of *L. aspera* against the fourth instar larvae of *A. aegypti*, *A. stephensi* and *C. quinquefasciatus*. They have isolated a phytochemical compound, catechin, which showed significant larvicidal activity even at a very low concentration.

Ramkumar *et al*.[165] analyzed the mosquitocidal and larvicidal activities in the leaf extract by using different solvents acetone, methanol, chloroform and ethyl acetate on three mosquito vectors. In their study, chemical compositions presenting in the leaf extract was recognized by GC-MS. From their findings, it was proposed that the acetone extracts showed significant larvicidal and adulticidal activities in the *Glycosmis pentaphylla* leaf extracts. Silapanuntakul *et al*.[166] studied the larvicidal activity of neem tree in Thailand. In their study, by using a dipping, test comparisons were made between Thai neem oil formulation and alginate bead formulation against the fourth stage of *A. aegypti* larvae. From their experiments, it was concluded that the Thai neem oil shows significantly greater larvicidal activity than alginate bead formulation. Mohankumar *et al*.[167] examined nine plant species in order to find a suitable insectidal activity against the fourth instar larvae of *A. aegypti* and *A. stephensi*. *Annona reticulata* showed more significant results and *Cosmos bipinnatus* showed the least effect.

5. Conclusion

In agriculture and public health hygiene, insect pests are considered as a very important factor of loss crops, grains and health. As an average, they account for 20%–30% loss of production in the field, but in some cases they cause a total loss. In addition, more than 550 species of insect pests have developed resistance against most current insecticide groups. So many scientists in industry and academia are currently trying to obtain useful compounds from plants as natural insecticides. Plant based products have been used from time immemorial in traditional insect control practice as a personal protection measure against host-seeking insects. Knowledge on traditional plants obtained through ethnobotanical studies is a valuable resource for the development of new natural products. Recently, several commercial products containing plant-based ingredients have gained increasing popularity among consumers, as these are commonly perceived as “safe” in comparison to long-established synthetic insecticides in general and pesticides in particular. This paper presents a summary of recent information on testing, efficacy and safety of plant-based repellents as well as promising new developments in the field.

Most plants contain compounds that they use in preventing attack from phytophagous (plant-eating) insects. These chemicals fall into several categories, including repellents, feeding deterrents, toxins, and growth regulators. Most can be grouped into five major chemical categories: nitrogen compounds (primarily alkaloids), terpenoids, phenolics, proteinase inhibitors and insect growth regulators. Although the primary functions of these compounds are defence against phytophagous insects, many are also effective against mosquitoes and other biting Diptera, especially those volatile components released as a consequence of herbivory. From the above review, it has been inferred that the plant kingdom consists of vast resources of phytochemical compounds and they can be possibly utilized in integrated pest management and intensive vector control programme in the near future.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgments

Authors are gratefully acknowledged to Professor and Head of the Department of Zoology, the principal of Govt. Arts College (Autonomous) Nandanam for their support and laboratory facilities provided. The authors are also thankful to University Grants Commission, New Delhi [Reference No. 42-583/2013 (SR)] for their financial assistance.

References

[1] Rajendran S. Post harvest pest losses. In: Pimentel D, editor. *Encyclopedia of pest management*. New York: Marcel Dekker Inc.; 2002, p. 654-6.

[2] Rajashekar Y, Gunasekaran N, Shivanandappa T. Insecticidal activity of the root extract of *Decalepis hamiltonii* against storedproduct insect pests and its application in grain protection. *J Food Sci Technol* 2010; **47**: 310-4.

[3] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Hagstrum DW, editors. *Integrated management of insects in stored products.* New York: Marcel Dekker; 1996, p. 287-330.

[4] Dyte CE, Halliday D. Problems of development of resistance to phosphine by insect pests of stored grains. *EPPO Bull* 1985; **15**: 51-7.

[5] Wink M. Production and application of phytochemicals from an agricultural perspective. In: Van Beek TA, Breteler H, editors. *Phytochemistry and agriculture.* Oxford: Claredon Press; 1993, p. 171-213.

[6] Prajapti ND, Purohit SS, Sharma AK, Kumar T. *A handbook of medicinal plants: a complete source book.* Johdhpur: Agrobios; 1982, p. 120, 362.

[7] Aslan I, Özbek H, Çalmaşur Ö, Şahin F. Toxicity of essential oil vapours to two greenhouse pests, *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. *Ind Crops Prod* 2004; **19**(2): 167-73.

[8] Luo DQ, Zhang X, Tian X, Liu JK. Insecticidal compounds from *Tripterygium wilfordii* active against *Mythimna separata*. *Z Naturforsch C* 2004; **59**(5-6): 421-6.

[9] Çalmaşur Ö, Aslan I, Şahin F. Insecticidal and acaricidal effect of three Lamiaceae plant essential oils against *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. *Ind Crops Prod* 2006; **23**(2): 140-6.

[10] Mishra D, Shukla AK, Dubey AK, Dixit AK, Singh K. Insecticidal activity of vegetabe oils against mustard aphid, *Lipaphis erysimi* under field condition. *J Oleo Sci* 2006; **55**(5): 227-31.

[11] Oigiangbe ON, Igbinosa IB, Tamo M. Insecticidal activity of the medicinal plant, *Alstonia boonei* De Wild, against *Sesamia calamistis* Hampson. *J Zhejiang Univ Sci B* 2007; **8**(10): 752-5.

[12] Kamaraj C, Rahuman AA, Bagavan A. Screening for antifeedant and larvicidal activity of plant extracts against *Helicoverpa armigera* (Hubner), *Sylepta derogata* (F.) and *Anopheles stephensi* (Liston). *Parasitol Res* 2008; **103**(6): 1361-8.

[13] Ramya S, Rajasekaran C, Sundararajan G, Alaguchamy N, Jayakumararaj R. Antifeedant activity of leaf aqueous extracts of selected medicinal plants on VI instar larva of *Helicoverpa armigera* (Hubner). *Ethnobotan Leaflets* 2008; **12**: 938-43.

[14] Mikami AY, Ventura MU. Repellent, antifeedant and insecticidal effects of neem oil on *Microtheca punctigera*. *Braz Arch Biol Technol* 2008; **51**(6): 1121-6.

[15] Ramya S, Jayakumararaj R. Antifeedant activity of selected ethno-botanicals used by tribals of vattal hills on *Helicoverpa armigera* (Hübner). *J Pharm Res* 2009; **2**: 1414-8.

[16] Gökce A, Stelinski LL, Whalon ME, Gut LJ. Toxicity and antifeedant activity of selected plant extracts against larval obliquebanded leafroller, *Choristoneura rosaceana* (Harris). *Open Entomol J* 2009; **3**: 30-6.

[17] Lingathurai S, Ezhil Vendan S, Gabriel Paulraj M, Ignacimuthu S. Antifeedant and larvicidal activities of *Acalypha fruticosa* Forssk. (Euphorbiaceae) against *Plutella xylostella* L. (Lepidoptera: Yponomeutidae) larvae. *J King Saud Univ* 2011; **23**: 11-6.

[18] Oyedokun AV, Anikwe JC, Okelana FA, Mokwunye IU, Azeez OM. Pesticidal efficacy of three tropical herbal plants leaf extracts against *Macrotermes bellicosus*, an emerging pest of cocoa, *Theobroma cacao* L. *J Biopestic* 2011; **4**(2): 131-7.

[19] Jeyasankar A, Premalatha S, Elumalai K. Biological activities of *Solanum pseudocapsicum* (Solanaceae) against cotton bollworm, *Helicoverpa armigera* Hübner and armyworm, *Spodoptera litura* Fabricius (Lepidotera: Noctuidae). *Asian Pac J Trop Biomed* 2012; **2**(12): 981-6.

[20] Praveena R, Devanand Venkatasubbu G, Jegadeesan M. Antifeedant activity of selected medicinal plants on *Earias vittella*. *J Biopestic* 2012; **5**(2): 96-9.

[21] Krishnappa K, Elumalai K. Larvicidal and ovicidal activities of *Chloroxylon swietenia* (Rutaceae) essential oils against *Spodoptera litura* (Lepidoptera: Noctuidae) and their chemical compositions. *Int J Curr Res Life Sci* 2012; **1**(1): 3-7.

[22] Yang ML, Ma XM, Hao FX. Insecticidal activity of extract from *Cynanchi auriculati* against agricultural pests. *Inf Technol Agric Eng* 2012; **134**: 419-24.

[23] Packiam SM, Baskar K, Ignacimuthu S. Ovicidal activity of botanical oil formulations against *Helicoverpa armigera* Hubner and *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). *Asian Pac J Trop Biomed* 2012; **2**(Suppl 3): S1241-4.

[24] Gokulakrishnan J, Krishnappa K, Elumalai K. Effect of plant oil formulation against armyworm, *Spodoptera litura* (Fab.) cotton bollworm, *Helicoverpa armigera* (Hub.) and fruit borer, *Earias vitella* (Fab.) (Lepidoptera: Noctuidae). *Int J Curr Life Sci* 2012; **2**(1): 1-4.

[25] Baskaran J, Arshid Gani, Krishnappa K, Elumalai K. Antifeedant activity of certain plants essential oils against armyworm, *Spodoptera litura*(Fab.) (Lepidoptera: Noctuidae). *International Journal of Current Agricultural Sciences* 2012; 2(10).

[26] Gokulkrishnan J, Krishnappa K, Elumalai K. Certain plant essential oils against antifeedant activity of *Spodoptera litura* (Fab.), *Helicoverpa armigera* (Hub.) and *Achaea janata* (Linn.) (Lepidoptera: Noctuidae). *Int J Curr Life Sci* 2012; **2**(1): 5-11.

[27] Sharma A, Kumar V, Rattan RS, Kumar N, Singh B. Insecticidal toxicity of spilanthol from *Spilanthes acmella* Murr. against *Plutella xylostella* L. *Am J Plant Sci* 2012; **3**: 1568-72.

[28] Degri MM, Mailafiya DM, Wabekwa JW. Efficacy of aqueous leaf extracts and synthetic insecticide on pod-sucking bugs infestation of cowpea (*Vigna unguiculata* (L.) Walp) in the Guinea savanna region of Nigeria. *Adv Entomol* 2013; **1**(2); 10-4.

[29] Sougui S, Chaieb I, Cheikh ZB, Laarif A. Insecticidal activities of essential oils from some cultivated aromatic plants against *Spodoptera littoralis* (Boisd). *J Plant Prot Res* 2013; **53**(4): 388-91.

[30] Mwine J, Ssekyewa C, Kalanzi K, Van Damme P. Evaluation of

selected pesticidal plant extracts against major cabbage insect pests in the field. *J Med Plants Res* 2013; **7**(22): 1580-6.

[31] Maheswari S, Chitra M, Sivasangari R. Isolation of insecticidal compound from *Alangium salvifolium* and its effect on *Mythimna separata*. *Res J Agric Environ Manag* 2013; **2**(8): 229-32.

[32] Jeyasankar A, Elumalai K, Raja N, Ignacimuthu S. Effect of plant chemicals on oviposition deterrent and ovicidal activities against female moth, *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *Int J Agric Sci Res* 2013; **2**(6): 206-13.

[33] Arivoli S, Tennyson S. Ovicidal activity of plant extracts against *Spodoptera litura* (Fab) (Lepidoptera: Noctiduae). *Bull Environ Pharmacol Life Sci* 2013; **2**(10): 140-5.

[34] Acheuk F, Doumandji-Mitiche B. Insecticidal activity of alkaloids extract of *Pergularia tomentosa* (Asclepiadaceae) against fifth instar larvae of *Locusta migratoria* cinerascens (Fabricius 1781) (Orthoptera: Acrididae). *Int J Sci Adv Technol* 2013; **3**(6): 8-13.

[35] Abbaszadeh G, Srivastava C, Walia S. Insecticidal and antifeedant activities of clerodane diterpenoids isolated from the Indian bhant tree, *Clerodendron infortunatum*, against the cotton bollworm, *Helicoverpa armigera*. *J Insect Sci* 2014; **14**: 29.

[36] Jeyasankar A, Premalatha S, Elumalai K. Antifeedant and insecticidal activities of selected plant extracts against *Epilachna* beetle, *Henosepilachna vigintioctopunctata* (Coleoptera: Coccinellidae). *Adv Entomol* 2014; **2**(1): 14-9.

[37] Selvam K, Ramakrishnan N. Antifeedant and ovicidal activity activity of *Tinospora cardifolia* willd (Menispermaceae) against *Spodoptera litura* (Fab.) and *Helicoverpa armigera* (Hub.) (Lepidoptera: Noctuidae). *Int J Recent Sci Res* 2014; **5**(10): 1955-9.

[38] Huang SH, Xian JD, Kong SZ, Li YC, Xie JH, Lin J, et al. Insecticidal activity of pogostone against *Spodoptera litura* and *Spodoptera exigua* (Lepidoptera: Noctuidae). *Pest Manag Sci* 2014; **70**(3): 510-6.

[39] Devi GD, Murugan K, Selvam CP. Green synthesis of silver nanoparticles using *Euphorbia hirta* (Euphorbiaceae) leaf extract against crop pest of cotton bollworm, *Helicoverpa armigera* (Lepidoptera: Noctuidae). *J Biopestic* 2014; **7**: 54-66.

[40] Lall D, Summerwar S, Pandey J. Bioefficacy of plant extracts against larvae of American bollworm *Helicoverpa armigera* (Nouctuidae: Lepidoptera) special reference to the effect on peritrophic membrane). International Conference on Chemical, Civil and Environmental Engineering. 2014 Nov 18–19; Singapore.

[41] Bhatt P, Thodsare N, Srivastava RP. Toxicity of some bioactive medicinal plant extracts to Asian army worm, *Spodoptera litura*. *J Appl Nat Sci* 2014; **6**(1): 139-43.

[42] Vattikonda SR, Amanchi NR, Raja SS. Antifeedant activity of forskolin, an extract of *Coleus forskohlii*, against *Papilio demoleus* L. (Lepidoptera: Papilionidae) larvae. *Eur J Exp Biol* 2014; **4**(1): 237-41.

[43] Arumugam E, Muthusamy B, Dhamodaran K, Thangarasu M, Kaliyamoorthy K, Kuppusamy E. Pesticidal activity of *Rivina humilis* L. (Phytolaccaceae) against important agricultural polyphagous field pest, *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *J Coast Life Med* 2014; **2**(8): 652-8.

[44] Motazedian N, Aleosfoor M, Davoodi A, Bandani AR. Insecticidal activity of five medicinal plant essential oils against the cabbage aphid, *Brevicoryne brassicae*. *J Crop Prot* 2014; **3**(2): 137-46.

[45] Santiago J, Cardoso M, Figueiredo A, Moraes J, Assis F, Teixeira M, et al. Chemical characterization and application of the essential oils from *Chenopodium ambrosioides* and *Philodendron bipinnatifidum* in the control of *Diabrotica speciosa* (Coleoptera: Chrysomelidae). *Am J Plant Sci* 2014; **5**: 3994-4002.

[46] Teixeira M, Cardoso M, Figueiredo A, Moraes J, Assis F, Andrade J, et al. Essential oils from *Lippia origanoides* Kunth. and *Mentha spicata* L. chemical composition, insecticidal and antioxidant activities. *Am J Plant Sci* 2014; **5**: 1181-90.

[47] Baskar K, Ignacimuthu S, Jayakumar M. Toxic effects of *Couroupita guianensis* against *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). *Neotrop Entomol* 2015; **44**(1): 84-91.

[48] Nia B, Frah N, Azoui I. Insecticidal activity of three plants extracts against *Myzus persicae* (Sulzer, 1776) and their phytochemical screening. *Acta Agric Slovenica* 2015; **105**(2): 261-7.

[49] Muthusamy B, Arumugam E, Dhamodaran K, Thangarasu M, Kaliyamoorthy K, Kuppusamy E. Bioefficacy of *Caesalpinia bonducella* extracts against tobacco cutworm, *Helicoverpa armigera* (Hub.) (Lepidoptera: Noctuidae) *J Coast Life Med* 2015; **3**(5): 382-8.

[50] Elanchezhiyan K, Gokulakrishnan J, Deepa J, Selvakumar B. Phyto-toxicity of Indian medicinal plant *Tinospora crispa* (Menispermaceae) and *Psidium guajava* (Myrtaceae) against tobacco cutworm, *Helicoverpa armigera* (Hub.) (Lepidoptera: Noctuidae). *Int J Curr Agric Sci* 2015; **5**(7): 1-6.

[51] Bhardwaj T, Sharma JP, Singh P, Arora S. Testing the insecticidal, antifeedancy and fungicidal activity of plant extracts. International Conference on Advances in Agricultural, Biological & Environmental Sciences. 2015 Jul 22–23; London, UK.

[52] Kuhns EH, Martini X, Hoyte A, Stelinski LL. Repellent activity of botanical oils against Asian citrus psyllid, *Diaphorina citri* (Hemiptera: Liviidae). *Insects* 2016; doi: 10.3390/insects7030035.

[53] Jiang H, Wang J, Song L, Cao X, Yao X, Tang F, et al. GC×GC-TOFMS analysis of essential oils composition from leaves, twigs and seeds of *Cinnamomum camphora* L. Presl and their insecticidal and repellent activities. *Molecules* 2016; **21**(4): 423.

[54] Pan L, Ren L, Chen F, Feng Y, Luo Y. Antifeedant activity of *Ginkgo biloba* secondary metabolites against *Hyphantria cunea* larvae: mechanisms and applications. *PloS One* 2016; **11**(5): e0155682.

[55] Tampe J, Parra L, Huaiquil K, Quiroz A. Potential repellent activity of the essential oil of *Ruta chalepensis* (Linnaeus) from Chile against *Aegorhinus superciliosus* (Guérin) (Coleoptera: Curculionidae). *J Soil Sci Plant Nutr* 2016; **16**(1): 48-59.

[56] El Nadi AH, Elhag EA, Zaitoon AA, Al Doghairi MA. Toxicity of three plant extracts to *Trogoderma granarium* everts (Coleoptera: Dermestidae). *Pak J Biol Sci* 2001; **4**(12): 1503-5.

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

[58] Sanna Passino G, Bazzoni E, Moretti DL. Microencapsulated essential oils active against indianmeal moth. *Bol San Veg Plagas* 2004; **30**: 125-32.

[59] Saljoqi AUR, Afridi MM, Khan SA, Sadur-Rehma. Effects of six plant extracts on rice weevil *Sitophilus oryzae* L. in the stored wheat grains. *J Agric Biol Sci* 2006; **1**(4): 1-5.

[60] Jbilou R, Ennabili A, Sayah F. Insecticidal activity of four medicinal plant extracts against *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). *Afr J Biotechnol* 2006; **5**(10): 936-40.

[61] Moreira MD, Picanço MC, de Almeida Barbosa LC, Guedes RNC, de Campos MR, Silva GA, et al. Plant compounds insecticide activity against coleoptera pests of stored products. *Pesq Agropec Bras* 2007; **42**(7): 909-15.

[62] Jovanović Z, Kostić M, Popović Z. Grain-protective properties of herbal extracts against the bean weevil *Acanthoscelides obtectus* Say. *Ind Crops Prod* 2007; **26**: 100-4.

[63] Bodroža-Solarov M, Almaši R, Draganić V, Inđić D, Budimčević M, Mastilović J. Application of plant extracts as agents against *Sitophilus oryzae* L. in stored wheat. *Food Process Qual Saf* 2008; **35**(1): 27-32.

[64] Pugazhvendan SR, Elumalai K, Ronald Ross P, Soundararajan M. Repellent activity of chosen plant species against *Tribolium castaneum*. *World J Zool* 2009; **4**(3): 188-90.

[65] Moharramipour S, Taghizadeh A, Meshkatalsadat MH, Fathipour Y, Talebi AA. Repellent activity and persistence of essential oil extracted from *Prangos acaulis* to three stored product beetles. *Am-Eur J Sustain Agric* 2009; **3**(2): 202-4.

[66] Ayvaz A, Sagdic O, Karaborklu S, Ozturk I. Insecticidal activity of the essential oils from different plants against three stored-product insects.*J Insect Sci* 2010; **10**: 21.

[67] Ashouri S, Shayesteh N. Insecticidal activities of two powdered spices, black pepper and red pepper on adults of *Rhyzopertha dominica* (F.) and *Sitophilus granarius* (L.). *Mun Entomol Zool* 2010; **5**(2): 600-7.

[68] Ebadollahi A, Safaralizadeh MH, Hoseini SA, Ashouri S, Sharifian I. Insecticidal activity of essential oil of *Agastache foeniculum* against *Ephestia kuehniella* and *Plodia interpunctella* (Lepidoptera: Pyralidae). *Mun Entomol Zool* 2010; **5**(2): 785-91.

[69] Yankanchi SR, Gadache AH. Grain protectant efficacy of certain plant extracts against rice weevil, *Sitophilus oryzae* L. (Coleoptera: Curculionidae). *J Biopestic* 2010; **3**(2): 511-3.

[70] Ebadollahi A, Mahboubi M. Insecticidal activity of essential oil isolated from *Azilia eryngioides* (PAU) hedge et lamond against two beetle pests. *Chil J Agric Res* 2011; **71**(3): 406-11.

[71] Jemâa JMB, Tersim N, Toudert KT, Khouja ML. Insecticidal activities of essential oils from leaves of *Laurus nobilis* L. from Tunisia, Algeria and Morocco and comparative chemical composition. *J Stored Prod Res* 2011; **48**: 97-104.

[72] Chaubey MK. Fumigant toxicity of essential oils against rice weevil *Sitophilus oryzae* L. (Coleoptera: Curculionidae). *J Biol Sci* 2011; **11**(6): 411-6.

[73] Mahmoudvand M, Abbasipour H, Basij M, Hosseinpour MH, Rastegar F, Nasiri MB. Fumigant toxicity of some essential oils on adults of some stored-product pests. *Chil J Agric Res* 2011; **71**(1): 83-9.

[74] Younes MW, Othman SE, Elkersh MA, Youssef NS, Omar GA. Effect of seven plant oils on some biochemical parameters in Khapra beetle *Trogoderma granarium* everts (Coleoptera: Dermestidae). *Egypt J Exp Biol* 2011; **7**(1): 53-61.

[75] Lü J, Wu C, Shi Y. Toxicity of essential oil from *Artemisia argyi* against *Oryzaephilus surinamensis* (Linnaeus) (Coleoptera: Silvanidae). *Afr J Microbiol Res* 2011; **5**(18): 2816-9.

[76] Khani A, Rahdari T. Chemical composition and insecticidal activity of essential oil from *Coriandrum sativum* seeds against *Tribolium confusum* and *Callosobruchus maculatus*. *ISRN Pharm* 2012; **2012**: 263517.

[77] Zahir AA, Bagavan A, Kamaraj C, Elango G, Rahuman AA. Efficacy of plant-mediated synthesized silver nanoparticles against *Sitophilus oryzae*. *J Biopestic* 2012; **5**: 95-102.

[78] Al Qahtani AM, Al-Dhafar ZM, Rady MH. Insecticidal and biochemical effect of some dried plants against *Oryzaephilus surinamensis* (Coleoptera-Silvanidae). *J Basic Appl Zool* 2012; **65**: 88-93.

[79] Rani PU. Fumigant and contact toxic potential of essential oils from plant extracts against stored product pests. *J Biopestic* 2012; **5**(2): 120-8.

[80] Pugazhvendan SR, Ross PR, Elumalai K. Insecticidal and repellant activities of four indigenous medicinal plants against stored grain pest, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). *Asian Pac J Trop Dis* 2012; **2**(Suppl 1): S16-20.

[81] Satti AA, Elamin MM. Insecticidal activities of two meliaceous plants against *Trogoderma granarium* Everts (Coleoptera: Dermestidae). *Int J Sci Nat* 2012; **3**(3): 696-701.

[82] Padin SB, Fuse C, Urrutia MI, Dal Bello GM. Toxicity and repellency of nine medicinal plants against *Tribolium castaneum* in stored wheat. *Bull Insectol* 2013; **66**(1): 45-9.

[83] Ileke KD. Insecticidal activity of four medicinal plant powders and extracts against Angoumois grain moth, *Sitotroga cerealella* (Olivier) [Lepidoptera: Gelechidae]. *Egypt J Biol* 2013; **15**: 21-7.

[84] Sümer Ercan F, Baş H, Koç M, Pandir D, Öztemiz S. Insecticidal activity of essential oil of *Prangos ferulacea* (Umbelliferae) against *Ephestia kuehniella* (Lepidoptera: Pyralidae) and *Trichogramma embryophagum* (Hymenoptera: Trichogrammatidae). *Turk J Agric For* 2013; **37**: 719-25.

[85] Obembe OM, Kayode J. Insecticidal activity of the aqueous extracts of four under- utilized tropical plants as protectant of cowpea seeds from *Callosobruchus macultus* infestation. *Pak J Biol Sci* 2013; **16**(4): 175-9.

[86] Zandi-Sohani N, Hojjati M, Carbonell-Barrachina ÁA. Insecticidal and repellent activities of the essential oil of *Callistemon citrinus* (Myrtaceae) against *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *Neotrop Entomol* 2013; **42**(1): 89-94.

[87] Ali WK, Mohammed HH. Toxic effect of some plant extracts on the mortality of flour beetle *Tribolium confusum* (Duval) (Coleoptera: Tenebrionidae). *Entomol Ornithol Herpetol* 2013; **2**: 115.

[88] Utono IM, Coote C, Gibson G. Field study of the repellent activity of lem-ocimum-treated double bags against the insect pests of stored sorghum, *Tribolium castaneum* and *Rhyzopertha dominica*, in northern Nigeria. *J Stored Prod Res* 2014; **59**: 222-30.

[89] Jaya, Singh P, Prakash B, Dubey NK. Insecticidal activity of *Ageratum*

conyzoides L., *Coleus aromaticus* Benth. and Hyptis suaveolens (L.) Poit essential oils as fumigant against storage grain insect *Tribolium castaneum* Herbst. *J Food Sci Technol* 2014; **51**(9): 2210-5.

[90] Adjalian E, Sessou P, Bothon FTD, Dangou J, Odjo T, Figueredo G, et al. Chemical composition and bioefficacy of *Dennettia tripetala* and *Uvariodendron angustifolium* leaves essential oils against the angoumois grain moth, *Sitotroga cerealella*. *Int J Biosci* 2014; **5**(8): 161-72.

[91] Pandey AK, Palni UT, Tripathi NN. Repellent activity of some essential oils against two stored product beetles *Callosobruchus chinensis* L. and *C. maculatus* F. (Coleoptera: Bruchidae) with reference to *Chenopodium ambrosioides* L. oil for the safety of pigeon pea seeds. *J Food Sci Technol* 2014; **51**(12): 4066-71.

[92] Sani UM. Phytochemical screening and antifeedant activity of the seed extracts of *Parkia biglobosa* against cowpea bean (*Vigna unguiculata*) storage pest (*Callosobruchus maculatus*). *Int J Innov Res Sci Eng Technol* 2014; **3**(9): 15991-5.

[93] Khan A, Islam MS, Rahman M, Zaman T, Haque ME. Pesticidal and pest repellency activities of a plant derived triterpenoid 2α,3β,21β,23,28-penta hydroxyl 12-oleanene against *Tribolium castaneum*. *Biol Res* 2014; **47**: 68.

[94] Benzi V, Stefanazzi N, Murray AP, González JOW, Ferrero A. Composition, repellent, and insecticidalactivities of two South American plants against the stored grain pests *Tribolium castaneum* and *Tribolium confusum* (Coleoptera: Tenebrionidae). *ISRN Entomol* 2014; **2014**: 175827.

[95] Abd El-Razik MAA, Zayed GMM. Effectiveness of three plant oils in binary mixtures with pyridalyl, abamectin, spinosad and malathion against *Callosobruchus maculatus* (F.) adults. *Am J Biochem Mol Biol* 2014; **4**(2): 76-85.

[96] Rajashekar Y, Ravindra KV, Bakthavatsalam N. Leaves of *Lantana camara* Linn. (Verbenaceae) as a potential insecticide for the management of three species of stored grain insect pests. *J Food Sci Technol* 2014; **51**(11): 3494-9.

[97] Wang X, Li Q, Shen L, Yang J, Cheng H, Jiang S, et al. Fumigant, contact, and repellent activities of essential oils against the darkling beetle, *Alphitobius diaperinus*. *J Insect Sci* 2014; **14**: 75.

[98] Emamjomeh L, Imani S, Talebi K, Moharramipour S, Larijani K. Chemical composition and insecticidal activity of essential oil of *Zataria multiflora* Boiss. (Lamiaceae) against *Ephestia kuehniella* (Lepidoptera: Pyralidae). *Eur J Exp Biol* 2014; **4**(3): 253-7.

[99] Najafabadi SSM, Beiramizadeh E, Zarei R. Repellency and toxicity of three plant leaves extraction against *Oryzaephilus surinamensis* L. and *Tribolium castaneum* Herbst. *J Biodivers Environ Sci* 2014; **4**(6): 26-32.

[100] Adjalian E, Sessou P, Odjo T, Figueredo G, Kossou D, Avlessi F, et al. Chemical composition and insecticidal and repellent effect of essential oils of two *Premna* species against *Sitotroga cerealella*. *J Insects* 2015; **2015**: 319045.

[101] Zhang WJ, You CX, Yang K, Wang Y, Su Y, Geng ZF, et al. Bioactivity and chemical consitituents of the essential oil from *Dendranthema indicum* (L.) Des Moul. against two stored insects. *J Oleo Sci* 2015; **64**(5): 553-60.

[102] Adebisi O. Chemical composition and insecticidal activity of *Citrus aurantifolia* essential oil. 3rd International Conference and Exhibition on Pharmacognosy, Phytochemistry & Natural Products. Oct 26–28, 2015; Hyderabad, India. [Online] Available from: http://www.omicsonline.org/proceedings/chemical-composition-and-insecticidal-activity-of-citrus-aurantifolia-essential-oil-38251.html [Accessed on 23rd September, 2016]

[103] Nattudurai G, Irudayaraj SS, Paulraj MG, Baskar K, Ignacimuthu S. Insecticidal and repellent activities of T*oddalia asiatica* (L.) Lam. extracts against three major stored product pests. *Entomol Ornithol Herpetol* 2015; **4**: 148.

[104] Wu Y, Zhang WJ, Huang DY, Wang Y, Wei JY, Li ZH, et al. Chemical compositions and insecticidal activities of *Alpinia kwangsiensis* essential oil against *Lasioderma serricorne*. *Molecules* 2015; **20**: 21939-45.

[105] Wang Y, You CX, Yang K, Wu Y, Chen R, Zhang WJ, et al. Bioactivity of essential oil of *Zingiber purpureum* rhizomes and its main compounds against two stored product insects. *J Econ Entomol* 2015; **108**(3): 925-32.

[106] Eliopoulos PA, Hassiotis CN, Andreadis SS, Porichi AE. Fumigant toxicity of essential oils from basil and spearmint against two major pyralid pests of stored products. *J Econ Entomol* 2015; **108**(2): 805-10.

[107] Cansian RL, Astolfi V, Cardoso RI, Paroul N, Roman SS, Mielniczki-Pereira AA, et al. Insecticidal and repellent activity of the essential oil of *Cinnamomum camphora* var. *linaloolifera* Y. Fujita (Ho-Sho) and *Cinnamomum camphora* (L.) J Presl. var. *hosyo* (Hon-Sho) on *Sitophilus zeamais* Mots. (Coleoptera, Curculionedae). *Rev Bras Plantas Med* 2015; **17**(4): 769-73.

[108] Shahab-Ghayoor H, Saeidi K. Antifeedant activities of essential oils of *Satureja hortensis* and *Fumaria parviflora* against Indian meal moth *Plodia interpunctella* Hubner (Lepidoptera: Pyralidae). *Entomol Ornithol Herpetol* 2015; **4**: 154.

[109] Jeyasankar A, Chennaiyan V, Chinnamani T. Evaluation of five essential plant oils as a source of repellent and larvicidal activities against larvae of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). *J Entomol* 2016; **13**(3): 98-103.

[110] Pinto JJ, Silva G, Figueroa I, Tapia M, Urbina A, Rodríguez JC, et al. Insecticidal activity of powder and essential oil of *Cryptocarya alba* (Molina) Looser against *Sitophilus zeamais* Motschulsky. *Chil J Agric Res* 2016; **76**(1): 48-54.

[111] Onaolapo Akinneye J, Oyeniyi EA. Insecticidal efficacy of *Cleistopholis patens* (Benth) against *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae) infesting rice grains in Nigeria. *J Crop Prot* 2016; **5**(1): 1-10.

[112] Guo S, Zhang W, Liang J, You C, Geng Z, Wang C, et al. Contact and repellent activities of the essential oil from *Juniperus formosana* against two stored product insects. *Molecules* 2016; **21**(4): 504.

[113] Liang JY, Guo SS, You CX, Zhang WJ, Wang CF, Geng ZF, et al. Chemical constituents and insecticidal activities of *Ajania fruticulosa* essential oil. *Chem Biodivers* 2016; **13**(8): 1053-7.

[114] Pandir D, Baş H. Compositional analysis and toxicity of four plant essential oils to different stages of mediterranean flour moth, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae). *Turk J Entomol* 2016;

40(2): 185-95.

[115]Choi WS, Park BS, Ku SK, Lee SE. Repellent activities of essential oils and monoterpenes against *Culex pipiens* pallens. *J Am Mosq Control Assoc* 2002; **18**(4): 348-51.

[116]Mello CB, Uzeda CD, Bernardino MV, Mendonça-Lopes D, Kelecom A, Fevereiro PCA, et al. Effects of the essential oil obtained from *Pilocarpus spicatus* Saint-Hilaire (Rutaceae) on the development of *Rhodnius prolixus* nymphae. *Braz J Pharmacogn* 2007; **17**(4): 514-20.

[117]Bagavan A, Kamaraj C, Rahuman AA, Elango G, Zahir AA, Pandiyan G. Evaluation of larvicidal and nymphicidal potential of plant extracts against *Anopheles subpictus* Grassi, *Culex tritaeniorhynchus* Giles and *Aphis gossypii* Glover. *Parasitol Res* 2009; **104**(5): 1109-17.

[118]Zahir AA, Rahuman AA, Bagavan A, Elango G, Kamaraj C. Adult emergence inhibition and adulticidal activities of medicinal plant extracts against *Anopheles stephensi* Liston. *Asian Pac J Trop Med* 2010; **3**(11): 878-83.

[119]Elango G, Rahuman AA, Bagavan A, Kamaraj C, Zahir AA, Rajakumar G, et al. Efficacy of botanical extracts against Japanese encephalitis vector, *Culex tritaeniorhynchus*. *Parasitol Res* 2010; **106**: 481-92.

[120]Kumar S, Wahab N, Warikoo R. Bioefficacy of *Mentha piperita* essential oil against dengue fever mosquito *Aedes aegypti* L. *Asian Pac J Trop Biomed* 2011; **1**(2): 85-8.

[121]Govindarajan M, Mathivanan T, Elumalai K, Krishnappa K, Anandan A. Ovicidal and repellent activities of botanical extracts against *Culex quinquefasciatus*, *Aedes aegypti* and *Anopheles stephensi* (Diptera: Culicidae). *Asian Pac J Trop Biomed* 2011; **1**(1): 43-8.

[122]Govindarajan M, Sivakumar R. Mosquito adulticidal and repellent activities of botanical extracts against malarial vector, *Anopheles stephensi* Liston (Diptera: Culicidae). *Asian Pac J Trop Med* 2011; **4**(12): 941-7.

[123]Tedeschi P, Leis M, Pezzi M, Civolani S, Maietti A, Brandolini V. Insecticidal activity and fungitoxicity of plant extracts and components of horseradish (*Armoracia rusticana*) and garlic (*Allium sativum*). *J Environ Sci Health B* 2011; **46**(6): 486-90.

[124]Tennyson S, Ravindran JK, Arivoli S. Screening of plant extracts for ovicidal activity against *Culex quinquefasciatus* Say (Diptera: Culicidae). *Elixir Appl Bot* 2011; **40**: 5456-60.

[125]Manimaran A, Jee Jee Cruz M, Muthu C, Vincent S, Ignacimuthu S. Larvicidal and knockdown effects of some essential oils against *Culex quinquefasciatus* Say, *Aedes aegypti* (L.) and *Anopheles stephensi* (Liston). *Adv Biosci Biotechnol* 2012; **3**: 855-62.

[126]Adebajo AC, Famuyiwa FG, John JD, Idem ES, Adeoye AO. Activities of some Nigerian medicinal plants against *Aedes aegypti*. *Chin Med* 2012; **3**: 151-6.

[127]Effiom OE, Avoaja DA, Ohaeri CC. Mosquito repellent activity of phytochemical extracts from peels of citrus fruit species. *Glob J Sci Front Res* 2012. [Online] Available from: https://globaljournals.org/GJSFR_Volume12/2-Mosquito-Repellent-Activity-of-Phytochemical-Extracts.pdf [Accessed on 23rd September, 2016]

[128]Elumalai K, Dhanasekaran S, Anandan A, Krishnappa K, Gokulakrishnan J, Elangovan A. Larvicidal, ovicidal and pupicidal activity of *Eranthemum roseum* (Vahl) R. Br. against malarial vector mosquito, *Anopheles stephensi* (Liston) (Diptera: Culicidae). *Int J Curr Agric Sci* 2012; **2**(7): 28-33.

[129]Kovendan K, Murugan K, Shanthakumar SP, Vincent S. Evaluation of larvicidal and pupicidal activity of *Morinda citrifolia* L. (Noni) (Family: Rubiaceae) against three mosquito vectors. *Asian Pac J Trop Dis* 2012; **2**: S362-9.

[130]Kovendan K, Murugan K, Panneerselvam C, Aarthi N, Kumar PM, Subramaniam J, et al. Antimalarial activity of *Carica papaya* (Family: Caricaceae) leaf extract against *Plasmodium falciparum*. *Asian Pac J Trop Dis* 2012; **2**: S306-11.

[131]Krishnappa K, Dhanasekaran S, Elumalai K. Larvicidal, ovicidal and pupicidal activities of *Gliricidia sepium* (Jacq.) (Leguminosae) against the malarial vector, *Anopheles stephensi* Liston (Culicidae: Diptera). *Asian Pac J Trop Med* 2012; **5**(8): 598-604.

[132]Sarah JS, Raji KP, Chandramohanakumar N, Balagopalan M. Larvicidal potential of biologically synthesised silver nanoparticles against *Aedes Albopictus*. *Res J Recent Sci* 2012; **1**: 52-6.

[133]Krishnappa K, Elumalai K, Dhanasekaran S, Gokulakrishnan J. Larvicidal and repellent properties of *Adansonia digitata* against medically important human malarial vector mosquito *Anopheles stephensi* (Diptera: Culicidae). *J Vector Borne Dis* 2012; **49**: 86-90.

[134]Krishnappa K, Elumalai K. Toxicity of *Aristolochia bracteata* methanol leaf extract against selected medically important vector mosquitoes (Diptera: Culicidae). *Asian Pac J Trop Dis* 2012; **2**: S553-7.

[135]Samidurai K. Mosquito larvicidal and ovicidal properties of *Pemphis acidula* Frost. (Lythraceae) against *Culex tritaeniorhynchus* Giles and *Anopheles subpictus* Grassi (Diptera: Culicidae). *Asian Pac J Trop Biomed* 2012; **2**: S1862-6.

[136]Trindade FTT, Stabeli RG, Facundo VA, Cardoso CT, da Silva MA, Gil LHS, et al. Evaluation of larvicidal activity of the methanolic extracts of *Piper alatabaccum* branches and *P. tuberculatum* leaves and compounds isolated against *Anopheles darlingi*. *Braz J Pharmacogn* 2012; **22**(5): 979-84.

[137]Murugan K, Kovendan K, Vincent S, Barnard DR. Biolarvicidal and pupicidal activity of *Acalypha alnifolia* Klein ex Willd. (Family: Euphorbiaceae) leaf extract and microbial insecticide, *Metarhizium anisopliae* (Metsch.) against malaria fever mosquito, *Anopheles stephensi* Liston. (Diptera: Culicidae). *Parasitol Res* 2012; **110**(6): 2263-70.

[138]Allison LN, Dike KS, Opara FN, Ezike MN, Amadi AN. Evaluation of larvicidal efficacy and phytochemical potential of some selected indigenous plant against *Anopheles gambiense* and *Culex quinquefasciatus*. *Adv Biosci Biotechnol* 2013; **4**: 1128-33.

[139]Veerakumar K, Govindarajan M, Rajeswary M. Green synthesis of silver nanoparticles using *Sida acuta* (Malvaceae) leaf extract against *Culex quinquefasciatus*, *Anopheles stephensi* and *Aedes aegypti* (Diptera: Culicidae). *Parasitol Res* 2013; **112**(12): 4073-85.

[140]Panneerselvam C, Murugan K, Kovendan K, Kumar PM, Subramaniam J. Mosquito larvicidal and pupicidal activity of *Euphorbia hirta* Linn. (Family: Euphorbiaceae) and *Bacillus sphaericus* against *Anopheles stephensi* Liston. (Diptera: Culicidae). *Asian Pac J Trop Med* 2013; **6**(2): 102-9.

[141]de Lima GP, de Souza TM, de Paula Freire G, Farias DF, Cunha AP, Ricardo NM, et al. Further insecticidal activities of essential oils from *Lippia sidoides* and *Croton* species against *Aedes aegypti* L. *Parasitol Res* 2013; **112**(5): 1953-8.

[142]El-Akhal F, El Ouali Lalami A, Ez Zoubi Y, Greche H, Guemmouh R. Chemical composition and larvicidal activity of essential oil of *Origanum majorana* (Lamiaceae) cultivated in Morocco against *Culex pipiens* (Diptera: Culicidae). *Asian Pac J Trop Biomed* 2014; **4**(9): 746-50.

[143]Bakhshi H, Abai MR, Amin G, Zolfi R, Pirmohammadi M, Bakhshi A, et al. Larvicidal properties of botanical extracts of *Lawsonia inermis* against *Anopheles stephensi*. *Adv Infect Dis* 2014; **4**: 178-85.

[144]Suganya G, Karthi S, Shivakumar MS. Larvicidal potential of silver nanoparticles synthesized from *Leucas aspera* leaf extracts against dengue vector *Aedes aegypti*. *Parasitol Res* 2014; **113**(3): 875-80.

[145]Naik BR, Gowreeswari GS, Singh Y, Satyavathi R, Daravath SS, Reddy PR. Bio-synthesis of silver nanoparticles from leaf extract of *Pongamia pinnata* as an effective larvicide on dengue vector *Aedes albopictus* (Skuse) (Diptera: Culicidae). *Adv Entomol* 2014; **2**: 93-101.

[146]Ramesh KK, Nattuthurai, Gopinath P, Mariappan T. Biosynthesis of Silver nanoparticles from *Morinda tinctoria* leaf extract and their larvicidal activity against *Aedes aegypti* Linnaeus 1762. *J Nanomed Nanotechnol* 2014; doi: doi:10.4172/2157-7439.1000242.

[147]Mavundza EJ, Maharaj R, Chukwujekwu JC, Finnie JF, Van Staden J. Screening for adulticidal activity against *Anopheles arabiensis* in ten plants used as mosquito repellent in South Africa. *Malar J* 2014; **13**: 173.

[148]Aruna P, Murugan K, Priya A, Ramesh S. Larvicidal, pupicidal and repellent activities of *Gaultheria* oil (Plantae: Ericaceae) against the filarial vector, *Culex quinquefasciatus* (Insecta: Diptera: Culicidae). *J Entolomol Zool Stud* 2014; **2**(4): 290-4.

[149]Thangarasu M, Kaliyamoorthy K, Kuppusamy E. Pesticidal and mosquitocidal activities of *Clausena excavata* Burm. F. (Rutaceae) against *Spodoptera litura* (Fab.) (Noctuidae: Lepidoptera) and *Aedes aegypti* L., *Anopheles stephensi* Liston, and *Culex quinquefasciatus* Say. (Diptera: Culicidae). *Adv Zool* 2014; doi: 10.1155/2014/745015.

[150]Reegan AD, Gandhi MR, Paulraj MG, Balakrishna K, Ignacimuthu S. Effect of niloticin, a protolimonoid isolated from *Limonia acidissima* L. (Rutaceae) on the immature stages of dengue vector *Aedes aegypt*i L. (Diptera: Culicidae). *Acta Trop* 2014; **139**: 67-76.

[151]Priya S, Murugan K, Priya A, Dinesh D, Panneerselvam C, Durga Devi G, et al. Green synthesis of silver nanoparticles using *Calotropis gigantean* and their potential mosquito larvicidal property. *Int J Pure Appl Zool* 2014; **2**(2): 128-37.

[152]Ramar M, Ignacimuthu S, Gabriel Paulraj M. Ovicidal and oviposition response activities of plant volatile oils against *Culex quinquefasciatus* say. *J Entomol Zool Stud* 2014; **2**(4): 82-6.

[153]Sivapriyajothi S, Mahesh Kumar P, Kovendan K, Subramaniam J, Murugan K. Larvicidal and pupicidal activity of synthesized silver nanoparticles using *Leucas aspera* leaf extract against mosquito vectors, *Aedes aegypti* and *Anopheles stephensi*. *J Entomol Acarol Res* 2014; **46**: 77-84.

[154]Alayo MA, Femi-Oyewo MN, Bakre LG, Fashina AO. Larvicidal potential and mosquito repellent activity of *Cassia mimosoides* extracts. *Southeast Asian J Trop Med Public Health* 2015; **46**(4): 596-601.

[155]Reegan AD, Gandhi MR, Paulraj MG, Ignacimuthu S. Ovicidal and Oviposition deterrent activities of medicinal plant extracts against *Aedes aegypti* L. and *Culex quinquefasciatus* say mosquitoes (Diptera: Culicidae). *Osong Public Health Res Perspect* 2015; **6**(1): 64-9.

[156]Kamakshi KT, Raveen R, Tennyson S, Arivoli S, Reegan AD. Ovicidal and repellent activities of *Cereus hildmannianus* (K. Schum.) (Cactaceae) extracts against the dengue vector *Aedes aegypti* L. (Diptera: Culicidae). *Int J Mosq Res* 2015; **2**(1): 13-7.

[157]Bhuvaneswari R, Xavier RJ, Arumugam M. Larvicidal property of green synthesized silver nanoparticles against vector mosquitoes (*Anopheles stephensi* and *Aedes aegypti*). *J King Saud Univ Sci* 2016; **28**(4): 318-23.

[158]Santhosh SB, Ragavendran C, Natarajan D. Spectral and HRTEM analyses of *Annona muricata* leaf extract mediated silver nanoparticles and its larvicidal efficacy against three mosquito vectors *Anopheles stephensi*, *Culex quinquefasciatus*, and *Aedes aegypti*. *J Photochemi Photobiol* 2015; **153**: 184-90.

[159]Poopathi S, De Britto LJ, Praba VL, Mani C, Praveen M. Synthesis of silver nanoparticles from *Azadirachta indica* – a most effective method for mosquito control. *Environ Sci Pollut Res* 2015; **22**(4): 2956-63.

[160]Araujo AF, Ribeiro-Paes JT, Deus JT, Cavalcanti SC, Nunes Rde S, Alves PB, et al. Larvicidal activity of *Syzygium aromaticum* (L.) Merr and *Citrus sinensis* (L.) Osbeck essential oils and their antagonistic effects with temephos in resistant populations of *Aedes aegypti*. *Mem Inst Oswaldo Cruz* 2016; **111**(7): 443-9.

[161]Anuradha V, Syed Ali M, Yogananth N. Efficacy of mosquito repellent and adulticidal activities of *Halophila ovalis* extract against filaria vectors. *J Trop Dis* 2016; doi:10.4172/2329891X.1000191.

[162]Carvalho Kda S, E Silva SL, de Souza IA, Gualberto SA, da Cruz RC, Dos Santos FR, et al. Toxicological evaluation of essential oil from the leaves of *Croton tetradenius* (Euphorbiaceae) on *Aedes aegypti* and *Mus musculus*. *Parasitol Res* 2016; **115**(9): 3441-8.

[163]Ajaegbu EE, Danga SP, Chijoke IU, Okoye FB. Mosquito adulticidal activity of the leaf extracts of *Spondias mombin* L. against *Aedes aegypti* L. and isolation of active principles. *J Vector Borne Dis* 2016; **53**: 17-22.

[164]Elumalai D, Hemavathi M, Hemalatha P, Deepaa CV, Kaleena PK. Larvicidal activity of catechin isolated from *Leucas aspera* against Aedes aegypti, *Anopheles stephensi*, and *Culex quinquefasciatus* (Diptera: Culicidae). *Parasitol Res* 2016; **115**(3) 1203-12.

[165]Ramkumar G, Karthi S, Muthusamy R, Suganya P, Natarajan D, Kweka EJ, et al. Mosquitocidal effect of *Glycosmis pentaphylla* leaf extracts against three mosquito species (Diptera: Culicidae). *PLoS One* 2016; **11**(7): e0158088.

[166]Silapanuntakul S, Keanjoom R, Pandii W, Boonchuen S, Sombatsiri K. Efficacy of Thai neem oil against *Aedes aegypti* (L.) larvae. *Southeast Asian J Trop Med Public Health* 2016; **47**(3): 410-5.

[167]Mohankumar TK, Shivanna KS, Achuttan VV. Screening of methanolic plant extracts against larvae of *Aedes aegypti* and *Anopheles stephensi* in Mysore. *J Arthropod Borne Dis* 2016; **10**(3): 303-14.