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PROSPECTS OF USING HERBAL PRODUCTS IN THE CONTROL OF MOSQUITO VECTORS

Several mosquito species belonging to genera Anopheles, Culex and Aedes are vectors for the pathogens of various diseases like malaria, filariasis, Japanese encephalitis (JE), dengue and dengue haemorrhagic fever, yellow fever, *etc.* Thus one of the approaches for control of these mosquito-borne diseases is the interruption of disease transmission by killing or preventing mosquitoes to bite human beings. Herbal products with proven potential as insecticide or repellent can play an important role in the interruption of the transmission of mosquito-borne diseases at the individual as well as at the community level. Some herbal products such as nicotine obtained from tobacco leaves, *Nicotiana tabacum*, anabasine and lupinine, the alkaloids extracted from Russian weed *Anabasis aphylla*[1], rotenone from *Derris eliptica* and pyrethrums from *Chrysanthemum cinererifolium* flowers[2] have been used as natural insecticides even before the discovery of synthetic organic insecticides[3]. However, the discovery, development and use of synthetic organic chemicals with persistent residual action not only overshadowed the use of herbal products against mosquitoes but also became the major weapon for mosquito control. Since the discovery of DDT, mosquito control approach has been almost completely based on synthetic organic insecticides. But the extensive use of synthetic organic insecticides during the last five decades have resulted in environmental hazards and also in the development of physiological resistance in major vector species. This has necessitated the need for search and development of environmentally safe, biodegradable, low cost, indigenous methods for vector control, which can be used with minimum care by individual and communities in specific situations.

Phytochemicals obtained from plants with proven mosquito control potential can be used as an alternative to synthetic insecticides or alongwith other insecticides under the integrated vector control. Plant products can be used, either as insecticides for killing larvae or adult mosquitoes or as repellents 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 or repellent activity against mosquito vectors[4], but very few plant products have shown practical utility for mosquito control. Plant products can be obtained either from the whole plant or from a specific part by extraction with different types of solvents such as aqueous, methanol, chloroform, hexane, *etc.*, depending on the polarity of the phytochemicals. Studies carried out so far have shown that some phytochemicals act as general toxicant (insecticide/larvicide) both against adult as well as larval

stages of mosquitoes, while others interfere with growth and development (growth inhibitors) or with reproduction (chemosterilant) or produce olfactory stimuli thus acting as repellent or attractant. An attempt has been made in the present write-up to review the reports on mosquitocidal and repellant activity of plant based products published during the past one decade with an emphasis on neem (*Azadirachta indica*) based products which have shown their practical utility under field conditions. A list of various plants/ products, which have been tested during past one decade and have been shown to possess insecticidal / larvicidal, growth inhibitor, chemosterilant and repellent effects against mosquitoes is given in the table.

Table. Plants reported for insecticidal, growth inhibition and repellent activity against mosquito vectors (1990-2002)

Plant species (Family)	Plant product	Species tested	Type of activity	References
Annona squamosa (Annonaceae)	Whole plant extract	*Anopheles stephensi*	Larvicidal, Growth regulator, Chemosterilant	Saxena *et al* (1993)[5]
Polyalthia longifolia (Annonaceae)	Leaf extract	*Culex quinquefasciatus*	Larvicidal	Murty *et al* (1997)[6]
Ageratum cony zoides (Compositae)	Whole plant extract	*An. stephensi*	Larvicidal, Growth regulator	Saxena & Sukumaran[7]
Tagetes errecta (Compositae)	Acetone extract, Steam distillated essential oil	*Cx.quinquefasciatus, Aedes aegypti An. stephensi*	Growth regulator, Larvicidal, Adulticidal	Pathak *et al* (2000)[8], Perich *et al* (1994)[9]
Tagetes minuta (Compositae)	Essential oil, Whole plant, flowers	*An.stephensi, Ae. aegypti,*	Adulticidal, Larvicidal,	Green *et al* (1991)[10] Perich *et al* (1994)[9]
		Cx.quinquefasciatus, Ae.aegypti An. stephensi	Repellent	Tyagi *et al* (1994)[11]
Cymbopogan spp (Gramineae)	Oil as topical application	*An. culicifacies, Cx.quinquefasciatus*	Repellent	Ansari & Razdan (1995)[12]
Mentha piperita (Labiatae)	Essential oil	*Cx.quinquefasciatus, An. stephensi*, *Ae. aegypti*	Larvicidal, Repellent	Ansari *et al* (1999)[13], Pathak *et al* (2000)[8]
Ocimum sanctum (Labiatae)	Steam distillated essential oil	*Cx.quinquefasciatus, Ae.aegypti, An.stephensi*	Larvicidal	Pathak *et al* (2000)[8]
Dalbergia sisoo Roxb. (Leguminasae)	Essential oil	*Cx.quinquefasciatus, An.stephensi*	Larvicidal, Repellent	Ansari *et al* (2000)[14]
Azadirachta indica (Meliaceae)	Neem oil – Oil water emulsion on wood scrappings	*Cx.quinquefasciatus, An.stephensi, Ae.aegypti*	Larvicidal, Growth regulator, Anti-pupational	Mittal *et al* (1993)[15], Batra *et al* (1998)[16], Nagpal *et al* (1995)[17]
	Neem oil volatiles	*An.culicifacies, An.stephensi*	Oviposition inhibitor	Dhar *et al* (1996)[18]

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Plant species (Family)	Plant product	Species tested	Type of activity	References
	Deoiled neem cake powder	*Culex spp.* *Anopheles spp.*	Larvicidal, Growth regulator	Rao *et al* (1992)[19]
	2% Neem oil - mixed with coconut/ mustard oil as topical application	*An. culicifacies,* *An. fluviatilis,* *An. annularis,* *An. stephensi,* *Ae.aegypti,* *Cx. quinquefasciatus,*	Repellent	Sharma *et al* (1993)[20], Rajnikant & Bhatt(1994)[21], Mishra *et al* (1995)[22], Sharma *et al* (1995)[23], Sharma *et al* (1996)[24],
		An.darlingi		Moore *et al* (2002)[25]
	5% neem oil in a cream base–Topical application	*Ae.aegypti,* *Ae.albopictus,* *Anopheles spp.,* *Culex spp.*	Repellent	Dua *et al* (1995)[26], Singh *et al* (1996)[27], Nagpal *et al* (2001)[28],
	5-10% neem oil-impregnated on mats (vapours)	*An.culicifacies,* *An.annularis,* *An.stephensi,* *Culex spp.*	Repellent	Sharma *et al* (1993)[29]
	1% neem oil in kerosene (Smoke)	*An.culicifacies,* *An. annularis,* *Culex spp.*	Repellent	Sharma & Ansari (1994)[30], Ansari & Razdan (1996)[31]
Eucalyptus maculata (Myrtaceae)	PMD spray 50% ai based on essential oil	*An. gambiae* *An. funestus*	Repellent	Trigg (1996)[32]
Citrus spp. (Rutaceae)	Fruit peel oil	*Cx. pipiens,* *Cx.quinquefasciatus*	Adulticidal, Larvicidal	al Dakhil & Morsy(1999)[33], Ezenou *et al* (2001)[34], Mwaiko (1992)[35], Mwaiko & Saveli (1994)[36]
Ferronia elephantum (Rutaceae)	Leaves, Methanolic extract	*Ae.aegypti*	Repellent	Venkatachalam & Jebanesan (2001)[37]
Solanum nigrum Linn. (Solanaceae)	Crude leaf extract,	*An. culicifacies,* *Cx.quinquefasciatus,* *Ae.aegypti*	Larvicidal	Singh *et al* (2002)[38]
	Ethanolic leaf extract	*Ae. caspius* *Cx. pipiens*	Larvicidal, Growth regulator	Ahmed *et al* (2001)[39]
Lantana camara (Verbnaceae)	Flower–Methanol extract +Coconut oil	*Ae.albopictus,* *Ae.aegypti*	Repellent	Dua *et al* (1996)[40]

Superscript nos. refer to sl.no. in the reference list.

Insecticides and Growth Inhibitors

Though many plants have been shown to possess insecticidal / larvicidal and growth inhibition activity against mosquitoes, most of these reports are based on laboratory observations only. Products of some plants are effective at a very high concentrations and thus may not be of much practical importance. However, some of the plant products have shown promise for mosquito control even under field conditions. One of the most commonly studied plant for control of mosquitoes is *Azadirachta indica,* (Meliaceae) commonly known as neem in India.

Neem

Neem contains at least 35 biologically active principles,[41] of which azadirachtin (AZA), a triterpenoid is the predominant insecticidal active ingredient in the seeds, leaves, and other parts of the tree. Neem products containing azadirachtin and other ingredients, have anti-feedant, ovipositional deterrence, repellency, growth disruption, sterility and larvicidal action against insects[42]. Neem based pesticides are now extensively used in agricultural practices all over the world. Neem oil and other commercial preparations of neem have been found as potential mosquito larvicide[15]. Dhar *et al*[18] demonstrated the effect of neem oil volatiles on gonotropic cycle and inhibition of oviposition in *An.stephensi* and *An. culicifacies*. Control of mosquito breeding has also been demonstrated in the field in some confined habitats using indigenous methods of application of neem oil in water and neem oil coated on wooden scraps[16,17]. Wood scrap balls soaked in 5 to 20% neem oil in acetone were tested in overhead tanks of 0.50 cubic meter against *An. stephensi* breeding. Though it did not prohibit egg laying, it arrested pupal formation and eventually the adult emergence for about 45 days[17]. Neem oil emulsion in water was also found to control breeding of *Cu. quinquefasciatus, An.stephensi and Ae. aegypti* in pools, basement tanks and desert coolers, and the effective control lasted for 2 to 3 weeks[16]. Neem cake powder and urea coated with neem cake powder were evaluated for the control of mosquito breeding in rice fields[19]. Application of neem cake powder alone or coated on urea resulted in drastic reduction in the late instar larvae and pupae of culicine mosquito for several weeks. Aqueous extract from deoiled neem seed kernels exhibited toxic and growth regulating activities against *Cx. quinquefaciatus* larvae with a 100% larval mortality especially during the first and second instars at all the tested concentrations[43]. Though neem products show high larvicidal activity, they do not show adulticidal action. Zebitz[44] suggested that azadirachtin acts as an anti-ecdysteroid and thus kills the larvae by growth inhibition effect. This, along with other delayed effects of neem products[18] provides an alternative approach to chemical larvicides in mosquito control.

Other herbal products

Several other plants have demonstrated toxic effects on mosquitoes mostly under laboratory conditions. *Tagetes sp.*, commonly known as marigold has shown both larvicidal as well as adulticidal activity against mosquitoes[8-10,45]. Active components have been isolated from different parts of this plant. Green *et al*[10] reported mosquito larvicidal activity in the extract of *Tagetes minuta* flowers. Perich *et al*[9] compared biocidal activites of the whole-plant extracts of three Tagetes species and showed that *T. minuta* had the greatest biocidal effect on the larvae and adults of *Ae. aegypti* (L.) and *An. stephensi* (L). Bioassays of simultaneous steam distillated extracts of *T. minuta* flowers showed larval mortality at $LC_{90,s}$ of 4 and 8 ppm and against the adult at 0.4 and 0.45% against *Ae. aegypti* and *An. stephensi*, respectively[9]. The extract from *T. minuta* was found to be most active among 83 plant species belonging to the compositae family, with a LC_{50} of 1 mg/l against *Ae. fluviatilis*. Active components of *T. minuta* have also been identified as thiophene derivatives, a class of compounds present in many plants of family asteraceae[45]. Pathak *et al* [8] reported 100% mortality with steam distillated oil extract from the whole plant of *T.errecta*, against larvae of *An. stephensi*, *Cx. quinquefasciatus* and *Ae. aegypti* at doses lower than 100 ppm. Ethanol extract of another plant *Eclipta paniculata* belonging to family compositae, has also shown significant insecticidal activity, with LC_{90} of 17.2 mg/l and LC_{50} of 3.3 mg/l[45]. Leaf extract of *Polyalthia longifolia* exhibits larvicidal and growth inhibition effect against larvae of *Cx. quinquefasciatus*[6]. Application of the extract at the dose of 250 to 350 ppm produced 64-96% inhibition of adult emergence of *Cx. quinquefasciatus* in tanks and U-drains .Another plant, *Murraya koengii* has also showed mosquito larvicidal activity[8,46], due to the presence of carbazole alkaloids, mahanimbine, murrayanol, and mahanine. Volatile oil from the peel of citrus fruits has also shown toxic effects on mosquito larvae as well as adults[33-36] . Susceptibility tests carried out against *Cx. quinquefasciatus* larvae and adults using peel oil extracts of bitter orange (*Citrus aurantium*), orange

(*C. sinensis*) and lemon (*C. limon*) indicated that the extracts may contain potentially useful insecticides. Volatile extracts of *C. sinensis* showed greater insecticidal potency[34]. The larvicidal action of three ethanol extracts of peels of lemon, grapefruit and navel orange, against *Cx. pipiens* revealed LC_{50} values as 18.5, 20.3 and 26.5 ppm, respectively[33]. The peel oil fulfilled other required specifications like suitable specific gravity, spreading pressure and viscosity. It is toxic at a wide pH range, stable to heat and light in terms of chemical change, which could alter larvicidal action. However, it is volatile and did not form a permanent film on water surfaces for long periods. This affected its larvicidal action[36]. Jaiprakash *et al*[47] isolated three limonoids, namely limonin, nomilin and obacunone, from the seeds of *C. reticulata* which showed growth inhibition effect on 4th instar larvae of *Cx. quinquefasciatus and* the EC_{50} for inhibition of adult emergence was 6.31, 26.61 and 59.57 ppm for obacunone, nomilin and limonin, respectively. The pattern of mortality at around the EC_{50} levels was indicative of moult inhibiting activity. Crude extract of leaves of *Solanum nigrum* in water showed larvicidal activity against *An.culicifacies*, *Cx. quinquefasciatus* and *Ae. aegypti* at a dose equivalent to LC_{90} ranging between 0.18 and 0.21%[38]. Toxicological studies on three ethanol extract preparations of *S. nigrum* leaves showed larvicidal activity against larvae of *Ae. caspius* and *Cx. pipiens*, (LC_{50} 51.29 and 125.89 mg/l within 24 h, and 21.38 and 38.11 mg/l within 48 h, respectively). Sunlight, pH, and turbidity did not affect the activity of this extract. The concentrated extract (1000 mg/l) can be stored at room temperature for six months without any change in its activity, but diluted solutions of this extract lost their activity after four weeks[39].

Alcoholic extracts of leaves and stems of *Vanilla fragrans* fractionated with ethyl acetate and aqueous butanol possess mosquito larvicidal activity[48] and 4-butoxymethylphenol was found to be the most effective compound against mosquito larvae. Butenolides 1 and 2, isolated from the endemic plants *Hortonia floribunda, H. angustifolia, and H. ovalifolia*, also exhibited potent mosquito larvicidal activity against the second instar larvae of *Ae. aegypti*[49]. Saxena *et at*[7] discovered growth inhibitory and juvenile hormone mimicing activity in the larvae of *Cx. quinquefasciatus* treated with acetone extracts of *Ageratum conyzoides, Cleome icosandra, and Tridax procumbens* resulting in larval pupal intermediates, demelanised pupae, defective egg rafts and adult with deformed flight muscles. Loss of fecundity was also observed in the treated mosquitoes but no sterilant effects could be seen. However, alkaloids from *Annona squamosa* exhibited chemosterilant effect in addition to larvicidal and growth inhibition in *An. stephensi*[5]. *Annona squamosa* and *Lansium domesticum* showed highest larvicidal potential against *Ae. aegypti* and *Cx. quinquefasciatus* amongst the five plant species, viz. *A. squamosa, Eucalyptus globulus, Lansium domesticum, Azadirachta indica* and *Codiaeum variegatum* with extracts showing maximum insecticidal activity after 48 hours of exposure. *L. domesticum* and *A. squamosa* were most effective against larvae of *Ae. aegypti* and *Cx. quinquefasciatus*, respectively. While, *Ae. aegypti* was more susceptible than *Cx. quinquefasciatus* to neem but *Cx. quinquefasciatus* was more susceptible than *Ae. aegyti* to *Eucalyptus globulus*[50]. Petroleum ether extract of thyme plant, *Thymus capitatus* was found to be toxic against the larvae and adults of *Cx. pipiens* (L). Among different fractions isolated from this extract, the volatile oil, thymol, and the unsaponifiable portion showed high larvicidal potency (LC_{50}=49.0, 58.0, and 100.0 ppm, respectively). Non-lethal concentrations of these substances synergized the toxicity of malathion, while unsaponifiable portion and volatile oil showed the highest adulticidal potency. Thymol as well as volatile oil affected egg hatchability[51].

Mosquito Repellents

Though various plants have been reported to possess repellent activity against mosquitoes[4], *Azadirachta indica Eucalyptus sp*. (Myrtaceae), *Lantana camara* (Verbanaceae), *Cymbopogon spp*. (Gramineae), *Mentha piperita* (Labiatae), *Tagetes minuta* (Compositae) and some other plants products have been studied more extensively during the past one decade. Smoke produced by burning of dried leaves of *Azadirachta indica* has been used for the protection against mosquitoes since ancient times.

Neem oil

Though neem oil has been used in various insecticidal and medicinal preparations, its mosquito repellent activity was not known. Recent studies carried out at the Malaria Research Centre (MRC), Delhi and elsewhere have shown repellent action of neem oil[20-25, 29-30]. Topical application of 2% neem oil mixed in coconut oil produced varying degree of protection against different vector species and the repellent effect was more pronounced against *Anopheles spp* than against *Cx. quinquefaciatus*[21-23, 25].

A complete protection for 12 h from the bites of all the anopheline mosquitoes species was reported by using 2% neem oil in coconut oil on the exposed part of the body[20]. However, Rajnikant and Bhatt[21] reported only 89 and 98% protection against *An. fluviatilis* and *An. culicifacies* respectively and only 68% protection against all anopheline species by using 2% neem oil. The protection from Culex and Aedes mosquitoes ranged between 76-86%. In another study 81-91% protection against *An. culicifacies* was reported during 12 h by using 1-4% neem oil in coconut oil[22]. But Moore *et al*[25], did not find any significant protection from *An. darling*i by using 2% neem oil, while a eucalyptus based repellent provided 96% protection for 12 h. Sharma *et al* [24], reported only a week repellant effect of neem oil against *Ae. aegypti.* Vanishing cream with 5% neem oil also provided 67 to 100% protection against malaria mosquitoes in different ecological terrains in India[26-28]. Application of the neem cream for protection against mosquitoes was more acceptable than neem oil because of its easy application, pleasant odour and more effective repellency up to 4 h after the application. Moreover, the application of neem oil and cream has been found safe[52] and hence can be used as a personal protection measure against mosquito bites particularly against malaria vectors.

Neem oil mats and lamps as mosquito repellent devices

In addition to the topical application, other methods of using neem oil were also developed and evaluated at MRC, Delhi[29-31]. Cardboard mats soaked in 5 and 10% neem oil were tested as mosquito repellent. Results revealed that mean catch per night per person in case of *Cx. quinquefasciatus* was 129.7 and 124.9 with mat containing 5 and 10% neam oil respectively and 187.6 with commercially available mat (containing allethrin) as compared to 729 mosquitoes in the control (no mat)[23]. When indoor resting density of mosquito was compared, 78 *Cx. quinquefasciatus* and 2 *An. culicifacies* mosquitoes were collected in rooms with 5% neem oil mats as against 142 Culex and 8 *An. culicifacies* in room with commercial mat and 212 Culex and 95 *An. culicifacies* in the control room without mat. Smoke produced by burning of neem oil mixed in the kerosene oil in lamps provided protection against mosquito bites[30]. Use of kerosene lamps with 1% neem oil mixed in kerosene, produced 100% protection from all Anopheles mosquito species for 10 nights, but against *Culex spp* only 79% protection was observed. The feasibility of malaria control by burning neem oil in kerosene lamps was also demonstrated in a village scale trial[31]. Results revealed that burning of neem oil in kerosene lamps resulted in the displacement of *An. culicifacies* from living rooms to cattle sheds. This was also reflected when malaria incidence was compared in experimental and control villages. Human cases per 1000 persons and *Plasmodium falciparum* rates per 1000 person were 1.03 and zero respectively in experimental village as against 9.6 and 4.3 in the control village. Discontinuing the burning of neem oil in kerosene lamps resulted in the recurrence of *An.culicifacies* in living rooms and an increase in malaria incidence in experimental village.

Other herbal products

In addition to neem some other plant-based products have also been found as effective mosquito repellents and have been evaluated against different vector mosquitoes. Flowers of *Lantana camara* extracted in methanol and mixed with coconut oil provided 94.5% protection against *Ae. albopictus* for two hour.[40] Four fractions *viz* MRC - HR1, HR2, HR3 and HR4 were isolated from Lantana flowers using solvent extraction and chromatographic methods. Of these, MRC-HR2 showed maximum repellency against Aedes mosquitoes with a mean protection time of 2.43 h. Repellent action of MRC-HR2 gave 85% protection for up to 6 h against *Aedes sp.* in field conditions[40]. Oils of *Cymbopogan martini martini*, *Cymbopogan citratus* and *Cymbopogan nardus* provided more than 95% protection against *Cx. quinquefasciatus* and *An. culicifacies* in whole night landing collection on human baits[12]. Essential oil extracted by steam distillation of *Mentha piperita* and *Dalbargia sisoo* provided 84.5 to 100% protection against *Cx. quinquefasciatus* and *An. culicifacies* during the whole night landing collection[13,14]. A high degree of repellency (>90% protection for 2 h. and >50% upto 4 h) was observed in the essential oil extract of *Tagets minuta* against *An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti* mosquitoes in the laboratory studies[11]. Govere *et al*[53] studied the repellency effect of three plants *viz* fever tea (*Lippia javanica*), rose geranium (*Pelargonium reniforme*) and lemon grass (*Cymbopogon excavatus*) against laboratory reared *An. arabiensis* mosquitoes. The alcoholic extracts of these plants provided significant protection ($p = 0.012$). *L. javanica* provided better and longer (76.7% for 4 h) protection against *An. arabiensis* compared to *C. excavatus* and *P. reniforme,* (66.7 and 63.3% protection for 3 h, respectively). At five hours post application only *L. javanica* alcoholic extract provided

appreciable protection (59.3%) against *An. arabiensis*. Methanol extract of *Ferronia elephantum* leaves provided 100% protection against *Ae. aegypti* at 1.0 and 2.5 mg/cm^2 up to 2.14 and 4.00 h respectively. The total protection of *Ferronia elephantum* was 45.8% at 1.0 mg/cm^2 and 59.0% at 2.5 mg/cm^2 for 10 h[37].

Eucalyptus-based products have been found effective as mosquito repellents in various studies[25,32,54] . Schreck and Leonhardt[54] evaluated Quwenling – an insect repellent product of China derived from extracts of the lemon eucalyptus plant (*Eucalyptus maculata*) and compared its repellency with deet against *An. albimanus*, *An. quadrimaculatus*, *Ae. aegypti and, Ae. albopictus* in laboratory tests and with *Ae. taeniorhynchus* in field tests. Cloth treated with Quwenling at 2x the dosage of deet was effective against 2 of the 4 species tested (*Ae. albopictus* 29 days, *An. quadrimaculatus* 28 days). On the skin of volunteers at 2x the dosage of deet, the duration of protection for Quwenling was significantly less compared to deet for *Ae. aegypti and Ae. taeniorhynchus*, but was not significantly different for *Ae. albopictus*. Both repellents were ineffective against the anopheline species. As a topically applied mosquito repellent, Quwenling, had a shorter duration of effectiveness than deet. Moore *et al*[25] reported upto 96.8% protection against *An. darlingi* using a eucalyptus based repellent as against 84.8% protection by deet. Eucalyptus and deet provided higher protection than 2% neem oil. Trigg [32] reported complete protection for 6-7 h against malaria vectors *An. gambiae* and *An. funestus* using a eucalyptus based insect repellent with active ingradient p-methane 3,8 diol.

Palsson and Jaenson[55] collected data on plant species and plant derived products or methods used by people to reduce mosquito-biting activity in Guinea Bissau and identified the potential plants for mosquito repellent activity. Fresh or smouldering *Hyptis suaveolens* Poit and smoke produced by the bark of *Daniellia oliveri* Rolfe, *Elaeis guineensis* Jacq, seed capsules of *Parkia biglobosa* Benth, leaves of *Azadirachta indica* and *Eucalyptus sp*. and fresh *Ocimum canum* Sims and *Senna occidentalis* L. were identified as showing mosquito repellent activity. The 'repellent activity' of these plants was compared with that of two commercially available mosquito repellents. In the first experiment, smouldering *H. suaveolens,* fresh *H. suaveolens* burning of the bark of *D. oliveri* and smoke of the leaves of eucalyptus showed 85.4,73.2,74.7 and 72.2% repellency respectively. In the second experiment smouldering *H. suaveolens,* fresh *H. suaveolens,* burning of the bark of *D. oliveri,* smoke of the leaves of *A. indica,* smoke of the infructescence of *E. guineensis,* fresh *O. canum* and fresh *S. occidentalis* showed 83.6, 66.5, 77.9, 76.0, 69.0, 63.6 and 29.4% repellency respectively. All the products tested, except *S. occidentalis* were significantly more effective than the negative control.

Live Plant as Mosquito Repellent

Most of the studies carried out so far have shown repellent effect of plant-based products derived from various plants, but there is no report of any live-intact plant showing repellent action against mosquitoes. However, a recent study has shown that certain plants such as *Lantana camara* and *Lippia uckambensis* repell *An. gambiae* mosquitoes (with an average of 39.7 and 32.4% protection) from human baits in an experimental plant house[56].

Conclusions

Some indigenous plant based products are very promising against mosquitoes and can be used as insecticides and/or repellents. They offer a safer alternative to synthetic chemicals and can be obtained by individuals and communities easily at a very low cost. Neem oil and other derivatives of neem can be used alone or in combination with other products for effective protection against mosquitoes. The neem products can also be used for control of mosquito breeding under integrated disease vector control programme in various situations. Besides, herbal derivatives of *Lantana camara*, *Cymbopogon spp.*, *Mentha piperita*, *Eucalyptus spp.*, *Tagetes minuta*, *Dalbergia sisoo, etc.* have also shown repellency effects against different mosquito species and can be used for personal protection against mosquitoes by individuals, thus minimizing the dependency on synthetic chemicals. Similarly, certain other plant derivatives obtained from *Tagetes spp. Citrus spp.*, *Solanum nigrum*, *Ageratum conyzoides* (Compositae) *Annona squamosa* (Annonaceae) have also shown insecticidal and/or growth inhibition activity against mosquitoes but their potential for mosquito control under field conditions needs to be evaluated. These plant derivatives are probable sources of some biologically active agents for mosquito control in the future.

Since most of the plant based products are not as effective as synthetic insecticides and do not produce fast results, their use for mosquito control in a large scale

programme under epidemic conditions may not be acceptable. However, the use of indigenous plant based products by individual and communities can provide a prophylactic measure for protection against various mosquito- borne diseases. There is a need for promoting the use of herbal products through community based vector control programme.

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