Plant Cell Biotechnology and Molecular Biology 21(43&44):105-124; 2020 ISSN: 0972-2025

A REVIEW ON BIODIVERSITY OF SOME MEDICINAL AND WILD PLANTS AND THEIR POSSIBLE ROLE IN VECTOR- BORNE DISEASES AND VECTOR CONTROL

ARTI PRASAD* AND SANJAY KUMAR MEENA
Laboratory of Public Health Entomology, Department of Zoology, University College of Science, Mohanlal Sukhadia University, Udaipur 313001, Rajasthan, India [AP, SKM].
[*For Correspondence: E-mail: artimlsu@yahoo.co.in]

Article Information

Editor(s):
(1) Dr. Afroz Alam, Banasthali University, India.
Reviewers:
(1) Misganaw Meragiaw, Addis Ababa University, Ethiopia.
(2) Tahany Ramzy Elias, National Research Centre, Egypt.

Received: 15 July 2020
Accepted: 21 September 2020
Published: 13 October 2020

Review Article

ABSTRACT

In the search for alternatives to conventional insecticides, plants have been widely investigated. Their toxic activities toward insects have drawn special interest during the last decade. Mosquitoes are nuisance pests and a major vector for the transmission of several life-threatening diseases. Vector and vector-borne diseases like Malaria, Chikungunya, Dengue and many more are becoming a big problem to public health these days as they have social and economic impact especially in subtropical and tropical countries. The present proliferation of these diseases is basically due to the increasing resistance of mosquitoes to current insecticides. In many parts of the world, plant-derived products have been used to repel or kill mosquitoes and other domestic insect pests. Plants may be a source of alternative agents for control of insects and parasites because they are rich in bioactive chemicals, active against a limited number of species including specific target insects or parasites, and are biodegradable. Whereas synthetic drugs and insecticides often cause widespread toxicity and harmful side effects to the end user other than targeted pathogen carrier. Therefore, After completed literature survey conclude that the uses of environment-friendly and biodegradable natural insecticides of plant origin have received renewed attention as agents for insect control and plant products are good source for provide the medicinal aspects and also for insecticides that are essential for elimination of vector and vector-borne diseases.

The present review is mainly focused on the potential of some commonly grown plants for their anti-plasmodial or insecticidal properties. These plants can be a good alternate for many vector-borne diseases if their products are properly formulated.

Keywords: Insecticidal; anti-malarial; plants; mosquitoes; plasmodium; vector -borne diseases.

INTRODUCTION

Insects can be the cause of major ecological problems. They can transmit microbes and parasites that affect humans, and damage food crops, trees, and homes. The total economic cost of insect-related damage and disease is immeasurable. Synthetic pesticides though are more effective and fast acting, repeated and indiscriminate application often leads to resistance, resulting in rebound of the vector population and its disease potential. To prevent the resistance phenomenon, there is a need for alternate compounds having different modes of action [1]. Ideally, the insecticides having different modes of action could be mixed on the assumption that they would complement the action each other for killing the target pest [2]. These new generation botanical insecticides have several ecological advantages compared to the organically synthesized insecticides. It is well known that the plant kingdom is the most efficient producer of chemical compounds (primary and secondary metabolites) having wide array of functions that are used in defence against insects and suitable for control of vector and vector-borne diseases [3].

The secondary metabolites and their constituents have received considerable attention in the search for new molecules having insecticidal activities, repellence, feeding deterrence, retardation of reproduction, growth regulation against various insect species etc [4,5]. Toxicity has also been reported against nematodes, mites, agricultural pests, fungi, virus and bacteria [6,7,8]. Plant chemicals have been demonstrated to be selective and biodegradable, which suggests environmental acceptability and compatibility in integrated pest management (IPM) programs as well as being effective in resistance management.

Worldwide, an estimated number of 3.4 billion people are still at risk of malaria. In 2012 approximately 207 million cases of malaria occurred globally with most cases (80%) and deaths (90%) occurring in Africa. Most deaths (77%) occurred in children under the age of five [9]. In other words, malaria continues to be a major cause of morbidity and mortality. It is caused by five species of parasite that affects humans. All the parasites belong to the genus *Plasmodium*: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale*, *Plasmodium malariae*, *Plasmodium knowlesi*. Of these, *Plasmodium vivax* and *Plasmodium falciparum* are the most important.

Documentation of Traditional medicines(TM) and plants traditionally used for the prophylaxis and treatment of malaria in Zimbabwe constitutes an important step not only in preserving the local traditions and indigenous knowledge but also in improving access to and participation in improving traditional malaria control interventions by the communities. Documentation of TM could facilitate future research on the safety and efficacy of medicinal plants and could provide a starting point for identifying single chemical entities with anti malarial activity which could lead to the development of standardized phytomedicines. Because the drug-resistance of *Plasmodium falciparum* and the resistance of *Anopheles* mosquitoes to insecticides are widespread, the search for new anti malarial drugs is increasingly important. Aedes species which are the primary source of dengue virus are becoming more and more widespread at global arena. Since there is no successful intervention through vaccines, use of plant products can be a strong future possible way to control dengue world over.

Medicinal plants play a major role in many communities over the world in the treatment and prevention of disease and the promotion of general health. Previous studies have shown that more than 1200 medicinal plants from 160 families are used worldwide to treat malaria or fever [10] and still many anti-malarial plant species remain to be discovered. Phytochemical? derived from various plants with proven mosquito control potential can be used as an alternative to synthetic insecticides or along with other insecticides under the integrated vector control. Plant products can be used, either as insecticides for killing larvae or adult mosquitoes for protection against mosquito bites, depending on the type of activity they possess. A Large number of plant extracts have been reported to have mosquitocidal insect growth regulator (IGR) activity against mosquito vectors but very few plant products have shown practical utility for mosquito control due to proper

formulation and commercialization. The study aimed to collect comprehensive data from traditional healers on medicinal plant-based remedies commonly used against malaria to document their methods of preparation and administration, together with information on how the healers conceptualize and diagnose malaria to contribute to the overall documentation of anti-malarial plant species.

PLANT SPECIES

Acalypha alnifolia Family Euphorbiaceae

Acalypha alnifolia is a shrub known as Cat-tail and Copper leaf found in the wild in South India (Fig.1). In Southern Kallar region, Nilgiris tribal people used this plant leaves as a smoke repellent. This plant contains phenolic, tannin and flavonoids .The adulticidal activities of leaf extracts of *A. alnifolia* were assayed for their toxicity against three important vector mosquitoes, viz., *Aedes aegypti*, *Anopheles stephensi and Culex quinquefasciatus. The adult mortality was observed after 24 h of* exposure. Extract showed moderate adulticide effects. The LC_{50} values of *A. alnifolia* leaf extracts against adulticidal activity [11].

Fig. 1.-*Acalypha alnifolia*

Souce:- From Wikipedia

Adansonia digitata Family: Malvaceae

Adansonia digitata (Baobab) is the most widespread of the *Adansonia* species (Fig. 2). Preliminary phytochemical analysis of *A. digitata* showed the presence of triterpenoids and saponins. The preliminary study indicated that *A. digitata* showed larvicidal and repellent activities against *An. stephensi* and could be used for controlling mosquitoes. Further studies are indicated to purify the active compounds from these plants for developing larvicide and repellents [12].

Fig. 2. *Adansonia digitata*

Source: - worldofsucculents.com

Ajuga bracteosa Family: Lamiaceae

Also known as bugleweed, ground pine, carpet bugle, or just bugle, is a genus of annual and perennial herbaceous flowering plants (Fig. 3) with high Anti plasmodial activities. The methanolic extract demonstrated a dose-dependent chemo-suppression during early and in established infections, along with significant (P<0.05) repository activity and have no toxic effect up to 5 g/kg weight [13]. It has some direct anti-plasmodial activity, additive to that of artemisinin in vitro and in vivo and synergistic with some other anti-malarial plants [14].

Fig. 3. *Ajuga bracteosa*

Source:- Natural medicine facts

Allium sativum L. Family: Amaryllidaceae

Allium sativum commonly known as garlic, is a species in the onion genus (Fig. 4). *A. sativum*

juice had insecticidal activity against *Delia radicum* and *Musca domestica* [15]. And larvicidal affects against *Anopheles stephensi* and *Culex quinquefasciatus* mosquitoes [16]. In addition to ovicidal and adulticidal against *Callosobruchus maculatus* [17].

Fig. 4. *Allium sativum*

Source:-https://plantingman.com/

***Andrographis paniculata* Family: Acanthaceae**

Andrographis paniculata, known in Indian subcontinent as Chirayetah and Kalmegh, is the commonly used plant in the traditional system of Unani and Ayurvedic medicines (Fig. 5). Substantial enhancement in their anti-malarial activities were observed whether used in isolation or in combination [18]. The repellent activities of crude extracts of leaf of *An. paniculata* at three different concentrations of 1.0, 2.5, and 5.0 mg/cm^2 against important vector mosquito *Aedes aegypti* the potential to be used as an ideal eco-friendly approach for the control of mosquitoes [19].

Fig. 5 *Andrographis paniculata*

Source:-chhajedgarden.com/

***Annona reticulata* L. Family: Annonaceae**

Annona reticulata is a small deciduous or semi-evergreen tree in the plant family Annonaceae (Fig. 6). It is best known for its fruit, called custard apple. The ethanol leaf extract of *A. reticulata* exhibited excellent larvicidal activity *against Cx. quinquefasciatus* and *Ae. Annona reticulata , Aegypti* mosquitoes [20]. The larvicidal activity is attributed by the mixture of compounds like saponin, terpenoids and alkaloids. However, it is required to optimize the concentration as well as to identify the novel compound with larvicidal efficacy [21].

Fig. 6. *Annona reticulate*

Source:-Tropical the ferns

***Argemone maxicana* Family: Papaveraceae**

Argemone maxicana is a native of tropical South America but now a day it is wide spread in all countries (Fig. 7). It is an annual herb with bright yellow sap. Leaves alternate, simple, with spines-tipped lobes and whitish wax that subs off, flowers with 4-6, bright yellow petals and many stamens. Insecticidal properties of Argemone (leaf and flower) were evaluated with different stages of mosquito larvae. The flower treatment is more effective during all the three hours of observations at all the dose level as compared to the leaf extract treatment. The extract of leaf and flower of *A. Maxicana* was also gives effective result on pupal stage [22].

Fig. 7. *Argemone maxicana*

Source:- Tropical the ferns

***Azadirachta indica* Family: Meliaceae**

Azadirachta indica (Neem), an herb extensively used as medicine (Fig. 8) was also tested *in vivo* against *P. berghei* following Peter's 4-day test and recorded about 70% parsitemia inhibition [23]. *A. indica* have been studied as possible mosquito repellents and have demonstrated good efficacy against some mosquito species [24, 25, and 26]. In a study on *Azadirachta indica* reported that different types of extracts (alcoholic, chloroform and Benzene) .with different parts of the plants exerted significant effect on the control of larval stages of *Aedes aegypti*.

Fig. 8. *Azadirachta indica*

Source:-Research gate

***Brucea mollis* Family: Simaroubaceae**

B.mollis is a shrubs or small trees, usually 1-2 m tall, branchlets yellow-green (Fig. 9). Crude extract from dried *B. mollis* root tested in vitro and in vivo antiplasmodial activity against *Plasmodium falciparum* and *Plasmodium yoelii* respectively. Mathenolic –aqueous extract of *B. mollis* have firstly report antiplasmodial activity in both In vivo and In vitro tests [27].

Fig. 9. *Brucea mollis*

Source:-Research gate

***Calotropis procera* Family: Apocynaceae**

Common names for the plant include apple of Sodom, Sodom apple, estabragh, kapok tree, king's crown, rubber bush, or rubber tree (Fig. 10). Leaves using *in vitro* methods. Preliminary phytochemical analysis of the extract showed the presence of phenolic compounds, flavonoids, alkaloids, tannins, saponins, glycosides and phytosterols as major phytochemical groups. The findings of a study emphasise the potentiality of *C. procera* leaves for controlling the mosquito population and their possible way in the developing the natural insecticide for the control of *Cx. tritaeniorhynchus* and *Cx. gelidus* mosquitoes [28].

Fig. 10. *Calotropis procera*

Source:-Research gate

***Capparis decidua* Family: Capparaceae**

Capparis decidua is a xerophytic popular shrub and its various plant parts and products have been used extensively for many years in food products and traditional folk medicine (Fig. 11). Plant contains toxic components, mainly volatile principles that have shown enormous insecticidal activity against a wide range of insect pests. On an average 90-95%, mortality was observed in larvae and adults of many insect species and it was found to be dose dependent. Further, *C. decidua* extracts and its constituents have shown significant repellent action in large number of insect larvae and adults, inhibited oviposition in susceptible female adults and disallow the emergence of individuals by blocking the development [29].Various solvents i.e. acetone, chloroform, petroleum ether, methanol, hexane and aqueous extracts of stem, root and flower of *C. decidua* were evaluated for insecticidal activity against the *Rhizopertha dominica* (Fabr). These have shown very high mortality i.e. 90-95% mortality and were found to be dose dependent [30].

Fig. 11. *Capparis deciduas*

Source:-en.wikipedia.org

***Cardiospermum halicacabum* Family: Sapindaceae**

Cardiospermum halicacabum, known as the balloon plant or love in a puff, is a climbing plant (Fig. 12). To determine adulticidal activity of hexane, ethyl acetate, benzene, chloroform and methanol leaf extracts of *C. halicacabum* against *Culex quinquefasciatus* (*Cx. quinquefasciatus*), *Aedes aegypti* (*Ae. aegypti*) and *Anopheles stephensi* (*An. stephensi*).

Excellent adulticidal activity ws observed from the crude extract of *C. halicacabum* was an excellent potential for controlling *Cx. quinquefasciatus*, *Ae. aegypti* and *An. Stephensi* mosquitoes [31].

Fig. 12. *Cardiospermum halicacabum*

Source:-en.wikipedia.org

***Carpolobia lutea Family*: Polygalaceae**

Carpolobia lutea, G. Don (Polygalaceae) is a medicinal plant commonly used by herbalists against dental and genitourinary infections (Fig. 13). Root and leaves extract also exhibited curative effect as demonstrated in the mean survival time of the mice in the extract and chloroquine treated group. This antiplasmodium activity of root and leaves extract of *Carpolobia lutea* due to some secondary metabolite and phytochemicals [32].

Fig. 13.*Carpolobia lutea*

Source http://www.sci-news.com/

***Catharanthus roseus* Family: Apocynaceae**

Catharanthus roseus, commonly known as the Madagascar periwinkle or rosy periwinkle (Fig. 14). Larvesidal activity against *Anopheles stephensi* L was tested. Highest larval percent was observed to be found in the flower extract of *C. roseus* L. plant with 100% mortality at 100mg/l concentration. LC_{50} value was calculated against different concentrations. It is recorded that lowest LC_{50} value was observed in the *C. roseus* L. flowers followed by leaves i.e. 37.15mg/l and 67.61mg/l respectively after 24 h of exposure time and 26.92mg/l, and 35.48mg/l, respectively, at 48 h of exposure time [33].

Fig. 14. *C. Roseus*

Source:-en.wikipedia.org

***Centrosema pubescens* Benth. Family: Fabaceae**

Centrosema pubescens, common name butterfly pea (Fig. 15). Secondary metabolites evolved in plants protect them from herbivores due to its toxicity activity. Potential larvicidal activity of CpB leaf and stem extracts was noted. All plant extracts showed moderate toxic effect on mosquito larvae after 48 hours of exposure at 10,000 ppm. Highest mortality was found in the leaf extract and results clearly indicate that the percentage of mortality being directly proportional to the concentration of the extracts. Larvicidal bioassay reveals that crude extracts possess risk to mosquito larvae at different concentrations. Leaf extract gives the higher risk to mosquito larvae [34].

Fig. 15. *Centrosema pubescens*

Source:-https://www.mozambiqueflora.com/

***Citrullus colocynthis* L. Family: Cucurbitaceae**

Citrullus colocynthis with many common names including colocynth, bitter apple, bitter cucumber, desert gourd, vine of Sodom, or wild gourd, is a desert vine plant (Fig. 16). *Citrullus colocynthis* leaf extracts have shown larvicidal, ovicidal, and repellency properties against the *Culex quinquefasciatus* mosquito [35,36]. In addition, the extract of the whole plant has been examined in different studies, and showed larvicidal activity against the early fourth instar larvae of *Anopheles stephensi* [37].

Fig. 16. *Citrullus colocynthis*

Source:- Plants of the world online

***Cryptocarya alba* Family: Lauraceae**

Cryptocarya alba, the Peumo or Chilean acorn, is an evergreen tree (Fig. 17). The insecticidal effect of the oil on the house fly *Musca domestica* was evaluated by placing flies in a sealed glass jar

containing a piece of EO-treated cotton yarn. The dose necessary to kill 50% of flies (LC50) in 0.5 and 1 h was determined at 26 ± 1 °C. The composition of the *C. alba* essential oil reported in this study is different to that reported in other publications with 4-terpineol (17.48%) ; 4- (3,3-dimethyl-but-1-ynyl) -4-hydroxy-2,6,6-trimethylcyclohex-2-enone (12.84%); 1,8-cineole (7.90%); p-cymene (7.11%) and sabinene (6.80%), accounting for 52.13% of the EO [38].

Fig. 17. ***Cryptocarya alba***

Source:-en.wikipedia.org/

***Cryptomeria japonica* Family: Cupressaceae**

Cryptomeria (literally "hidden parts") is a monotypic genus of conifer and a very large evergreen tree (Fig. 18). Natural products of plants posses insecticidal property which have been tried recently for various insect, vectors and pest control. Essential oil is extract from leaf and bark of *C. japonica* demonstrated high larvicidal activity against *Aedes aegypti* (Diptera, culicidae) larvae [39].

Fig. 18. ***Cryptomeria japonica***

Source: - https://www.vallonchene.fr/

***Curcuma longa* Family: Zingiberaceae**

Ayurveda has a vast literature [40, 41] in several Indian languages, covering various aspects of diseases, therapeutics and pharmacy. Widely used Ayurvedic compound turmeric, is a potent biological compound and curcumin, a component of turmeric isolated from rhizomes of the *C. longa* plant (Fig. 19). Curcumin inhibits chloroquine-resistant *P. falciparum* growth in culture in a dose dependent manner [42].

Fig. 19. ***Curcuma longa***

Source:-http://www.spicegarden.eu/

***Dodonaea angustifolia* Family: Sapindaceae**

Dodonaea angustifolia (Dodonaea), is an early succession shrub (Fig. 20). *D. angustifolia* contain different secondary metabolites that have antiplasmodial activity [43]. Tannins [44], alkaloids [44] and phenols [45]. Which have been suggested to be responsible for antiplasmodial activity of other plants were also detected in the seed of a *D. angustifolia*.

Fig. 20. ***Dodonaea angustifolia***

Source:- Research gate

***Gongronema latifolium* Family: Asclepiadaceae**

Gongronema. latifolium, an edible rainforest climbing plant. It is used widely as a staple vegetable and spice in tradomedicine (Fig. 21). This ethanolic leaf extract of *G. latifolium* exhibited significant antimalarial activity is consistent with the traditional use of the plant as herbal medication against the disease and indicative of its potential as a chemotherapeutic antimalarial agent [46].

Fig. 21. *Gongronema latifolium*

Source:- Research gate

***Holarrhena antidysenterica* Family: Apocynaceae**

Holarrhena antidysenterica is a typical Indian medicinal plant (Fig. 22). The anti-malarial activity of the principal steroidal alkaloid, conessine was evaluated. Conessine isolated from the bark of *H. antidysenterica* exhibited substantial anti-malarial activity with slight cytotoxic nature [47].

Fig. 22. *Holarrhena antidysenterica*

Source:- https://www.ayurtimes.com/

***Hyptis suaveolens* Family: Lamiaceae**

Hyptis suaveolens pignut or chan, is a branching pseudocereal plant (Fig. 23). Lamiaceae have traditionally been used in developing countries for their insecticidal and repellent properties against several insect species. The essential oil (EO) extracted from fresh leaves of *H. suaveolens* (Lamiaceae), and its main constituents were evaluated for larvicidal and repellent activity against the Asian tiger mosquito, *Aedes albopictus* Skuse (Diptera: Culicidae), [48].

Amongst the solvent extracts tested, acetone exhibited highest larvicidal activity and LC_{50} values was 485.61 followed by petroleum ether and chloroform extract which were 493.44 and 625.97 mg/L after 24 hours. In the case of 48 hours, petroleum ether extract (LC_{50} 298.76 mg/L) was found to exhibit highest larvicidal activity followed by acetone (LC_{50} 344.03 mg/L) and chloroform (LC_{50} 429.50 mg/L) [49].

Fig. 23. *Hyptis suaveolens*

Source:- https://sites.google.com/

***Lantana camara* L. Family: Verbenaceae**

Chick pea and tomato crops are severely infested by pest *Helicoverpa armigera* in South Rajasthan (India) (Fig. 24). When recommended doses of leaf and Flower extracts of *Lantana camara* (L.) was applied in chickpea and tomato crops respectively in a Randomised Block Design with Endosulfan as standard check, the results were interesting. Percent infestations with highest dose of 1000ml per hectare of *L. camara* (L) were 9.11 and 8.51 on weight basis and 64.58 and 14.35 on number basis for leaf and flower respectively

against 6.63 for Endosulfan. Similarly 32.35 (Weight basis) Bioeconomics again revealed that cost benefit ratio were 1:23.26 and 1:24.20 for leaf and flower of *Lantana camara*(L)respectively against 1:31.82 with Endosulfan at highest applied dose of 1000 ml /l/hectare. Similarly cost and benefit ratio of entomopathogen was 1:52.60 against 1:62.37 for Endosulfan at highest applied dose of 400 ml/l/hectare [50].

Fig. 24. *Lantana camara*

Source:-https://en.wikipedia.org/

***Laurus nobilis* L. Family: Lauraceae**

It is known as bay laurel, sweet bay, bay tree (especially in United Kingdom), true laurel, Grecian laurel, laurel tree or simply laurel (Fig. 25). The pure essential oil of *L. nobilis* has shown aphidicidial activity against *Brevicoryne brassicae*) [51]. Moreover, the essential oil of the leaves has shown fumigant toxicity against all of the life stages of *Tribolium confusum* [52] repellent potential against *Tribolium custaneum, Rhyzopertha dominica* [53].

Fig. 25. *Laurus nobilis*

Source:-https://en.wikipedia.org/

***Maesa indica* Family: Myrsinaceae**

This is a large, evergreen, glabrous shrub, with a thin, warty bark. The highest mortality (100%) was observed in acetone extracts of *M. indica* (Fig. 26). The larvicidal activity of the different selected plant extracts was found to be dose depended [54].

Fig. 26. *Maesa indica*

Source:-http://www.flowersofindia.net/

***Melaleuca alternifolia* Family: Myrtaceae**

Melaleuca alternifolia, commonly known as narrow-leaved paper bark, narrow-leaved tea-tree, narrow-leaved ti-tree, or snow-in-summer, is a species of tree or tall shrub (Fig. 27). The chemical composition of *M. alternifolia* essential oil was investigated by GC-MS analysis. Tea tree essential oil was mainly composed by oxygenated monoterpenes, with 1,8-cineole as the major constituent. *M. alternifolia* essential oil exerted toxic activity against *Aedes albopictus* larvae, with a LC_{50}=267.130 ppm [55]

Fig. 27. *Melaleuca alternifolia*

Source:-https://en.wikipedia.org/

***Mentha longifolia* Family: Lamiaceae**

Since fumigants play major role in insect pest control in storage, there is a global interest in alternative strategies including development of plant products such as essential oils and their constituents. Our observations showed that fumigant activity of *M. longifolia* oil was characterized by hyperactivity, convulsion, paralysis and quick knock down followed by death. Needless to say, that there is an urgent need for environmentally safe alternatives to conventional fumigants phosphine and methyl bromide, for the control of stored product insects [56].

Fig. 28. *Mentha longifolia*

Source:-https://en.wikipedia.org

***Moringa oleifera* Family: Moringaceae**

India is the largest producer of Moringa plants (Fig. 29). It is a fast-growing, drought-resistant tree. Leaves, flowers and seeds of *Moringa oleifera* Lam. were evaluated for their larvicidal activities against *Anopheles stephensi* (L. (Fig. 42). The obtained data indicates that phytochemical derived from *M. oleifera* Lam. seed extracts are effective mosquito vector control agent [57].

The eggs of A. *stephensi* were treated with extracts of *M. oleifera* to ee the ovicidal acting. In case of larvicidal activity as the concentration increases the percent hatching decreases and it is highly significant at CD 5%. The calculated value of F for the different dose level is significant at 0.01% significance level and at 2,42 df [58].

Fig. 29. *Moringa oleifera*

Source:-https://en.wikipedia.org

Nigella sativa Family*: *Ranunculaceae

Nigella sativa (black-caraway, also known as nigella or *kalonji*), often called black cumin, is an annual flowering plant (Fig. 30). Water extract of the Seeds of *N. sativa* reduce plasmodium parasite when it administer in *Plasmodium berghei* infected Swiss albino mice. Reductions in parasite level a0re due to the reducing level of nitric oxide (NO) and an immune mechanism. By reducing the No level it act as anti-oxidant [59].

Fig. 30. *Nigella sativa*

Source:-https://en.wikipedia.org

***Ocimum americana* Family: Lamiaceae**

It is an erect, much branched medicinal herb with striate stem (Fig. 31), leaves ellipticlanceolate, petiole hairy, and flowers in close whorls in spiciform recemes. The ovicidal action of *O.*

americana is observed during the observation that the percent hatching is very much reduced with the increase of the dose level. The pupae of the *Anopheles stephensi* were treated with the extracts for assessing pupicidal action. During the different treatments of *O. americana*, all the three i.e. time period, concentration and plant parts show very significant result. During observation at 24 hours, the flower extract proves to be more effective than that of leaf (Fig. 44) [60].

Fig. 31. *Ocimum Americana*

Source:-https://en.wikipedia.org

Ocimum basilicum L. Family: Lamiaceae

Basil, Thai basil, or sweet basil, is a common name for the culinary herb *Ocimum basilicum* (Fig. 32). The essential oil of the *Ocimum basilicum* plant has shown insecticidal activity against *Acyrthosiphon pisum*, *Myzus persicae* [61], and *Musca domestica* [62] it has also exhibited repellency against *Aedes aegypti*, *Anopheles stephensi*, *Culex quinquefasciatus* [63]. The larvicidal effect of the crude petroleum ether leaf extracts of a widely grown medicinal plant and extracts are highly toxic against mosquito larvae from a range of species; therefore, they may be useful for the management of mosquito larvae to control vector borne diseases [64].

The formulations also included the synergist, piperonyl butoxide. The plant can, therefore, serve as a substitute for some expensive synthetic insecticides which have toxic residual effects [65].

Fig. 32. *Ocimum basilicum*

Source:- https://www.gardenia.net/

***Ocimum sanctum* Family: Lamiaceae**

A widely used traditional medicinal plant *Ocimum sanctum* (Tulsi), the Queen of herbs, the legendary 'Incomparable one' of India was tested for its anti-malarial activity (Fig. 33). Leaf and root extracts of *Ocimum sanctum* have good antiplasmodium activity with 35.5% suppuration at highest dose (1000mg/ kg) level. *O. sanctum* was investigated for its activity against *P. falciparum*. When the leaf and root [66,67] extracts of *O. sanctum* was tested *In vitro* against *P. falciparum, the extracts* showed excellent result.

Fig. 33. *Ocimum sanctum*

Source:-https://en.wikipedia.org

***Parthenium hysterophorus* L. Family: Asteraceae (Compositae)**

Parthenium is worldwide in distribution (Fig. 34). The weed is found all over the area in wastelands, roadsides, unused cultivated lands etc.When the eggs were treated with the leaf and flower extract to see the ovicidal action, it is observed that in case of the leaf extract 68.66 percent egg hatching took place with the maximum dose level of 0.2 ml per 100 ml of water. In both the extracts as the concentration increases the percent hatching of eggs decreases.

Fig. 34. *Parthenium hysterophorus*

Source:- https://keys.lucidcentral.org/

***Phyllanthus emblica* Family: Phyllanthaceae**

Phyllanthus emblica, also known as *Emblica officinalis* (Fig. 35), Indian gooseberry, Malacca tree, or amla from Sanskrit amalika. The ethanol and methanol extracts of *P. emblica* were tested for phytochemical, larvicidal, oviposition-deterrent and ovicidal activities. *P. emblica* also showed excellent ovipositional deterrent and ovicidal activities. The oviposition activity index value of ethanol and methanol extracts of *P. emblica* at 500 ppm were -0.80 and -0.92, respectively [68] Promising antiplasmodial activity was found in the extracts from two plants, *P.* emblica leaf 50% inhibitory concentration (IC_{50}) 3D 7: 7.25 µg/mL (ethyl acetate extract), 3.125 µg/mL (methanol extract) [69].

Fig. 35. *Phyllanthus emblica*

Source:-https://en.wikipedia.org

***Phytolacca dodecandra* L. Family: Phytolaccaceae**

Sarcoca dodecandra, basionym *Phytolacca dodecandra* (Fig. 36), commonly known as endod, gopo berry is a trailing shrub or climber. Study was to evaluate insecticidal effect of *P. dodecandra* plant extracts against cabbage flea beetle (*Phyllotreta cruciferae)*. These plant extracts can be useful for small scale farming community to control cabbage flea beetle *P. cruciferae* [70].

Fig. 36. *Phytolacca dodecandra*

Source:-https://en.wikipedia.org)

***Picrorhiza kurrooa Family*: Polygalaceae**

Picrorhiza kurrooa is a non-timber forest products found in the Nepalese Himalayas (Fig. 37). It is commonly known as 'Kutki' in local language is found in North-East region. Roots of this plant are medically used to cure stomachache and dysentery

values of parasitaemia ranged between 17.31 to 30.02%. Oral administration of extract of *P. kurrooa* (Scrophulariaceae) to inoculated mice resulted in inhibition of *Plasmodium berghei* to significant values of 4.36 ± 2.25 [71].

Fig. 37. *Picrorhiza kurrooa*

Source:-https://www.dreamstime.com/

***Rhizophora mucronata* (Lam) *Family*: Rhizophoraceae**

Rhizophora mucronata is a mangrove plant also known as loop-root mangrove and red mangrove (Fig. 38), the ethanolic bark extract of this plant exhibited *in vitro* antiplasmodial activity at IC_{50} = 62.18 µg/ml [72]. This species is widespread and common within its range, and is the preferred species for mangrove restoration. crude extract of *R. mucronata* showed maximum larvicidal activity (LC50 value 0.0275 ± 0.0066 µg/ml and LC90 = 0.0695 ± 0.156 µg/ml) followed by the bark extract (LC50 value of 0.03 ± 0.0076 µg/ml and LC90 = 0.0915 ± 0.156 µg/ml). Column chromatographic fractions of *R. mucronata* bark extracts (E1) showed maximum larvicidal activity (LC50 = 0.0496 ± 0.0085 µg/ml and LC90 = 0.1264 ± 0.052 µg/ml) followed by the *acetone* extract (LC50 = 0.0564 ± 0.0069 µg/ml and LC90 = 0.1187 ± 0.05 µg/ml) [73]. There have been numerous reports on the mosquito larvicidal activity of terrestrial plants. Ours was the first study on mosquito larvicidal and repellent activity of marine plants (Kathiresan and Thangam 1987). Subsequently the mosquito larvicidal activity of seaweeds, *Plocamium telfairiae* and *Laurencia nipponica* was also reported by other authors [74,75 a&b].

Fig. 38. *Rhizophora mucronata*

Source:-https://alchetron.com/

***Synaptolepis alternifolia* Family**

ThymelaeaceaeSynaptolepis *alternifolia* is a shrub or woody climber with slender hairless branches (Fig. 39), growing from 0.5 - 10 metres tall. Extracts of *S. alternifolia* were screened for phytochemicals and tested for cytotoxicity and insecticidal activity. Tests indicated the presence of reducing sugars, terpenoids, flavonoids, saponins, tannins and alkaloids. Cytotoxic effects of the plant were assessed through the Brine shrimp lethality (BSL) bioassay showing a higher insecticidal activity after 48 hours of exposure to the extract. The results show a huge potential of *S. alternifolia* as an insecticide [76].

Fig. 39. *S. Alternifolia*

Source:-https://en.wikipedia.org

***Syzygium aromaticum* Family**

Myrtaceae Cloves are the aromatic flower buds of a tree. *Syzygium aromaticum* (Fig. 40) oil

exhibited 100% repellency at 5% concentration (dilution with absolute ethanol). (There was a significant difference in repellency rate between concentrations for each extract [77]. The isolation of compounds *S. aromaticum* seems to be of special interest for further antimalarial studies [78].

Fig. 40. *Syzygium aromaticum*

Source:-https://en.wikipedia.org

***Zanthoxylum zanthoxyloides* Family: Loranthaceae**

Z. zanthoxyloides is a shrub or small tree, spiny and more or less scandent, up to 6–8(–12) m tall (Fig. 41). They are considered antiseptic, analgesic and diaphoretic. Powder of *Z. zanthoxyloides* had the highest mortality effect on the weevil as it achieved 100% within 72 h at 5%(wt/wt) and its effect was significantly ($p < 0.05$) different from other powders. Powder of *Z. zanthoxyloides*, showed a reduction capacity on the emergence of the adult weevil at 20 %(wt/ wt*). Z. zanthoxyloides* prevented the damage of the seeds at 5, 10 and 20 %(wt/wt) [79,80,81,82].

Fig. 41. *Zanthoxylum zanthoxyloides*

Source:-https://en.wikipedia.org

CONCLUSIONS

The plants studied here can be seen as a potential source of useful drugs and insecticides. Several plants are used in traditional medicine for the prevention and treatment of diseases in many parts of the world. The flora of India has rich aromatic plant diversity with the potential for the development of natural insecticides for the control of mosquitoes. These studies would encourage the search for new active natural compounds offering an alternative to synthetic repellents, insecticides and antiplasmodial activities from other medicinal plants. As revealed in the present review, the screening of mosquitocidal potential by the isolation of natural products seems to be an attractive approach, which can result in the efficient elucidation of new lead compounds. Search for larvicidal active compound(s) is one of the several attempts to find effective and affordable ways to control many vectors and parasites. Thus, it will serve as useful guides in the collection of plants for laboratory and field research studies.

Native plants have further an additional advantage of low cost and easy availability. countries like India and Africa to develop their own low-cost technologies to control vast problem of vector-borne diseases.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Aydin H, Gürkan MO. The efficacy of spinosad on different strains of *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae). Turkish Journal of Biology. 2006;30:5–9.
2. Bhagavan BVK, Chandrasekhar R., Rao VP, Raju KS, Madhulety TY, Rao KV. Effect of seed corm weight, spacing and time of harvest for raising quality seed planting material of elephant foot yam. In: National Seminar on Amorphophallus: Innovative Technologies-Abstract Book and Extended Summary. Palaniswami MS,

Anil SR, Sajeev MS, Unnikrishnan M, Singh PP, Choudhury BC. (Eds.). Central Tuber Crops Research Institute, Sreekariyam, Thiruvanathapuram, Kerala, India. 2008;107

3. Croteau R, Kutcahn TM, Lewis NG. .Natural products. In Biochemistry and Molecular Biology of Plants (Buchanan, B., Gruissem, W. and Jones, R., eds). Rockville, MD: American Society of Plant Physiologists. 2000;1250–1318.
4. Rice PJ, Coats JR. Insecticidal properties of several monoterpenoids to the housefly (Diptera: Muscidae), red flour beetle (Coleoptera : Tenebrionidae) and southern corn root-worm (Coleoptera: Chrysomelidae). J. Econ. Entomol. 1994;87:1172–1179.
5. Isman MB. Plant essential oils for pest and disease management. Crop Prot. 2000;19: 603–608.
6. Prakash A, Rao J. Evaluation of plant productsas anti-feedant against the rice storage insects. Proc. Symp. Resid. And Environt. Pollutioa. 1986;201-205.
7. Prakash A, Rao J. (Botanical pesticides in agriculture.CRC Lewis Publs. Boca Raton USA. 1997;481.
8. Copping L, Menn J. Biopesticides: a review of their action, applications and efficacy. Pest Management Science. 2000;56:651-676.
9. Watanabe K, Umeda K, Kurita Y, Takayama C, Miyakado M. Two insecticidal monoterpenes, telfairine and aplysiaterpenoid A, from the red alga Plocamiurn telfairiae: Structure elucidation, biological activity, and molecular topographical consideration by a semiempirical molecular orbital study. Pestic. Biochem. Physiol. 1975;37:275-286.
WHO. Mimeographed docunzent, WHONBC175.583.
10. Willcox ML, Bodeker G. Traditional herbal medicines for malaria. Clinical Review British Medical Journal. 2004;329:1156–1159.
11. Kovendan K, Murugan K, Kumar PM, Thiyagarajan P, William SJ. Ovicidal, repellent, adulticidal and field evaluations of plant extract against dengue, malaria and filarial vectors. Parasitol Res. 2013;112: 1205–1219.
12. 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.
13. Chandel S, Bagai U. Antiplasmodial activity of *Ajuga bracteosa* against *Plasmodium berghei* infected BALB/c mice. Indian J Med Res. 2010;131:440-444.
14. Rasoanaivo P, Wright CW, Willcox ML, Gilbert B. Whole plant extracts versus single compounds for the treatment of malaria: synergy and positive interactions. Malaria Journal. 2011;10(1):S4.1475-2875.
15. Prowse GM, Galloway TS, Foggo. A Insecticidal activity of garlic juice in two dipteran pests. Agric For Entomol. 2006;8(1):1–6.
16. Singha S, Chandra G. Mosquito larvicidal activity of some common spices and vegetable waste on *Culex quinquefasciatus* and *Anopheles stephensi*. Asian Pac J Trop Med. 2011;4(4):288–93.
17. Denloye A .A Bioactivity of Powder and Extracts from Garlic, *Allium sativum* L. (Alliaceae) and Spring Onion, *Allium fistulosum* L. (Alliaceae) against *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) on Cowpea, *Vigna unguiculata* (L.) Walp (Leguminosae) Seeds. Psyche. 2010;5.
18. Mishra K, Dash AP, Swain BK, Dey N. Anti-malarial activities of *Andrographis paniculata* and *Hedyotis corymbosa* extracts and their combination with curcumin. Malaria Journal. 2009;8-26.
19. Govnidarajan M, Sivakumar R. Adulticidal and repellent properties of indigenous plant extracts against *Culex quinquefasciatus* and *Aedes aegypti* (Diptera: Culicidae). Parasitol Res. 2011;109(2):353–367.

20. Mallick S, Banerjee R, Chandra G. Mosquito larvicidal potential of ethanol leaf extract of the plant, *Annona reticulata* L. against *Aedes aegypti* L. and *Culex quinquefasciatus* Say (Diptera: Culicidae) Journal of Mosquito Research. 2015;5(19):1-7.
21. Govindarajulu B, Srimathi A, Bhuvana R, Karthikeyan J. Mosquito Larvicidal Efficacy of the Leaf Extracts of *Annona reticulata* Against *Aedes aegypti* Int.J.Curr.Microbiol.App. Sci. 2015;4(8):132-140.
22. Bhanawat S. Evaluation of some plant products for their Insecticidal and Repellent activities against Mosquitoes (Unpublished thesis). Mohan Lal Sukhadiya University, Udaipur, Rajasthan, India; 2002.
23. Devi CU, Valecha N, Atul PK, Pillai CR. Antiplasmodial effect of three medicinal plants: A preliminary study. Cur Sci. 2001;80(8):917-919.
24. Kirton LG. Laboratory and field tests of the effectiveness of the lemon-eucalyptus extract, Citridiol, as a repellent against land leeches of the genus Haemadipsa (Haemadipsidae). Ann Trop Med Parasitol. 2005;99:695-714.
25. Sharma VP, Ansar MA, Razdan RK. Mosquito repellent action of neem (*Azadirachta indica*) oil. J Am Mosq Control Assoc. 1993;9:359-60.
26. Jessinta A/P Sandanasamy, Azhari H. Nour, Abdurahman H. Nour. Neem (Azadirachta Indica): Larvicidal Properties of Extracts of Neem against Aedes aegypti Mosquitoes' Larvae Lap Lambert Academic Press; 2012.
27. Prakash A, Sharma SK, Mohapatra PK, Bhattacharjee K, Gogoi K, Gogoi P, Mahanta J, Bhattacharyya DR. In vitro and in vivo antiplasmodial activity of the root extracts of *Brucea mollis* Wall. ex Kurz. Parasitol Res 2013; 112:637–642.
28. Kumar G, Karthik L, Rao KVB, Kirthi AV, Jayaseelan C, Rahuman A .A Phytochemical composition, mosquito larvicidal, ovicidal and repellent activity of *Calotropis procera* against *Culex tritaeniorhynchus* and *Culex gelidus*. Bangladesh J Pharmacol. 2012;7:63-69.
29. Upadhyay RK. Insecticidal properties of kareel plant (*Capparis decidua*: Capparidaceae) a Desert Shrub. World Journal of Zoology. 2013;8(1):75-93.
30. Upadhyay RK, Agric J. Insecticidal potential of *Capparis decidua* to *Rhizopertha dominica* (Fabr.) (Coleoptera: Bostrichidae). Food Chem. 2006;54:9747–9751.
31. Govindarajan M. Sivakumar R. Adulticidal properties of *Cardiospermum halicacabum* plant extracts against three important vector mosquitoes European Review for Medical and Pharmacological Sciences. 2012;16(3):95-104.
32. Okokon JE, Effiong IA, Ettebong E. In vivo antimalarial activities of ethanolic crude extracts and fractions of leaf and root of *carpolobia lutea*. Pak. J. Pharm. Sci. 2011;24:57-61.
33. Prasad A, Mathur P, Shrivastava M, Kumar D, Sharma E. Larvicidal efficacy of *Catharanthus roseus* linn leaves and flowers against the malaria vector *Anopheles stephensi* liston (Insecta: Diptera: Culicidae) International Journal of Recent Scientific Research. 2014;5(9):1620-1623.
34. Mina EC. Abstracts Larvicidal potential of the crude ethanolic extracts of *centrosema pubescens* benth. Forum abstracts. 2015;109.
35. Mullai K, Jebanesan. A Larvicidal, ovicidal and repellent activities of the leaf extract of two cucurbitacious plants against filarial vector *Culex quinquefasciatus* (Say) (Diptera: Culicidae). Trop Biomed. 2007;24(1):1–6.
36. Rahuman AA, Venkatesan P. Larvicidal efficacy of five cucurbitaceous plant leaf extracts against mosquito species. Parasitol Res. 2008;103(1):133–9.
37. Arivoli S, Ravindran KJ, Tennyson S. Larvicidal efficacy of plant extracts against the malarial vector *Anopheles stephensi* Liston (Diptera: CulicidaeWorld Journal of Medical Sciences. 2012;7(2):77-80.
38. Cosmo DD, Santander R, Urzúa A, Palacios MS, Rossi Y. Insecticidal effect of

Cryptocarya alba essential oil on the housefly, *Musca domestica* L. Efecto insecticida del aceite esencial de Cryptocarya alba en la *mosca doméstica*, *Musca domestica* L.] . Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas. 2015;14(2):113–117.

39. Das NG, Goswami D, Rabha B. Preliminary evaluation of mosquito larvicidal efficacy of plant exterects. J vect borne Dis. 2007;44:145-148.
40. Sharma S. Realms of Ayurveda. Arnold-Heinemann, New Delhi; 1979.
41. Dev S. Ethnotherapeutics and modern drug development: the potential of Ayurveda. Current Science. 1997;73:909–928.
42. Reddy RC, Vatsala PG, Keshamouni VG, Padmanaban G, Rangarajan PN. Curcumin for malaria therapy. Biochem Biophys Res Commun. 2005;14:326(2):472–474.
43. Abdulelah HAA, Zainal-Abidin. BAH In vivo Antimalarial tests of *Nigella sativa* (BlackSeed) different extracts. Amer. J. Pharmacol. Toxicol. 2007;2(2):46–50.
44. Saxena S, Pant N, Jain DC, Bhakuni RS. Antimalarial agents from plant sources. Current Sc. 2003;85(9):1314-1329.
45. Hilou H, Nacoulma OG, Guiguemde TR. In vitro antimalarial activity of extracts of *Amaranthus spinosus L.* and *Boerhaavia erecta L.* in mice. J Ethnophramcol. 2006;103:235-40.
46. Akuodor GC, Idris-Usman M, Anyalewechi N, Odo E, Ugwu CT, Akpan JL, Gwotmut MD, Osunkwo UA. In vivo antimalarial activity of ethanolic leaf extract of *verbena hastata* against *Plasmodium berghei berghei* in mice. J. of Herbal Med. and Toxicology. 2010;4(2):17-23.
47. Dua VK, Verma V, Singh B, Rajan A, Bagai U, Agarwal DD, Gupta NC, Kumar S, Rastogi. A Anti-malarial property of steroidal alkaloid conessine isolated from the bark of *Holarrhena antidysenterica*. Malaria Journal. 2013;12:194.
48. Conti B, Benelli G, Flamini G, Cioni LP, Profeti R, Ceccarini L, Macchia M, Canale. A Larvicidal and repellent activity of *Hyptis suaveolens* (Lamiaceae) essential oil against the mosquito *Aedes albopictus* Skuse (Diptera: Culicidae) Parasitol Res. 2012;110:2013–2021.
49. Sakthivadivel M, Gunasekaran P, Sivakumar M, Arivoli S, Raveen R, Tennyson S. Mosquito larvicidal activity of *Hyptis suaveolens* (L.) Poit (Lamiaceae) aerial extracts against the filarial vector *Culex quinquefasciatus* Say (Diptera: Culicidae). Journal of Medicinal Plants Studies. 2015;3(4):1-5.
50. Prasad A, Purohit S. Field study for the bioefficacy and economics of herbal-*Lantana Camara* (L.) And Fungal-*Beauveria Bassiana* (Balsamo), Biopesticides against *Helicoverpa Armigera* (Hubner) In South Rajasthan (India). A thesis submitted to Mohan Lal Sukhadia University, Udaipur, Rajasthan; 2003.
51. Işik M, Görür G. Aphidicidial activity of seven essential oils against the cabbage aphid, Brevicoryne brassicae L. (Hemiptera: Aphididae). Munis Entomol Zool. 2009;4(2):424–31.
52. Isikber AA, Alma MH, Kanat M, Karci A. Fumigant toxicity of essential oils from Laurus nobilis and Rosmarinus officinalis against all life stages of Tribolium confusum. Phytoparasitica. 2006;34(2):167–77.
53. 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. 2012;48:97–104.
54. Shivakumar MS, Srinivasan R, Natarajan D. (larvicidal potential of some indian medicinal plant extracts against *Aedes aegypti* (l.). Asian J Pharm Clin Res. 2013;6(3):77-80.
55. Conti B, Flamini G, Cioni PL, Ceccarini L, Macchia M, Benelli G. Mosquitocidal essential oils: are they safe against non-target aquatic organisms? Parasitol Res. 2014;113:251–259.
56. Saeidi M, Moharramipour S. Insecticidal and repellent activities of *Artemisia khorassanica*, *Rosmarinus officinalis* and *Mentha longifolia* essential oils on

Tribolium confusum. J. Crop Prot. 2013;2(1):23-31.
57. Prasad A, Sharma E. Phytotoxicological assessment of *Moringa oleifera* Lam. against larvae of important human malaria vector Anopheles *stephensi* Liston (Insecta:Diptera:Culicidae). International Journal of Innovation and Applied Studies. 2014;7:1633-1641.
58. Bhanawat S. Evaluation of some plant products for their Insecticidal and Repellent activities against Mosquitoes (Unpublished thesis). Mohan Lal Sukhadiya University, Udaipur, Rajasthan, India; 2002.
59. Sosiawan TI, Linda W, Etty W. Anti-malaria study of *Nigella sativa* L. seed water extract in *Mus musculus* Mice Balb C Strain In Vivo. Makara Journal of Science. 2012;16(3):192-196.
60. Parsad, Bhanawat S. Evaluation of some plant products for their insecticidal and repellent activities against mosquitoes (Unpublished thesis). Mohan Lal Sukhadiya University, Udaipur, Rajasthan, India; 2002.
61. Digilio MC, Mancini E, Voto E, De Feo V. Insecticide activity of Mediterranean essential oils. J Plant Interact. 2008;3(1):17–23.
62. Pavela R. Insecticidal properties of several essential oils on the house fly (*Musca domestica* L.). Phytother Res. 2008;22(2):274–8.
63. Amer A, Mehlhorn H. Repellency effect of forty-one essential oils against Aedes, Anopheles, and Culex mosquitoes. Parasitol Res. 2006;99(4):478–90.
64. Maurya P, Sharma P, Mohan L, Batabyal L, Srivastava CN. Evaluation of the toxicity of different phytoextracts of *Ocimum basilicum* against *Anopheles stephensi* and *Culex quinquefasciatus* Prejwltta. Journal of Asia-Pacific Entomology. 2009;12:113–115.
65. Umerie SC, Anaso HU, Anyasoro LJC. Insecticidal potentials of *Ocimum basilicum* leaf-extract. Bioresource Technology. 1998;64(3):237–239.
66. Venkatesalu V, Gopalan N, Pillai CR, Singh V, Chandrasekaran M, Senthilkumar A, Chandramouli. N *In vitro* anti-plasmodial activity of some traditionally used medicinal plants against *Plasmodium falciparum*. Parasitol Res. 2012;111(1):497-501.
67. Murugan K, Madhiyazhagan P, Nareshkumar A, Nataraj T, Dinesh D, Hwang JS, Nicoletti M. Mosquitocidal and water purification properties of *Ocimum sanctum* and *Phyllanthus emblica*. Journal of Entomological and Acarological Research. 2012;44:e17.
68. Murugan K, Madhiyazhagan P, Nareshkumar A, Nataraj T, Dinesh D, Hwang JS, Nicoletti M. Mosquitocidal and water purification properties of *Ocimum sanctum* and *Phyllanthus emblica*. Journal of Entomological and Acarological Research. 2012;44:e17.
69. Bagavan A, Rahuman AA, Kaushik NK, Sahal D. *In vitro* anti-malarial activity of medicinal plant extracts against *Plasmodium falciparum*. Asokan Parasitol Res. 2011b;108:15–22.
70. Raja N, Masresha G, Jemberie W. Insecticidal activity of *Phytolacca dodecandra* L. Herit (Phytolaccaceae) plant extracts against cabbage flea beetle *Phyllotreta cruciferae* Goeze (Coleoptera: Chrysomilidae) American-Eurasian Journal of Scientific Research. 2015;10(5):325-331.
71. Singh V, Banyal HS. Antimalarial Effects of *Picrorhiza kurrooa* Royle Ex Benth Extracts on *Plasmodium berghei*. Asian j. exp. biol. Sci. 2011;2(3):529-532.
72. Ravikumar S, Inbaneson SJ, Suganthi P, Gnanadesigan M. *In vitro* antiplasmodial activity of ethanolic extracts of mangrove plants from South East coast of India against chloroquine-sensitive *Plasmodium falciparum*. Parasitol Res. 2011;108:873–878.
73. Ravikumar S, Inbaneson SJ, Suganthi P, Gnanadesigan M. *In vitro* antiplasmodial activity of ethanolic extracts of mangrove plants from South East coast of India against chloroquine-sensitive *Plasmodium*

falciparum. Parasitol Res. 2011;108:873–878.

74. Watanabe K, Miyakado M, Ohono N, Okada A, Yanagi K, Moriguchi K. A polyhalogenated insecticidal monoterpene from the red alga, Plocamitrm telfairiae. Phytocl~enzistry. 1989b;28:77-78.
75. Watanabe K, Umeda K, Kurita Y, Takayama C, Miyakado M. Two insecticidal monoterpenes, telfairine and aplysiaterpenoid A, from the red alga Plocamiurn telfairiae: Structure elucidation, biological activity, and molecular topographical consideration by a semiempirical molecular orbital study. Pestic. Biochem. Physiol. 1975;37:275-286. WHO, Mimeographed docunzent, WHONBC175.583.
76. Mungenge C, Zimudzi C, Zimba M, Nhiwatiwa T. Phytochemical screening, cytotoxicity and insecticidal activity of the fish poison plant *Synaptolepis alternifolia* Oliv. (Thymelaeaceae). Journal of Pharmacognosy and Phytochemistry. 2014;2(5):15-19.
77. Hanifah AL, Ming HT, Narainasamy VV, Yusoff AT. Laboratory evaluation of six crude plant extracts as repellents against larval *Leptotrombidium deliense* (Acari: Trombiculidae). Asian Pacific Journal of Tropical Biomedicine. 2012;S257-S259.
78. Bagavan A, Rahuman AA, Kaushik NK, Sahal D. *.In vitro* anti-malarial activity of medicinal plant extracts against *Plasmodium falciparum*. Asokan Parasitol Res. 2011b;108:15–22.
79. Akinneye JO, Ogungbite OH. Insecticidal activities of some medicinal plants against *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae) on stored maize. Archives of Phytopathology and Plant Protection. 2013;46(10):1206–1213.
80. Elujoba AA, Nagels. Chromatographic isolation and estimation of Zanthoxylol: an antisickling agent from the roots of Zanthoxylum species. J Pharm Biomed Anal. 1985;3(5):447–451.
81. Wongo LE. Biological activity of Sorghum tannin extracts on the stored grain pests *Sitophilus oryzae* (Linnaeus), *Sitotroga cerealella* (Olivier) and *Tribolium castaneum* (Herbst). Insect Sci Appl. 1998;18:17–23.
82. Udo IO. Potentials of *Zanthoxylum xanthoxyloides* Lam. (Rutaceae) for the control of stored product insect pests. J Stored Prod Postharvest Res. 2011;2(3):40–44.