Research Article

Larvicidal Activities of Leaf Extracts of *Adansonia digitata* L. (Malvales: Malvaceae) and *Ficus sur* Forssk (Rosales: Moraceae) against *Culex quinquefasciatus* Mosquito (Diptera: Culicidae)

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Abstract Due to the ineffectiveness of synthetic insecticides for sustainable control of Mosquito vectors, whose transmitted diseases are the major causes of morbidity and mortality in the world today, attention has been directed towards insecticide formulations of plant origin. This study was, therefore, carried out to evaluate the larvicidal potential of the methanolic and n-hexane crude extracts of leaves of *Adansonia digitata* and *Ficus sur* against fourth larval instar of *Culex quinquefasciatus* mosquito. The leaves of the plants were collected from Minna, Nigeria, pulvrisered, extracted and evaporated using Soxhlet apparatus, with methanol and n-hexane as solvents of extraction. The crude extracts of the leaves were screened for phytochemical constituents following standard methods. The larvae were obtained from a Laboratory colony of mosquitoes raised following standard protocols. Test concentrations of 0.0125, 0.025, and 0.05 mg/L of n-hexane and 0.1, 0.25 and 0.5 mg/L of the methanolic extracts were prepared and tested for larvicidal activities against the mosquito following the WHO standard protocols. Larval Mortality was recorded after 24 hours of exposure and mean mortalities computed. Lethal concentration values (LC50 and LC90) of the extracts were determined using Probit regression analysis. Phytochemical screening revealed the presence of Flavonoids, Tannin, Saponin, Alkaloids, Steroids, Terpenoid, Cardiac glycosides and Anthraquinone, whose presence were solvent- and plant-species-dependent. There were significant differences in the recorded mortalities between the various concentrations of each extracts, the solvents types and plant species. The n-hexane extracts of both plants showed significantly higher larvicidal efficacy against the larvae than their methanolic counterpart. While the n-hexane extract of *A. digitata* was more potent than its *F. sur* counterpart, the latter’s methanolic extract was more potent than the former. The median (LC50) and upper (LC90) Lethal concentration of methanolic and n-hexane crude extracts of *A. digitata* leaf were 0.15 and 0.008 mg/L, and 1.21 and 0.22 mg/L, respectively, while these values for methanolic and n-hexane crude extracts of *F. sur* were 0.13 and 0.015 mg/L, and 2.64 and 0.15 mg/L, respectively. The plants extracts also elicited dose dependent mortality. The findings of this study suggest that *A. digitata* and *F. sur* are promising sources of botanical lead agents in the development of sustainable potent larvicides, for integrated control programmes against mosquito-borne diseases.

Keywords Bio-assay; Botanicals; Lethal Concentration; Methanol; n-hexane; Phytochemicals

Background

In most developing countries of the tropical and subtropical regions of the world, mosquitoes constitute foremost vectors of several debilitating diseases affecting humans and domestic animals (Reuda, 2008; Olayemi et al., 2014a). These diseases have not only caused very high level of morbidity and mortality, but also loss of manpower, man-hours and economic loss (Omalu et al., 2012; Olayemi et al., 2014b). *Culex quinquefasciatus* mosquitoes, belonging to one of the disease transmitting mosquito genera, is among the most abundant mosquitoes in Africa (Adeleke et al., 2008) and a major vector of lymphatic filariasis; a disease responsible for deaths of millions of people every year in developing countries (James, 1992; Ukubuiwe et al., 2013).
Mosquito vector control for the reduction of diseases transmitted has been principally through a single approach, the use of synthetic insecticides. This strategy, though, effective in reducing the burdens of mosquito-borne diseases, its successes are often not sustainable, as it is associated with a number of environmental, ecological, entomological, and economic short-comings. Some of these include cases of resurgence and resistance in target species (Tikar et al., 2008), disruption of the ecosystem (Tehri and Singh, 2015), destruction of non-target beneficial fauna and biomagnification of active ingredients (Ghosh et al., 2012), and some attendant human health concerns (Olayemi et al., 2011).

These and other pitfalls have compelled Scientists to advocate for a refocus on Botanicals, in Integrated Mosquito Management (IMM) protocols. This is predicated on the fact that plants have co-evolved with insects, and, overtime, have been equipped with a superfluity of chemical defences (secondary metabolites) such as alkaloids, terpenoids, essential oils, steroids, phenols, saponins, glycosides and tannins (Pratheeaba et al., 2015), which constitute some of the defence line system against predatory insects and herbivore (Shaalan et al., 2010; Remia and Logaswamy, 2009; Rattan, 2010). These compounds are known to play vital roles in the physiology of plant (Katie and Thorington, 2006; Arivoli et al., 2012). Furthermore, these bioactive compounds have been used in local medicine (Gonzalez et al., 2002; Svobodová et al., 2003; Akinpelu and Onakoya, 2006; Ehlimwenna and Osagie, 2007; Egunyomi et al., 2009; Friedman, 2007; Yisa, 2009; Manner et al., 2013) and against micro-organisms of medical importance (Cazarolli et al., 2008; Oyeleke et al., 2008; Abalaka et al., 2011; Cushnie and Lamb, 2011; Arun et al., 2012).

With these bioactive chemicals, significant reduction in chances of development of resistance by pests has been reported, as the substances strongly act on both behavioural and physiological processes of insects (Ghosh et al., 2012). They are also relatively cheap, readily available and affordable (Kumar and Maneemegalai, 2008), non-toxic to mammals (Sukthtankar et al., 2014), biodegradable (Gomathi et al., 2014) and more environmentally friendly (Kamaraj et al., 2011). To this end, many herbal products have been evaluated and used as natural insecticides (De Caluwé et al., 2009; Zewdneh et al., 2011), even before the discovery of synthetic insecticides (Shahi et al., 2010). In addition, to constituting potent sources of oviposition deterrents, attractants, repellents, anti-feedants, and anti-moulting hormones (Prabu, 2011; Meenakshi and Jayaprakash, 2014); botanicals also act as larvicides (Chocho et al., 2009; Olayemi et al., 2014b), growth inhibitors and juvenile hormone mimics (Olayemi et al., 2013).

The potency of plant extracts depends on plant species (Das et al., 2007; Kishore et al., 2011; Shooshtaari et al., 2012), plant part used (Arivoli et al., 2012; Kazembe and Chaibya, 2012; Amrutha et al., 2013), age of plant parts (Breem et al., 2009; Pushpalatha et al., 2014) mosquito species targeted or used as model (Kamaraj et al., 2011; Zewdneh et al., 2011), geographical varieties of the plant or insect species (Singh and Mittal, 2013; Tyagi et al., 2013), extraction procedure (Bagavan and Rahuman, 2010; Maragathavalli et al., 2012) and the polarity of solvents of extraction (Tennyson et al., 2012; Shivakumar et al., 2013; Malik et al., 2014).

In Africa, **Adansonia digitata** (Baobab) (Malvaceae), a large iconic indigenous tree, is symbolic, culturally important and physically majestic sub-tropical tree (Wickens and Lowe, 2008). In the past decades, it has attracted the interest of several pharmaceutical companies and researchers due to its medicinal, nutritional and cosmetic usages (Codjia, 2001). Almost all parts of the tree are used in traditional medicine in Africa as a panacea for disease, but specific documented uses include the treatment of malaria fever and tuberculosis (Nguta et al., 2010), microbial infections (Sidibe and Williams, 2002), diarrhoea (Shukla et al., 2001), anaemia, dysentery, toothache, and internal pains, diseases of the urinary tract, otitis, and arthritis (Wickens and Lowe, 2008), as a tonic and for insect bites and Guinea worms, against excessive sweating and as a stringent (De Caluwé et al., 2009) and as an insect repellent (Denloye et al., 2006).

Also, **Ficus sur** Forssk belonging to the family Moraceae, is a medium size tree, which grows cylindrically up to 6-9 metres with brown bark with small scales (Keay, 1989). **Ficus sur** is used to treat diarrhoea, epilepsy and anaemia as well as sexually transmitted diseases (Adeshina et al., 2010). Methanolic extracts from the roots has
been reported effective against chloroquine-resistant malaria (Lansky and Paavilainen, 2011). Previous phytochemical screening of some species belonging to the genus *Ficus* have led to the isolation of tannins and saponins (Stary, 1998).

However, despite the confirmed significant medicinal and insecticidal activities of these plants species, there is a dearth of information on their mosquito larvicidal potentials. This study, was, therefore, carried out to elucidate the mosquito-larvicidal activities of *A. digitata* and *F. sur*, using *Cx. quinquefasciatus* as model vector.

1 Materials and Methods

1.1 Collection and processing of plant materials

Fresh leaves of *A. digitata* and *F. sur* were collected from a suburb of Minna metropolis (Lat. 9° 27’ N and Long. 6° 33´ E) in North Central Nigeria. The leaves were authenticated by a Botanist in the Department of Biological Sciences, Federal University of Technology (FUT), Minna, Nigeria; where voucher specimens were deposited in the Herbarium. The leaves were air-dried in the Laboratory at room temperature (28.00± 2.00°C) for a period of two weeks. The dried leaves were pulverised using a milling machine (Model no: QASA QLB – 20L40).

1.2 Extraction process

Methanolic and n-hexane crude extracts of the leaves were prepared using Soxhlet’s apparatus, following the methods of Koyel (2011). This involved 50 g of the milled plant material wrapped in a filter paper. The weighed powdered leaves were placed in the extracting flask of the Soxhlet’s apparatus, after which 300ml of the solvent was poured into the round bottom flask of the setup, with the extracting chamber attached to the condenser, and the temperature set at 60°C and 30°C for methanol and n-hexane, respectively. Subsequently, the leaves were changed after exhaustive extraction, and the whole process was repeated until sufficient crude extract of the leaves were obtained. The crude extracts were dried in a rotary evaporator and preserved in a refrigerator at 4°C before use.

1.3 Source and maintenance of mosquito larvae

The *Cx. quinquefasciatus* mosquitoes used for this experiment came from a colony maintained in the Laboratory of the Department of Biological Sciences, FUT, and Minna. The mosquitoes were maintained following standard protocols (Ukubuiwe et al., 2012).

1.4 Phytochemical screening of plant extracts

Phytochemical screening of the plant extracts was carried out using the methods described by Sofowara (1993) and Harborne (1998).

1.5 Preparation of stock and working solutions of extracts

Stock solutions of the plant extracts were prepared according to World Health Organisation (WHO) protocols (WHO, 2005) with slight modification. Briefly, for stock solution of methanolic extracts of the plants, 5 g of the extracts were dissolved in 50 ml of methanol while that of n-hexane had 1 g of the extract in 10 mls of solvent. Working solution was, thereafter, prepared by adding 1 ml of stock solution to 99 mls of distilled water. Test concentrations of 0.0125, 0.025 and 0.05 mg/L and 0.1, 0.25, and 0.5 mg/L, respectively, of the n-hexane and methanolic extracts were prepared by respectively adding 0.125, 0.25, 0.5, 1, 2.5, and 5 ml of working solution to 99.875, 99.75, 99.95, 99, 97.5, and 95 ml of distilled water.

1.6 Bioassay of plant extracts against Fourth instar larvae of *Culex quinquefasciatus*

The mosquitoes were exposed to the extracts following standard World Health Organisation’s Protocols for testing the efficacy of insecticides (WHO, 2005), with slight modifications. For the methanolic extracts, batches of 4th instar larvae of *Cx. quinquefasciatus* were separately exposed to 0.10, 0.30, and 0.50 mg/L of the extracts in 250 ml capacity bowls. There were two Controls namely, positive and negative, containing 1% methanol-distilled water, and only distilled water (i.e., neither extract nor solvent), respectively. Each test concentration and Controls had five replicates. The n-hexane extract bio-assay had the same set-up as the methanolic extract counterpart, except that the test concentrations were 0.0125, 0.025 and 0.05 mg/L, and the positive control was 1%
n-hexane-distilled water. The experiments were maintained in the Laboratory at ambient conditions of 28.00±1.00°C, 70.20±2.63 % RH, and 12:12 hours (L: D). The larvae were monitored and mortality recorded after post-24 hours of exposure.

1.7 Statistical analysis
The effects of extracts concentrations on larval mortality were subjected to Analysis of Variance (ANOVA), and differences in means were separated using Duncan Multiple Range Test (DMRT) at p = 0.05 level of significance, using the Statistical Packages for Social Sciences (SPSS), 16.0. The larval mortality data were subjected to Probit analysis for calculating LC$_{50}$, and LC$_{90}$ (Finney, 1971).

2 Results

2.1 Phytochemical components of Adansonia digitata and Ficus sur
The phytochemical components of methanolic and n-hexane leaf extracts of A. digitata and F. sur are shown in Table 1. It revealed the presence of bioactive components in all extracts. These components include Flavonoid, Tannins, Saponnin, Alkaloids, Steroid, Cardiac glycosides, and Anthraquinones. However, there was disparity in their presence in the two different solvent extracts of a plant, as well as between plant species. While Flavonoid, Cardiac glycosides and steroids were present in all four plant extracts, Tannins and Anthraquinones were present in all extracts except n-hexane extract of F. sur and methanolic extract of F. sur respectively. Terpenoid was conspicuously absent in all plant extracts except n-hexane extract of A. digitata, while, Saponnin and Alkaloids were found, exclusively, in methanolic and n-hexane extracts of the plants species, respectively.

There was a comparative difference in the presence of phytochemicals between the solvent type and species’ extracts of the plants; as five (5) and seven (7) phytochemical constituents were present in methanolic and n-hexane extracts of the leaves of A. digitata, respectively, while those of F. sur were six (6) and five (5), respectively (Table 1).

Table 1 Qualitative Phytochemical constituents of Adansonia digitata and Ficus sur leaf extracts, from Minna, Niger State, Nigeria

| Phytochemicals          | A. digitata | F. sur |
|-------------------------|-------------|--------|
|                         | Solvent of Extraction | Solvent of Extraction |
|                         | Methanol     | n-hexane | Methanol     | n-hexane |
| Flavonoids              | +            | +        | +            | +        |
| Tannins                 | +            | +        | +            | -        |
| Saponnin                | +            | -        | +            | -        |
| Alkaloids               | -            | +        | -            | +        |
| Steroids                | +            | +        | +            | +        |
| Terpenoid               | -            | +        | -            | -        |
| Cardiac glycosides      | +            | +        | +            | +        |
| Anthraquinones          | -            | +        | +            | +        |
| Aggregate               | 5            | 7        | 6            | 5        |

Note: Key: + = present, - = absent

2.2 Larvicidal activities of extracts of against Cx. quinquefasciatus
The leaf extracts of A. digitata and F. sur demonstrated significant (p<0.05) toxicity against 4th instar larvae of Cx. quinquefasciatus under Laboratory conditions (Table 2). Though, both the methanolic and n-hexane extracts of the plants achieved 100% mortality against the mosquitoes, the later were considerably more toxic than the former, even, at very low concentrations. While, it took 0.5 mg/L to achieve 100% larval mortality in the methanolic leaf extracts of both plant species, similar results were attained with one-tenth (i.e., 0.05 mg/L) of that concentration in the n-hexane extracts.

Characteristically, the toxicity of the extracts was concentration- and plant species-dependent. Although, n-hexane extracts of both plant types produced the highest mortality (100.00%) at 0.05 mg/L, those of A. digitata were significantly (p<0.05) and consistently more toxic than the F. sur counterparts at the lower concentrations of
0.0125 and 0.025 mg/L. The reverse was, however, the case with methanolic extracts of the plant species, where *F. sur* was significantly (p<0.05) more toxic than *A. digitata* at lower concentrations of 0.1 and 0.25 mg/L, although, both extracts elicited absolute mortality (100.00%) at 0.5 mg/L.

Table 2 Larvicidal effects (%) of Methanolic and n-hexane leaf-extracts of *Adansonia digitata* and *Ficus sur* against 4\textsuperscript{th} instar larvae of *Culex quinquefasciatus* mosquito

| Extract Concentration (mg/L) | *A. digitata* Mortality (%) due to Solvent of Extraction | *F. sur* Mortality (%) due to Solvent of Extraction |
|-----------------------------|--------------------------------------------------------|--------------------------------------------------|
|                             | Methanol | n-hexane | Methanol | n-hexane |
| 0.0125                      | -        | 75.00±0.83\textsuperscript{b} | -        | 45.00±5.76\textsuperscript{a} |
| 0.025                       | -        | 86.00±1.33\textsuperscript{b} | -        | 68.30±2.86\textsuperscript{a} |
| 0.05                        | -        | 100.00±0.00\textsuperscript{a} | -        | 100.00±0.00\textsuperscript{a} |
| 0.1                         | 23.33±3.03\textsuperscript{a} \textsuperscript{***} | -        | 46.70±4.06\textsuperscript{b} | - |
| 0.25                        | 65.00±6.30\textsuperscript{a} | -        | 91.70±1.00\textsuperscript{b} | - |
| 0.5                         | 100.00±0.00\textsuperscript{a} | -        | 100.00±0.00\textsuperscript{a} | - |
| Negative Control            | 0.00±0.00\textsuperscript{a} | 0.00±0.00\textsuperscript{a} | 0.00±0.00\textsuperscript{a} | 0.00±0.00\textsuperscript{a} |
| Positive Control            | 0.00±0.00\textsuperscript{a} | 0.00±0.00\textsuperscript{a} | 0.00±0.00\textsuperscript{a} | 0.00±0.00\textsuperscript{a} |

Note: \textsuperscript{a}Not Applicable; \textsuperscript{b}Values followed by same superscript alphabets, in a column within an extract type are not significantly different at p>0.05; \textsuperscript{***}Values followed by same subscript alphabets, in a row for the same solvent type are not significantly different at p>0.05; Values are represented by percentage ± standard error of mean of four replicates.

Generally, among all extract types of both plant species, the lethal concentrations (LC) of n-hexane extracts against the larvae were lower than those of the methanol extracts. Between the methanolic extracts, *F. sur* had considerably lower LC\textsubscript{50}, and the reverse was the case for LC\textsubscript{90} values. While, between n-hexane extracts, *A. digitata* had the lower LC\textsubscript{50}, while the reverse was for LC\textsubscript{90}. The LC\textsubscript{50} and LC\textsubscript{90} of the methanolic extracts of *A. digitata* and *F. sur* were, respectively, 0.15 and 1.21 mg/L, and 0.13 and 2.64 mg/L. While those of n-hexane extracts of *A. digitata* and *F. sur*, were respectively, 0.008 and 0.22 mg/L, and 0.015 and 0.15 mg/L, respectively (Table 3).

Table 3 Lethal concentrations (mg/L) of leaf-extracts of *Adansonia digitata* and *Ficus sur* against 4\textsuperscript{th} instar larvae of *Culex quinquefasciatus* mosquitoes

| Plant Species | Solvents | LC\textsubscript{50} | LC\textsubscript{90} | R\textsuperscript{2} | Regression equation |
|---------------|----------|----------------------|----------------------|----------------------|----------------------|
| *A. digitata* | Methanol | 0.15                 | 1.21                 | 0.9379               | Y=2.7667x +10.803 |
|               | n-hexane | 0.008                | 0.22                 | 0.9999               | Y=4.3772x +8.6322 |
| *F. sur*      | Methanol | 0.13                 | 2.64                 | 0.7231               | Y=3.0395x +7.7207 |
|               | n-hexane | 0.015                | 0.15                 | 0.9196               | Y=4.1x +12.45 |

3 Discussion

Plant serves as a reservoir of metabolically active substances that can be harnessed in the production of insecticidal lead agents (Vasudevan et al., 2009). The results of this study showed presence of such inherent bio-active phytochemicals in leaf extracts of *A. digitata* and *Ficus sur*. The phytochemical constituents detected in the leaves of these plants namely Flavanoids, Tannin, Saponin, Alkaloids, Steroids, Terpenoid, Cardiac glycosides and Anthraquinone, have been demonstrated to have larvicidal activities against mosquitoes (Kamalakannan et al., 2015), and further expands the toxico-physiological scope of the plants. There was variation in the presence or absence of phytochemical constituents among the plant and solvent types; this could be responsible for the differential larvicidal activities of the extracts of these plants, as earlier observed by Olayemi et al. (2013).

In the present study, irrespective of plant source, n-hexane extracts were more effective as larvicidal agents against *Cx. quinquefasciatus* than methanolic extracts as they elicited relatively higher mortality than their methanolic counterparts. This could be due to the presence of Alkaloids, present only in the n-hexane extracts, which have been reported to possess enormous insecticidal potentials (Quevedo et al., 2011). Between the...
The presence of bioactive components could be responsible for the activities of the extracts of *A. digitata* and *F. sur* as larvicides, as shown in this study. Bioactivity of *A. digitata* as an insecticide and as a repellent, against *Anopheles gambiae* and *Musca domestica* has been reported earlier (Denloye et al., 2006). Further, larvicidal activity of its crude extracts from different solvents (benzene, chloroform, hexane and methanol) has been reported and showed increased mortality with increasing concentration (Klempner and Unnasch, 2007). These agree with the bioactivity of the plant in the present study.

Generally, the extracts, though effective, their activities were dose-, solvent-, and plant species- dependent. Though, the tendency of n-hexane extracts been more biologically effective has been reported in previous studies (Ghosh et al., 2012). The LC$_{50}$ of both extracts of *A. digitata* in this study were much lower than that of methanolic leaf extract of another member of the family, Malvaceae, *Pavonia zeylanica* (22.14 mg/L) (Vahitha et al., 2002), while that of *F. sur* was lower than that of petroleum ether leaf extract of *Cannabis sativa* (3.77 mg/L), a member of the same family, Moraceae (Maurya et al., 2007).

The LC$_{50}$ and LC$_{90}$ values reported in this study for methanolic extracts of the leaf of the plants in the present study were lower than that reported for methanolic extracts of *Azadirachta indica* Momordica charantia, *Trichosanthes anguina, Luffa acutangula, Benincasa cerifera, Citrullus vulgaris* and *Vitex negundo* (Prabakar and Jebanesan, 2004). They were, also, lower than those reported for *V. trifolia, V. peduncularis,* and *V. altissima* (Krishnan et al., 2007), *Pavonia zeylanica* and *Acacia ferruginea* (Vahitha et al., 2002), *Coccinia indica* and *Cucumus sativus*, (Rahuman and Venkatesan, 2008). Further, the LC$_{50}$ and LC$_{90}$ of n-Hexane leaf extracts were lower than that reported for Hexane fruit extracts of *Momordica charantia* (Singh et al., 2006), Rhizome of *Kaempferia galanga* (Choochote et al., 1999), *Khaya senegalensis* and *Daucus carota* (Shalaan et al., 2005), *Curcuma aromatic* (Choochate et al., 2005) and n-hexane leaf extract of *Eucalyptus citriodora* (Singh et al., 2007).

Therefore, the relatively high toxicities of extracts of *A. digitata* and *F. sur* stand these plant species as promising sources of potent insecticidal lead-agent for mosquito vector control.

4 Conclusions

The outcomes of this study on the potency of *A. digitata* and *F. sur* leaf extracts for larvicidal efficacy against the fourth instar larvae of *Culex quinquefasciatus* mosquito opens new frontier of possibilities for a lead potential agent for combating mosquitoes. These extracts, judging by the relatively low lethal concentrations, could be environmentally friendly, and hence show great promise as source of sustainable efficacious mosquito larvicides. However, further studies are advocated to determine larvicidal activities of fractions of the extracts, evaluate mammalian toxicities and also efficacies of other flora part of the plants vis-à-vis other solvents of extraction.

Authors’ contributions

Conceived and designed the experiment: OIK, AAT and UAC. Analysed the data: UAC and AKA. Wrote the first draft of the manuscript: OIK, SOM, and UAC. Contributed to writing of the manuscript: AKA and SKO. Agree with manuscript results and
conclusion: all authors. Made critical revisions and approved final version: all authors. All authors reviewed and approved the final manuscript.

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References
Abalaka M.E., Adeyemo S.O., and Daniyan, S.Y., 2011, Evaluation of the Antimicrobial Potentials of Leaf Extracts of Khaya senegalensis, Journal of Pharmaceutical Research and Opinion, 1(2): 48-51
Adeleke M.A, Maliana C.F., Idowu A.B., Adekunle M.F., and Dansu B.M., 2008, Morphometric studies on Culex quinquefasciatus and Mansonia africana (Diptera: Culicidae) in Abeokuta, south-western Nigeria, Tanzania Journal of Health Research, 10(2): 99-102
Adeshina O., Okeke E., and Osuagwu O., 2010, Preliminary in-vitro antibacterial activities of ethanolic extracts of Ficus sur and Ficus platyphylla (Moraceae), African Journal of Microbiology Resource, 4(8): 598-601
Akinpelu D.A., and Onakoya T.M., 2006, Antimicrobial activities of medicinal plants used in folklore remedies in south-western Nigeria, African Journal of Biotechnology, 5(11): 1078-1081
Amrutha P., Priya B., Lakshmanasenthil S., Jenifer, AA, Pillai LS, and Suja G., 2013, Pyrethrin from Tanacetum cinerifolium as repellent against mosquitoes, International Current Pharmaceutical Journal, 2 (10): 170-176
Arivoli S., John R.K., and Tennyson S., 2012, Larvicidal Efficacy of Plant Extracts against the Malarial Vector Anopheles stephensi Liston (Diptera: Culicidae). World Journal of Medical Sciences, 7 (2): 77-80
Arun K.P., Ravichandran N., Vajrai R., and Brindlia P., 2012, Studies on micro morphological Standardization of Antimicrobial efficanly nutritional values of Jatropha tanjorensis, International Journal of Pharmacy and Pharmaceutical Sciences, 4 (2): 139-142
Bagavan A., and Rahuman A.A., 2010, Evaluation of larvicidal activity of medicinal plant extracts against three mosquito vectors. Asian Pacific Journal of Tropical Medicine, 8:29-34
Bream A.S., Hassan M.I., Fouda M.A., and El-Sheikh T.M., 2009, Toxicity and repellent activity of Pheranmites australis extracts against the mosquito vector Culex pipiens, Tunisian Journal of Plant Protection, 4:157-172
Cazanelli L.H., Zanatta L., Alberton, E.H., Figueiredo M.S., Folador P., Damazio R.G., and Silva F.R., 2008, Flavonoids: Prospective Drug Candidates, Mini-Reviews in Medicinal Chemistry, 8(13): 1429-1440
https://doi.org/10.2174/138955708786369564
PMid:18991758
Chochate W., Kanjanapothi D., Panthong A., Tassetikul T., Jitpakdi A., and Chaihong U., 1999, Larvicidal, adulticidal and repellent effects of Kaempferia galangal, South East Journal of Tropical Medicine and Public Health, 30: 470-476
Chochote W., Tuetun B., Kanjanapothi D., Rattanachanpichai E., Chaihong U., and Chaiwong P., 2004, Potential of crude seed extract of celery, Apium graveolens L., against the mosquito Aedes aegypti (L.) (Diptera: Culicidae), Journal of Vector Ecology, 29: 340-346
Codjia C., Fonton K., Assogbadjo E., and Ekue M, 2001, Le Baobab (Adansonia digitata), Une Espèce à Usage Multiple au Bénin, Cecodi, CBDD, V eco, SNV , FSA constituents identified in Foeniculum vulgare fruit against Aedes aegypti
Cushnie T.P., and Lamb A.J., 2011, Recent advances in understanding the antibacterial properties of flavonoids, International Journal of Antimicrobial Agents, 38 (2): 99-107
https://doi.org/10.1016/j.ijantimicag.2011.02.014
PMid:21514796
Das N.G, Goswami D., Radha B., 2007, Preliminary evaluation of mosquito larvicidal efficacy of plant extracts, Journal of Vector Borne Disease, 44: 145-148
De Caluwé E., Halamová K., and Van Damme P., 2009, Baobab (Adansonia digitata L.): a review of traditional uses, phytochemistry and pharmacology, In: Rodolfo, H., Simon, J. E., Ho, C. T. (Eds.), African natural plant products: new discoveries and challenges in chemistry and quality, Oxford University Press, USA, pp.51-84
Denloye A., Teslim K., and Fasasi O., 2006, Insecticidal and repellency effects of Smoke from plant pellets with or without D- allethrin 90 EC against three medical insects, Journal of Entomology, 3(1): 9-15
https://doi.org/10.3329/icpj.v2i10.16411
Eggunyomi A., Moody J.O., and Eletu O.M., 2009, Anti-sickling activities of two ethnomedicinal plant recipes used for the management of sickle cell anaemia in Ibadan, Nigeria, African Journal of Biotechnology, 8(1): 20-25
Ehimbwena S.O., Osagie A.U., 2007, Phytochemical screening and anti anaemic effects of Jatropha tanjorensis leaf in protein malnourished rats, Plant Archives 2007, 7(2):509-516
Finney D.J., 1971, Probit analysis, London: Cambridge University Press, p. 68-72

121
Friedman M., 2007, Overview of antibacterial, antitoxin, antiviral, and antifungal activities of tea flavonoids and teas, Molecular Nutrition and Food Research 51 (1): 116-134
https://doi.org/10.1002/mnfr.200600173
PMid:17195249

Ghosh, A., Chowdhury, N. and Chandra G., 2012, Plant extracts as potential mosquito larvicides, Indian J Med Res 135; pp 581-598

Gomathi R., Indradharmi I. and Karpagam S., 2014, Larvicidal activity of Monstera adansonii plant extracts against Culex quinquefasciatus, Journal of Pharmacognosy and Phytochemistry, 3(3): 160-162

Gonzalez M., Zazzuelo A., Gamez M.J., Utrilla M.P., Jimenez J., and Osuna L., 1992, Hypoglycemic activity of olive leaf, Planta Medica, 58(6): 513-515
https://doi.org/10.1055/s-2006-961538
PMid:1484890

Harborne J., 1998, Phytochemical methods: A guide to modern techniques of plant analysis, III education, London: Chapman and Hill, p.279

James A., 1992, Mosquito molecular genetics: the hands that feed bite back Science; 257: 37-8

Kamalakannan S., Murugan K., and Chandramohan B., 2015, Insect growth regulatory activity of Acalypha abinjoula (Euphorbiaceae) and Vitex negundo (Verbenaceae) leaf extracts against Aedes aegypti (Diptera: Culicidae), International Journal of Mosquito Research; 2(1): 47-52

Kamaraj C., Bagavan A., Elango G., Zahir A.A., Rajakumar G., Marimuthu S., Santoshkumar T., Rahuman A.A., 2011, Larvicidal activity of medicinal plant extracts against Anopheles subpictus and Culex tritaeniorhynchus, Indian J Med Res, 134:101-106

Katz E.F., and Thornton R.W., 2006, Squirrels: the animal answer guide. Baltimore: Johns Hopkins University Press, p.91

Kazembe T.C., Chaibva M., 2012, Mosquito repellency of whole extracts of Monstera adansonii leaves on Aedes aegypti (Diptera: Culicidae) on natural feeds. Entomol Res 42(1): 61-65

Keay R.W.J., 1989, Trees of Nigeria, Clarendon Press Oxford London, PP 294

Kishore N., Mishra B., and TIwari K., 2011, A Review on journal of the American Mosquito Control Association 7(20): 210-237

Klempner M., and Unnasch T., 2007, Taking a bite out of vector-transmitted infectious diseases. Journal of Medical Sciences, 356: 2567-2569
https://doi.org/10.1056/NEJMoa078081

Koyel M., and Papiya G., 2011, Evaluation of Target Specific Larvicidal Activity of Cassia auriculata flower, fitoterapia, 78(1): 46-47

Krishnan K, Senthilkumar A, Chandrasekar M, Venkatesalu V. Differential larvicidal efficacy of four species of Vitex against Culex quinquefasciatus larvae. Parasitol Res 2010; 10: 1721-3

Kumar M.S., and Maneemegalai S., 2008, Evaluation of Larvicidal Effect of Lantana Camara Linn Against Mosquito Species Aedes aegypti and Culex quinquefasciatus, Advances in Biological Research 2 (3-4): 39-43

Lansky E.P., and Paavilainen H.M., 2011, Figs: The genus Ficus. CRC Press - 710 pp

Lansky E.P., and Paavilainen H.M., 2011, Figs: The genus Ficus. CRC Press - 710 pp

Malik B.R., Malik M.M., Balakrishnan N., Sureh B., 2014, Evaluation of Larvicidal efficacy of four species of Ficus plants on Aedes aegypti and Anopheles gambiae s.l., Journal of Ethnopharmacology 153: 2569-2573
https://doi.org/10.1016/j.jep.2014.05.020
PMid:24071942 PMCid:PMC8321565

Maragathavalli S., Brindha S., Kaviyarasi N.S., Annadurai B. Gangwar S.K., 2012, Effect of Neem on Mosquito larvicidal activity, International Journal of Advanced Biological Research, 2(1): 138-142.

Maurya P., Mohan L., Sharma P., Batabyal L., Srivastava C.N., 2007, Larvicidal efficacy of Aloe barbadensis and Cannabis sativa against the malaria vector Anopheles stephensi. Journal of Parasitology and Vector Biology, 6(1): 11-15
https://doi.org/10.1016/j.parv.2006.11.001

Meenakshi S.V., and Jayaprakash K., 2014, Mosquito larvicidal efficacy of leaf extract from mangrove plant Rhizophora mucronata (Family: Rhizophoraceae) against Anopheles and Aedes species. Journal of Pharmacognosy and Phytochemistry, 3(1):78-83

Nguta J.M., Mbaria M., and Gathumbi P.K., 2010, Antimalarial herbal remedies of Msambweni, Kenya, Journal of Ethnopharmacology 128, 424–432
https://doi.org/10.1016/j.jep.2010.01.033
PMid:20906761

Olayemi I.K., Ande A.T. Chita S., and Ibumesi G., 2011, Insecticide susceptibility profile of the principal malaria vector, Anopheles gambiae s.l., in North Central Nigeria. Journal of Vector Borne Diseases, 48: 109-112

Olayemi I.K., Busari J., Adeniyi K.A., and Ukubuwae A.C., 2014b, Comparative larvicidal efficacy of leaf and stem extract of Jatropha carcas against Culex pipiens pipiens, Malaysian Journal of Biosciences, 1(2): 104-108

Olayemi I.K., Ukubuwae A.C., and Oyibo-Usman K.A., 2014a, Mosquito species occurrence and diversity in conventional larval breeding sites in Minna metropolis, Nigeria, International Journal of Innovation and Scientific Research, 9(1): 86-93

Olayemi I.K., Yakuh H., and Ukubuwae A.C., 2013, Larvicidal and insect growth regulatory (IGR) activities of leaf-extract of Carica papaya against the filarial vector mosquito, Culex pipiens pipiens (Diptera: Culicidae), Acta Biologica Malaysiana, 2(3): 100-106

Oyeleke S.B., Dauda B.E.N., and Boye O.A., 2008, Anti-bacterial activity of Ficus capensis. African Journal of Biotechnology, 7(10): 1414-1417

Prabhakar K. Jebanasa A., 2004, Larvicidal efficacy of some cucurbitaceous plant leaf extracts against Culex quinquefasciatus, Bioresource Tech, 95: 113-114
https://doi.org/10.1016/j.biortech.2003.05.001
PMid:15207304
Prabhu K., Muragan K., Nareshkumar A., and Bragadeeswaran S., 2011, Larvicidal and repellent potential of the Moringa oleifera against malarial vector, Anopheles stephensi Liston (Insecta: Diptera: Culicidae), Asian Journal of Tropical Biomed, 4: 610-613
https://doi.org/10.1016/S2221-1691(11)60099-9

Pratheeba T., Ragavendran C., and Natarajan D., 2015, Larvicidal, pupicidal and adulticidal potential of Ocimum gratissimum plant leaf extracts against filariasis inducing vector, International Journal of Mosquito Research, 2 (2): 01-08

Pushpalatha E., Njebea M.B., and Santhini KP., 2014, Efficacy of Anamurita cocculus (Linn.) wight and arr and Pogostemon paniculatus (Wild) benth extract on Culex pipiens, International Applied Biology and Pharmaceutical Technology, 5(3): 159-162

Quevedo R., Baquero E., and Quinones M.L., 2011, 1-Phenyllisoquionoline larvicidal activity against Culex quinquefasciatus, Natural Product Research
https://doi.org/10.1080/14786419.2011.606846

Rahuman A., and Venkatesan P., 2008, Mosquito larvicidal activity of oleic and linoleic acids isolated from Citrullus colocynthis (Linn.) Schrad, Parasitology Resource Technology, 103: 1383-1390
https://doi.org/10.1007/s00436-008-1146-6

PMid:18688644

Rattan R.S., 2010, Mechanism of action of insecticidal secondary metabolites of plant origin, Crop Protec, 29: 919-20
https://doi.org/10.1016/j.cropro.2010.05.008

Remia K.M., and Logaswamy S., 2009, Larvicidal efficacy of leaf extract of two botanicals against the mosquito vector Aedes aegypti (Diptera: Culicidae), Indian Journal of Natural Products and Resources, 1(2): 208-212

Reudla L.M., 2008, Global diversity of mosquitoes (Insecta: Diptera: Culicidae) in freshwater, Developments in Hydrobiology, 198: 477-487
https://doi.org/10.1007/978-1-4020-8259-7_48

https://doi.org/10.1007/10750-007-9307-x

Shaalan E.A.S., Canyonb D., Younesc M.W.F, Abdel-Wahab H., and Mansoura A.H., 2005, A review of botanical phytoschemicals with mosquitocidal potential, Environ Int, 3: 1149-66
https://doi.org/10.1016/envint.2005.03.003

PMid:15964629

Shah M., Hanafi-Bojd A., and Iranshahi M., 2010, Larvicidal Efficacy of Latex and Extract of Adansonia digitata (Diptera: Culicidae) Vector Borne Diseases 17: 77-90

Shallan E.A., Canyon D., Younes M.W.F, Abdel-Wahab H., and Mansoura A., 2005, A review of botanical phytoschemicals with mosquitocidal potential
https://doi.org/10.1016/envint.2005.03.003

Shivakumar M.S., Srinivasan R., and Natarajan D., 2013, Larvicidal potential of some Indian medicinal plant extracts against Aedes aegypti L. Asian Journal of Pharmaceutical and Clinical Research, 6(3): 77-80

Shooshhtari M.B., Kashani H.H., Heidari S., and Ghalandari R., 2013, Comparative mosquito repellent efficacy of alcoholic extracts and essential oils of different plants against Anopheles stephensi, African Journal of Pharmacy and Pharmacology, 7(6): 310-314
https://doi.org/10.5897/AJPP12.1144

Shukla Y.N., Dubey S., Jain S.P., and Kumar S., 2001, Chemistry, biology and uses of Adansonia digitata—a review, Journal of Medicinal and Aromatic Plant Sciences, 23: 429–434

Sidibe M., and Williams J.T., 2002, Baobab, (Adansonia digitata), Fruits for the Future, 4, International Centre for Underutilized Crops, Southampton, UK, p. 100

Singh R.K., Dhimana R.C., and Mittla P.K., 2006, Mosquito larvicidal properties of Momordica charantia Linn (Family: Cucurbitaceae), J Vect Borne Dis, 43: 88-91

Singh S.P., and Mittla P.K., 2013, Mosquito Repellent and Oviposition deterrent activities of Solanum nigrum seed extract against malaria vector Anopheles stephensi, Online International Interdisciplinary Research Journal, 3(4): 326-333

Sofowora A., 1993, Medicinal Plants and Traditional Medicine in West Africa, John Wiley and Sons, pp. 256, New York

Stary F., 1998, Medicinal Herbs and Plants, Tiger Books internal Plc.U.K.PP6-20

Sukhthankar J.H., Kumar H., Godinho M.H.S., and Kumar A., 2014, Larvicidal activity of methanolic leaf extracts of plant, Chromolaena odorata L. (Asteraceae) against vector mosquitoes International Journal of Mosquito Research, 1(3): 33-38

Svobodová A., Pozová J., and Walterová D., 2003, Natural Phenolics in the Prevention of UVInduced Skin Damage, A Review, Biomedical Papers, 147(2): 137-145
https://doi.org/10.5507/bp.2003.019

Tehr K., and Singh N., 2015, The role of botanicals as green pesticides in integrated mosquito management—A review. International Journal of Mosquito Research, 2(1): 18-23

Tennyson S., Ravindran K.J., and Arivoli S., 2012, Screening of twenty five plant extracts for larvicidal activity against Culex quinquefasciatus Say (Diptera: Culicidae), Asian Pacific Journal of Tropical Biomedicine, S1130S1134

Tikar S.N., Mendi M.J., Chandel K., Parashar B.D., and Prakash S., 2008, Susceptibility of immature stages of Aedes aegypti, the vector of dengue and chikungunya to insecticides from India, Parasitol Res, 102: 907-913
https://doi.org/10.1007/s00436-007-0848-5

PMid:18172687
Tyagi V., Yadav R., Sharma A.K., Tyagi V., Yadav S., Vijay V., et al., 2013, Larvicidal activity of leaf extract of some weeds against malaria vector Anopheles stephensi, International Journal of Malaria Research and Reviews, 1(3): 3539

Ukubuiwe A.C., Olayemi I.K., Omalu I.C.J., Odeyemi M.O., Jibrin A.I., and Oyibo-Usman K.A., 2012, Comparative assessment of immature survivorship and developmental duration of Culex piperis piperis (Diptera: Culicidae) populations in north central Nigeria, Biomed Central EPIDEMIOLOGY, 3(10): WMC003753

Ukubuiwe A.C., Olayemi I.K., Omalu I.C.J., Jibrin A., and Oyibo-Usman K., 2013, Molecular Bases of Reproductive and Vectorial Fitness of Culex piperis piperis (Diptera: Culicidae) Mosquito Populations, for the Transmission of Filariasis in North Central Nigeria, Journal of Medical Sciences, DOI: 10.3923/jms.2013

Vahitha R., Venkatachalam M.R., Murugan K., and Jebanesan A., 2002, Larvicidal efficacy of Pavonia zeylanica L. and Acacia ferruginea D.C. against Culex quinquefasciatus Say. Bioresource Tech, 82: 203–204

Vasudevan K., Malarmagal R., Charulatha H., Saraswatula V.L., and Prabakaran K., 2009, Larvicidal effects of crude extracts of dried ripened fruits of Piper nigrum against Culex quinquefasciatus larval instars, Vector Borne Dis 46, 153–156

Wickens G.E., and Lowe P., 2008, The baobabs: pachycauls of Africa, Madagascar and Australia, Springer, UK

World Health Organization, 2005, Guidelines for Laboratory and Field Testing of Mosquito Larvicides, http://whqlibdoc.who.int/hq

Yisa J., 2009, Phytochemical Analysis and Antimicrobial Activity of Scoparia dulcis and Nymphaea lotus. Australian Journal of Basic and Applied Sciences, 3(4): 3975–3979

Zewdneh T., Mamuye H., Asegid T., Yalemsehay M., and Beyene P., 2011, Larvicidal effects of Jatropha curcas L. against Anopheles arabiensis (Diptera: Culicidae) MEJS; 3(1): 52-64