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

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1. Introduction

Phylum 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 an 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 activities, 384 plant species showing antifeedant activities, 297 plant species showing repellent properties, 27 plant species showing attractant...
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 EC50 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 nympha 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 charantia, Momordica dioica, Lagenaria siceraria 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.

Ogiangbe et al.[11] analyzed Alystoma 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 results 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), Albizic amara, Cardiospermum halicacabum, Abutilon indicum, Cassia tora, Tribulus terestris, 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, Albizica amara, Gymnema sylvestre, Cardiospermum halicacabum, Vitis negundo, Abutilon indicum, Cassia tora, Tribulus terestris, Achyranthus aspera and Aerva lanata, Gökçe 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 rosacea. 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 Platella 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, Dodonaea viscosa, Anacardium occidentale (A. occidentale) and Nicotiana tabacum to study its antifeedant activity against Earias vitellata. 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 Cynanchus auriculati against Plutella xylostella (P. xylostella), Mythimna separata. 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 aphids, 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 vitellata. 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 – Earias vitellata, 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 citratus (C. citratus) against the larvae of S. littoralis. 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. citratus against fourth instar larvae of S. litura at 1000 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 1000 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 spilanthon 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 Phytoleucca 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 salviolifolium 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 Syzygium 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-1-en-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 koenigii 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.

Abbaspasdeh et al. [35] studied the insecticidal and antifeedant activities of Clerodendron infortunatum against the H. armigera.
Jeyasankar et al. 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 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 Pogostemon cablin and insecticidal activities in the essential oil of the leaves of Lippia origanoides were carvacrol, α-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.

Muthusamy et al. analyzed the benzene, diethyl ether, ethyl acetate, dichloromethane and methanol extracts of Caesalpinia bondocella for their antifeedant, ovoposition 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 deterency against H. armigera. Similarly, different solvent extracts of Balanites aegyptiaca, Paederia foetida, Limonia acidissima and Polyalthia longifolia were tested for their antifeedant activities against Lipaphis erysimi and S. litura. The maximum potency was noted in the chloroform and petroleum ether extract.

Recently, Kuhns et al. suggested that essential oils played a major role against Citrus psylid and Diaphorina citri under field condition. Jiang et al. 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. 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. 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 offactometric bioassays. From their experiment, the major compounds present 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. analyzed the three plant species – Rhazya stricta, A. indica and Heliotropium lanceiforme for their insecticidal activities with the aqueous, methanolic and acetic extracts against Trogoderma granarium (T. granarium). Their results suggested that acetone extracts exhibited remarkable toxicity on T. granarium. Kim et al. 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
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 Aetyllo 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. Jemāa et al.[71] analyzed that the essential oils of Laurus nobilis collected from Tunisia, Algeria and Morocco 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 were treated with the essential oils of Laurus nobilis from Morocco 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 acetylcholinestase enzyme on rice weevil. Mahmoudvand et al.[73] investigated the essential oils of R. officinalis, Mentha pulegium, Z. multiflorus 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. sarinamensis. Khani and Rahgari[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 officinalis (Z. officinalis), Elettaria cardamomum and F. vulgare, were analyzed against O. sarinamensis. The experimental results revealed that Z. officinalis followed by Elettaria cardamomum and F. vulgare showed considerable insecticidal activities. Further, under polyacrylamide gel electrophoresis for protein analysis of O. sarinamensis, there observed a significant alteration in the protein configuration[78]. Essential oils of Pinus longifolia, Eucalyptus oblique and C.
Mentha longifolia and C. chinesis and Corepyra 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 Prospolis juliflora against T. castaneum. From their results, chloroform 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 canpestris 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 Prunus 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 a 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 suppressed 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. Adjian et al. [90] showed that the essential oils of D. tripetala and U. 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. chinesis and C. maculatus. In vitro 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-pentahydroxyxyl 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-pentahydroxyxyl 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. chinesis 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.

Adjianian 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 α-cis-farnesene[101]. Furthermore, the insecticidal and repellent activities were shown by the essential oil and chamazulene on targeted pests, T. castaneum and Stegobium paniceum.

Adebisi[102] investigated the insecticidal activity of the essential oil of Citrus aurantifolia against C. maculatus. They have also identified 37 components and the major components of terpenoids were limonene, β-myrcene, cymene, and thymol. Nattudurai et al.[103] reported that the fumigant and repellent activities of Toddalia asiatica were studied on C. maculatus, S. oryzae and T. castaneum. From their findings, it was clearly revealed that Toddalia asiatica showed 100% repellency against C. maculatus, 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 purpurascens against two stored pests T. castaneum and Lasioderma serricorne. In their study, essential oil of the rhizome of Zingiber purpurascens showed contact and fumigant toxicity against the grain storage pest. Also, major compounds sabinen, terpinen-4-ol, γ-terpinene, α-turpinene, 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.

Canisan 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 Saedidi[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, Gautheria 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 Cryptocarya 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 Cleistoholishis 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, Cappsisium annuum, M. piperta 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 Eucalyptus globulus, Lavender 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 moultling 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 following extracts such as C. sinensis, O. canum, O. sanum and Rhinacanthus nasutus as they have larvicidal and nymphicidal activities against the vectors and cotton pests. Anopheles subpictus, Culex tritaeniorhynchus and Aphis gossypii. Aniseomeles malabarica, E. hirta, O. basilicum, R. communis, Solanum trilobatum, Tridax procumbens and seeds of Gloriosa superba extracts were determined for theiradulticidal 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, whereas 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 Marhamia tomentosa and Newholdia 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 activities 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 solvent 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 alabackum and Piper tuberculatum for their insecticidal activities against Anopheles darlingi. Their experiment clearly exhibited the larvicidal activity with the compounds 3,4,5-trimetoxy-dihydronicamidic acid, dihydropiptartline, piplartine, piprartine-dihydropiprartine and 5,5′,7-trimetoxy and 3′,4′-methylendioxiflavone with Piper alabackum and Piper tuberculatum.

Murugan et al.[137] analyzed the larvicidal and pupicidal properties of the leaf extract of Acalypha anifolia 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 pupicidal 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 LC50 and LC90 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 zebrina and Croton argyrophylloides 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 extract 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 repellents 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. calanus, 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. Therefore, 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 mimosoids (C. mimosoids) against Anopheles gambiae. In their studies, phytochemical examination showed the presence of saponins, antraquiones, flavonoids steroids and tannins and absence of alkaloids and cardiac glycosides in a powdered C. mimosoids. 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. mimosoids. 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. Bhuwaneswari et al. [157] studied the larvicidal property of the silver nanoparticles synthesized from the leaf extract of Belosynapsis kewensis against
A. steplansi 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 activities 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 nanoparticles 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. aegypti. 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. stephani 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 mosquitoicidal 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 pentaphylly 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 insecticidal activity against the fourth instar larvae of A. aegypti and A. stephani. 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-seekings 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.

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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, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[4] Dyte CE, Halliday D. Problems of development of resistance to pesticides. *Encyclopedia of pest management* (Euphorbiaceae) against cotton bollworm, *Helicoverpa armigera* Hübner and armyworm, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae) essential oils against Spodoptera litura (Lepidoptera: Noctuidae) and their chemical compositions. *Int J Curr Res Life Sci* 2012; 1(1): 3-7.

[5] Aslan I, Özbek H, Çalışmur 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.

[6] 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.

[7] Çalışmur 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.

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

[9] Ogiangbe ON, Igbinsosa IB, Tamon M. Insecticidal activity of the medicinal plant, *Altostia boomei* De Wild, against *Sesamia calamistis* Hampson. *J Zhejiang Univ Sci B* 2007; 8(10): 752-5.

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

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

[12] Jyotishkumar A, Balasubramanian K. Antifeedant activity of leaf aqueous extracts of *Acalypha fruticosa* Forssk. against storedproduct insect *Yponomeutidae) larvae. *J King Saud Univ Sci* 2011; 23(4): 131-7.

[13] Lingathurai S, Ezhil Vendan S, Gabriel Paulraj M, Ignacimuthu S. Antifeedant and larvicidal activities of *Cynanchi auriculati* against storedproduct insect pests and its application in grain protection. *J Food Sci Technol* 2010; 47: 310-4.

[14] Mohamed AA, Anikwe JC, Okelana FA, Mokwunye IU, Azeez OM. Repellent, antifeedant and insecticidal effects of *Tripterygium wilfordii* Huber and armyworm, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). *Asian Pac J Trop Biomed* 2012; 2(12): 981-6.

[15] Aslan I, Özbek H, Çalışmur 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.

[16] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[17] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[18] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[19] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[20] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[21] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[22] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[23] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[24] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[25] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[26] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[27] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[28] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[29] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.

[30] White NDG, Leesch JG. Chemical control. In: Subramanyam B, Prajapti ND, Purohit SS, Sharma AK, Kumar T. *New York: Marcel Dekker Inc.; 1982*, p. 120, 362.
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 salviifolium* 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 deterent 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: Noctuidae). *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 (Fabriciis 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] 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* (Hub.) (Lepidoptera: Noctuidae). *Int J Recent Sci Res* 2014; 5(10): 1955-9.

[37] Selvam K, Ramakrishnan N. Antifeedant and ovicidal activity of *Tinospora cardifolia* willd (Menispermacæae) against *Spodoptera litura* (Fab.) and *Helicoverpa armigera* (Hub.) (Lepidoptera: Noctuidae). *Int J Agric Sci Plant Nutr* 2016; 3(22): 1580-6.

[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(4): 54-66.

[40] Lall D, Summerwar S, Pandey J. Bioefficacy of plant extracts against larvae of American bollworm *Helicoverpa armigera* (Nocutuidae: 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, Adeosfoor 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 *Courosopia 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 physicochemical screening. *Acta Agric Slovaca* 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. Phytoxicity of Indian medicinal plant *Tinospora crispa* (Menispermacæae) and *Psidium guajava* (Myrtaceæae) 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. Prels 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 *Hypzaphylin 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 *Aegorhines supercilious* (Güerin) (Coleoptera: Curculionidae). *J Soil 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.
Moreira MD, Picanço MC, de Almeida Barbosa LC, Guedes RNC, Jovanović Jbilou R, Ennabili A, Sayah F. Insecticidal activity of four medicinal plant extracts on rice weevil Sitophilus oryzae L. in the stored wheat grains. J Agric Biol Sci 2006;1(4):1-5.

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

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.

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.

Bodroža-Solarov M, Almatiš M, Draganić V, Indić D, Budimirživić 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.

Pugazhevendan 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.

Moharrampour S, Taghizadeh A, Meshkatalsadat MH, Fatipour Y, Talebi AA. Repellent activity and persistent effect of essential oil extracted from Prangos acaulis (PAU) against three stored product beetles. Am-Eur J Sustain Agric 2009;3(2):202-4.

Ayyaz 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.

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

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

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.

Ebadollahi A, Mahboubi M. Insecticidal activity of essential oil isolated from Azilia eringyoides (PAU) hedge et lamond against two beetle pests. Chil J Agric Res 2011;41(3):406-11.

Jemía JMB, Tersim N, Toudent 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.

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

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;41(1):83-9.

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: Dermentidae). Egypt J Exp Biol 2011;7(1):53-61.

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.

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.

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

Al Qhtani 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.

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

Pugazhevendan SR, Ross PR, Elumalai K. Insecticidal and repellent activities of four indigenous medicinal plants against stored grain pests, Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae). Asian Pac J Trop Dis 2012;2(Suppl 1):S16-20.

Satti AA, Elamim MM. Insecticidal activities of two meliaceous plants against Trogoderma granarium Everts (Coleoptera: Dermentidae). Int J Sci Nat 2012;3(3):96-701.

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.

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

Sümer ERC, Baş H, Koç M, Pandir D, Öztēmiz S. Insecticidal activity of essential oil of Pranxos ferulae (Umbelliferae) against Ephesia kuehniella (Lepidoptera: Pyralidae) and Trichogramma embryophagum (Hymenoptera: Trichogrammatidae). Turk J Agric For 2013;37:719-25.

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

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.

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.

Utomo IM, Coote C, Gibson G. Field study of the repellent activity of lem-oicium-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.

Jaya, Singh P, Prakash B, Dubey NK. Insecticidal activity of Ageratum conyzoides against Sitophilus oryzae L. in stored wheat, Res Bull 2015;63:213-21.
Pandey AK, Palni UT, Tripathi NN. Repellent activity of some essential oils against three stored product beetles Callosobrachus 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.

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

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

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

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

Rajashekar Y, Ravindra KV, Baktahvatsalam 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.

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.

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.

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.

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

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

Adebisi O. Chemical composition and insecticidal activity of *Citrus aurantiifolia* 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]

Nattudurai G, Irundayaraj SS, Paulraj MG, Baskar K, Ignacimuthu S. Insecticidal and repellent activities of *Odorita asiamatica* (L.) Lam. extracts against three major stored product pests. *Entomol Ornithol Herpetol* 2015; **4**: 148.

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

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.

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.

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

Shahab-Ghayoor H, Sacidi 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.

Jeyasankar A, Chennamani 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.

Pinto JJ, Silva G, Figueroa I, Tapia M, Urbina A, Rodríguez JC, et al. Insecticidal power of essential oil and larvicidal oil of *Cryptocarya alba* (Molina) Looser against *Sitophilus zeamais* Motshwsky. *Chl J Agric Res 2016; 76**(1): 48-54.

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; **8**(1): 1-10.

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.

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.

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;*
Zahir AA, Rahuman AA, Bagavan A, Elango G, Kamaraj C.  

Elango G, Rahuman AA, Bagavan A, Kamaraj C, Zahir AA, Pandiyan Kumar S, Wahab N, Warikoo R. Bioefficacy of  

Bagavan A, Kamaraj C, Rahuman AA, Elango G, Zahir AA, Pandiyan Mello CB, Uzeda CD, Bernardino MV, Mendonça-Lopes D, Kelecom A, Fevereiro PCA, et al. Efficacy of botanical extracts against Japanese encephalitis vector, Culex tritaeniorhynchus Giles and Aphis gossypii Glover. Parasitol Res 2009; 104(5): 1109-17.  

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.  

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.  

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.  

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.  

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.  

Tedesci P, Leis M, Pezzi M, Civolani S, Maitetti 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.  

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.  

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.  

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.  

Effiom OE, Avoja 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]  

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.  

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.  

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 faliciparum. Asian Pac J Trop Dis 2012; 2: S306-11.  

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.  

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.  

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.  

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: 5553-7.  

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

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 alabacuimm branches and P. tuberculatum leaves and compounds isolated against Anopheles darlingi. Braz J Pharmacogn 2012; 22(5): 979-84.  

Murugan K, Kovendan K, Vincent S, Barnard DR. Biorlarvicidal and pupicidal activity of Acabyla alnifolia Klein ex Wild. (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.  

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.  

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.  

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.
