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Larvicidal potential of some plants from West Africa against *Culex quinquefasciatus* (Say) and *Anopheles gambiae* Giles (Diptera: Culicidae)

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ABSTRACT

Background & objectives: Mosquitoes increased resistance to insecticides, and environmental concerns about the use of insecticides, pose a major challenge in the search for new molecules to deplete and incapacitate mosquito populations. Plants are the valuable source as practices consisting in exploiting plant materials as repellents, and are still in wide use throughout developing countries. The aim of the present study was to screen plants from Côte d'Ivoire for larvicidal activity against mosquitoes.

Methods: Resistant and sensitive larvae (III and IV instar) of *Anopheles gambiae* and *Culex quinquefasciatus* were exposed to crude ethanol extracts (90%) of 45 plants and viability observed after 30 min, 6, 12 and 24 h post-incubation. After partition of active extracts, each fraction (hexane and chloroform washed with NaCl 1%, tannins and aqueous) was tested using the same protocol at various concentrations (1000–31.2 ppm).

Results: Of 49 extracts tested, 7 exhibited high potential (LC_{50} = 80 to 370 ppm) against resistant and sensitive III and IV instar larvae of *An. gambiae* and *Cx. quinquefasciatus*. These extracts were from *Cissus populnea*, *Cochlospermum planchonii*, *Heliotropium indicum*, *Phyllanthus amarus*, *Vitex grandifolia* and *Alchornea cordifolia*. However, three most active plant species (LC_{50} = 80–180 ppm) were *Cs. populnea*, *Cm. planchonii* and *P. amarus*. Their hexane and chloroform fractions showed high larvicidal activity.

Conclusion: This study demonstrated that plants from Côte d'Ivoire have a real potential for malaria, yellow fever, filarial and dengue vector control. Those could be used as sources or provide lead compounds for the development of safe plant-based biocides.

Key words *Anopheles gambiae; Culex quinquefasciatus;* larvicidal activity; plants; phytochemistry; West Africa

INTRODUCTION

More than two billion people, mostly in tropical countries are at risk from mosquito-borne diseases such as malaria, dengue, haemorrhagic fever and filariasis[1]. These infectious diseases mainly impact the tropic's poorest people. An estimated 50 million people are infected with dengue each year[2]. Malaria has a crippling effect on Africa's economic growth and perpetuates vicious cycles of poverty[3]. Approximately 300–500 million clinical cases and >1 million deaths are recorded every year[4].

The responsible pathogens are transmitted by bites of blood sucking mosquitoes which are considered to be harmful towards the populations in tropical and subtropical regions[5]. The genera *Culex*, *Aedes* and *Anopheles* are the most important vectors involved in diseases transmission to humans.

Although there are proven strategies to control mosquito-borne diseases, mosquitoes still cause a huge public health problem in Africa. Across African people are exposed to mosquito bites because the larval habitats are widely distributed in humid areas such as flood areas and rice farms. These sites with larvae might be altered to decrease the mosquito population for the interruption of disease transmission. One of the strategies recommended by WHO is the use of organochlorines (DDT, endosulfan), organophosphates (parathion, temephos) and carbamates. However, these chemical interventions are severely compromised by the development of insecticide resistance in some mosquito vectors and environmental concerns[6–8]. Also in many African countries the most widely tested interventions based on bednets treated with pyrethroid, have been difficult to implement correctly because of problems related to cost and acceptability[8,]

This situation highlights the need to search for new efficient products with fewer effects on environment[9]. Recently the environmentally safe and biodegradable, natural products of plants have been considered as alternative sources in the control of insects of public health importance[10]. Natural products contain a range of bioactive com-

Table 1. Plant species selected for larvicidal screening

Voucher No.	Plant species	Common names (English)	Families	Tested organ
6470	*Acacia flava* Forsk.	Flood-plain acacia	Mimosaceae	Leaves
2308295	*Acacia nilotica* L.	Babul acacia	Mimosaceae	Leaves
2308811	*Acacia polyacantha* Wild	Catechu tree	Mimosaceae	Stem bark
5867	*Aframomum spectrum* Oliv. Hanb	Bear berry	Zingiberaceae	Leaves
8429	*Afzelia africana* Sn et Perr	Apa, Pod mahogany	Caesalpiniaceae	Leaves
19839	*Alchornea cordifolia* Muell. Arg	Christmas bush, dovewood	Euphorbiaceae	Leaves
16004	*Allophyllus africanus* Beauv.	African false currant, African Allophyllus	Sapindaceae	Roots
2309690	*Andira inermis* Kunth ex DC	Angelin, Dog almond, Bastard mahogany	Fabaceae	Leaves
6138	*Apodostigma pallens* Planch. ex Oliv.	Not found	Hyppochrateaceae	Leaves and stem
4650	*Baissea multiflora* A. DC	Not found	Apocynaceae	Roots
2308107	*Bobgunnia madagascariensis* (Desv.) J.H. Kirkbr & Wiersema	Snake-bean tree	Caesalpiniaceae	Roots
19945	*Bridelia ferruginea* Benth	Ira	Euphorbiaceae	Roots
2288053	*Cissus populnea* Guill. & Perr	Food gum	Vitaceae	Roots
18546	*Cochlospermum planchonii* Hook ex Planch	False cotton, Cotton plant	Cochlospermaceae	Roots
2288334	*Cola cordifolia* R. Br.	Mandingo kola	Sterculiaceae	Bark
11772	*Combretum molle* R. Br ex Don	Velvet-leaved combretum	Combretaceae	Roots, leaves and stem
113612	*Daniellia oliveri* Hutch et Dalz	West African copal, African copaiba, balsam tree, nigercopal, maaje	Caesalpiniaceae	Young leaves
115451	*Eleusine indica* L.	Goose grass, Bermuda grass, wiregrass, fowl foot	Poaceae	Leaves
66252	*Entada africana* Guill et Perr	Entada	Mimosaceae	Stem bark
68854	*Erythrina senegalensis* DC	Senegal coral tree, Parrot tree, coral tree	Fabaceae	Roots
2314388	*Fadogia erythrophloea* Hutch & Dalziel	Not found	Rubiaceae	Leaves
39365	*Ficus congensis* Engl	Swamp or hippo fig	Moraceae	Stem bark
2308048	*Heliotropium indicum* L.	Indian heliotrope, Heliotrope, cock's comb	Boraginaceae	Leaves
2309989	*Jatropha curcas* L.	Jatropha, Physic nu	Euphorbiaceae	Leaves
2303193	*Keetia hispida* (Benth.) Bridson		Rubiaceae	Leaves and stem
16507	*Khaya senegalensis* Desr. A. Juss	Dry-zone mahogany	Meliaceae	Stem bark
2309941	*Kigelia africana* Lam. Benth	Sausage tree	Bignoniaceae	Roots
2316413	*Landolphia owariensis* Smith	White-ball rubber, Vine rubber, rubber vine, ciwo	Apocynaceae	Leaves
113251	*Leptadenia pyrotechica* L.	Leptadenia	Asclepiadaceae	Leaves
1774	*Lonchocarpus cyanescens* (Schum. & Thonn.) Benth.	West African indigo	Fabaceae	Leaves
63592	*Lophira lanceolata* Van Tiegh	Dwarf red ironwood, Ironwood, ekki, meni oil tree, nambanchi	Ochnaceae	Bark
2313051	*Mimusops kummel* Bruce	Red milkwood, Bullet wood	Sapotaceae	Roots
115154	*Parkia biglobosa* Jacq R. Br	West African locust bean, Dadawa tree	Mimosaceae	Roots and stem bark
2177601	*Phyllanthus amarus* Schumach & Thonn	Black catnip, Phyllanthus, amarus plant	Euphorbiaceae	Whole plant
8693	*Phyllanthus muellerianus* Kuntze	Myrobalan	Euphorbiaceae	Leaves
2177703	*Premna lucens* A. Chev	Not found	Verbenaceae	Roots
2291444	*Pseudocedrela kostchyi* Harms	Dry-zone cedar	Meliaceae	Roots
113985	*Sclerocarya birrea* A. Rich	Marula	Anacardiaceae	Roots
70889	*Securidaca longepedunculata* Fres	Violet-tree	Polygalaceae	Roots
2308860	*Syzygium guineense* Willd DC	Water berry, Water Pear	Myrtaceae	Stem bark
2308288	*Tapinanthus dodeneifolius* DC	Not found	Loranthaceae	Leaves
20656	*Uapaca togoensis* Pax	Charcoal, somon	Euphorbiaceae	Leaves and stem bark
19621	*Vernonia guineensis* Benth	Guinean ginseng	Asteraceae	Leaves
2316528	*Vitex grandifolia* Gürke	Black plum, Chocolate berry tree	Verbenaceae	Leaves and stem bark
2293337	*Ximenia americana* Wild	False sandalwood, Blue Sourplum	Olacaeae	Roots

pounds[6] and related commercial insecticides are commonly perceived as "safe" in comparison to synthetic repellents[10]. Traditionally plant based repellents have been used for generations as protection measures against mosquitoes. These are still extensively used throughout rural communities in Benin[11], Tanzania[12] and Côte d'Ivoire. These plants are burned overnight in rooms to drive away nuisance mosquitoes. Some of these African plants have been shown to be larvicides[13, 14].

The present study investigated 45 plants from West Africa for larvicidal activity against mosquitoes as safer natural alternatives to synthetic molecules. Most of the selected plants have been used for medicinal purposes for a long time, because these are not harmful to either humans or domestic animals.

MATERIAL & METHODS

Preparation of extracts

The plant species studied were selected on the basis of criteria (Table 1), such as lack of information on activity against *Anopheles* and *Culex* larvae, botanical families (Euphorbiaceae, Verbenaceae, and Meliaceae) from which number of larvicidal plant were reported and large distribution in West Africa. Voucher specimens are deposited at the herbarium (Base ivoire) of Centre Suisse de Recherches Scientifiques en Côte d'Ivoire, Adiopodoumé.

A quantity of the different plant parts were collected from April to October 2005 in the region of Ferkessedougou (northern Côte d'Ivoire), located in the Savanna area (9–11°N, 4– 7°W) of the Côte d'Ivoire. The roots, leaves and stem bark were dried in an air-conditioned room (22°C) and pounded by hand in a mortar. A quantity of 10 g of the powder was extracted with 100 ml of 90% ethanol under mechanical stiring (150 rpm) during 24 h and then filtered. The extracts were concentrated in a rotary evaporator (Rotavapor) at 40°C and lyophilized. In all, 49 extracts have been prepared for *in vitro* larvicidal screening.

Mosquito larvae tested

The larvae included wild resistant *An. gambiae* strains, resistant *Cx. quinquefasciatus* strains, and sensitive Kisumu strain (from Kenya). The resistant strains were collected from breeding sites around the village of Adiopodoumé, located in the northern peri-urban part of Abidjan. These sites were selected because of their proximity to Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS). Breeding sites located in this village were around crop farms. After collection, the III and IV instar larvae were transferred in plastic bottles and maintained at the laboratory.

The susceptible strain (Kisumu) was provided by the insectarium of CSRS. The eggs were put in distilled water maintained at 21–22°C and safe from contaminations. Eggs hatched after 24 h and larvae were fed with powdered cat kibble.

Larval bioassays

Larvicidal activity was assessed as per the protocol previously described by WHO with slight modification[15]. The assays were performed in two steps: (i) Detection of susceptibility of larvae to extracts; and (ii) Determination of larvicidal concentration (LC_{95}). The sensitivity of the larvae to the extracts was determined at single concentration (1000 ppm). In 220 µl of distilled water or dimethylsulfoxide (DMSO) 220 mg of extract was dissolved. Then 100 µl of extract solution was added to 5 ml of water from breeding site (wild strain) or distilled water (Kisumu strain). The final volume was adjusted to 10 ml and 20 larvae were added to each tube. A control tube containing only distilled water or 0.1% DMSO was prepared. Mortality is assessed by direct observation of larvae movements. An extract is active if 100% of larvae died between 30 min and 24 h[16]. The tests were repeated three times.

The extracts showing larvicidal activity at 1000 ppm were further diluted from 1000 to 31.2 ppm. The viability of larvae was observed after 30 min, 6, 12 and 24 h and scored according to larvae movements and physiological state: 0 = Dead larvae; 1 = Low or almost absence of movement; 2 = Activity; and 3 = Hyperactivity. The number of dead larvae was counted to determine the mortality rate and monitored for determination of $KT_{50,}$ the time required to kill 50% of the larvae.

Partition of active extracts

The three most active extracts were subjected to a liquid-liquid partition with different solvents of increasing polarity. In whole 10 g of plant powder was extracted with ethanol 90% using 10-fold solvent under mechanical stiring (150 rpm) during 14 h. The filtrate was successively partitioned with hexane, chloroform and water. The chloroform fraction was washed with NaCl 1% (1 g/100 ml water) in order to remove tannins. All fractions were evaporated in a rotary evaporator to dryness at 40°C and lyophilized.

Larvicidal test with fractions prepared from active extracts

The fractions obtained from active extracts were tested

against III and IV instar larvae of *An. gambiae* and *Cx. quinquefasciatus* where 11 mg of each fraction was dissolved in 110 µl of DMSO. The test was performed as mentioned above. Mortality was assessed visually by direct observation of larvae movements. A fraction is active if 100% of larvae died between 30 min and 24 h of exposure.

TLC phytochemical analysis

Plant extracts (hexane, and chloroform) showing larvicidal activity were investigated by thin layer chromatography (TLC). TLC plates were prepared from 10 µl of extract solution (10 mg/ml in methanol) on silicagel 60 F_{254} plates (aluminum), developed in hexane-ethyl acetate (1:1) as mobile phase. After drying, the chromatograms were analyzed at 254 and 366 nm, pre- and post-spraying with specific reagents according to the nature of chemicals[17–19]. The retention factor (Rf) values were calculated, using the following formula:

$$Rf = \frac{\text{Distance moved by the compound}}{\text{Distance moved by the solvent front}}$$

RESULTS

In this study, we investigated the larvicidal activities of 45 plants, traditionally used in Côte d'Ivoire. Of the 49 ethanol crude extracts 7 (14.29%) showed high activity against III and IV instar larvae of *Anopheles* and *Culex* at 1000 ppm 24 h post-exposure. These seven extracts were obtained from six plant species: *A. cordifolia*, *P. amarus*, *H. indicum*, *C. populnea*, *V. grandifolia* and *Cm. planchonii*. Six of the extracts had effect on viability of susceptible and resistant larvae of *Anopheles*, resulting

Table 2. Mortality rates of resistant larvae of *Anopheles gambiae* and *Culex quinquefasciatus* in the presence of active plant species

Mosquito species	Concentrations (ppm)	Mortality ± S.D.				
		0.5 h	1 h	6 h	12 h	24 h
	Control (DMSO)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Anopheles gambiae	*Phyllanthus amarus*					
	1000	28.33 ± 7.64	83.33 ± 7.64	100 ± 0	100 ± 0	100 ± 0
	500	23.33 ± 7.64	70 ± 1	100 ± 0	100 ± 0	100 ± 0
	250	16.67 ± 7.67	18.33 ± 7.64	66.67 ± 7.64	100 ± 0	100 ± 0
	125	0 ± 0	0 ± 0	5 ± 0	15 ± 0	35 ± 0
	62.5	0 ± 0	0 ± 0	6.67 ± 2.89	8.33 ± 1	33.33 ± 2.89
	31.2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	Cissus populnea					
	1000	33.33 ± 7.64	78 ± 7.64	100 ± 0	100 ± 0	100 ± 0
	500	28.33 ± 7.64	73 ± 1.00	100 ± 0	100 ± 0	100 ± 0
	250	0 ± 0	11.67 ± 2.89	11.67 ± 2.89	81.67 ± 10.41	100 ± 0
	125	0 ± 0	0 ± 0.00	1.67 ± 2.89	3.33 ± .5.77	6.67 ± 7.64
	62.5	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	31.2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	Cochlospermum planchonii					
	1000	0 ± 0	0 ± 0	11.67 ± 7.64	76.67 ± 2.89	100 ± 0
	500	0 ± 0	0 ± 0	8.33 ± 2.89	71.67 ± 2.89	100 ± 0
	250	0 ± 0	0 ± 0	3.33 ± 2.89	66.67 ± 2.89	100 ± 0
	125	0 ± 0	0 ± 0	3.33 ± 2.89	18.33 ± 2.89	23.33 ± .2.89
	62.5	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	31.2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Culex quinquefasciatus	*Cochlospermum planchonii*					
	1000	0 ± 0	0 ± 0	25 ± 0	83.33 ± 7.64	100 ± 0
	500	0 ± 0	0 ± 0	16.67 ± 2.89	75 ± 1	100 ± 0
	250	0 ± 0	0 ± 0	0 ± 0	20 ± 1	25 ± 1
	125	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	62.5	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	31.2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

S.D. : Standard deviation.

in death of larvae.

Alchornea cordifolia extract exhibited activity only against Kisumu strain. The extract of *Cm. planchonii* was the only active against larvae of *Culex*. Mere weak or no effect on larvae was observed following exposure to the remaining 42 extracts.

The decrease in viability is more pronounced at high concentrations from 1000 to 250 ppm at all examination points. At the lowest concentrations, no effect on larvae was observed with any of the extracts tested. These results show a dose response activity.

Phyllanthus amarus and *Cs. populnea* caused 100% mortality of resistant larvae of *Anopheles* after 6 h contact (Table 2). The mortality rates range between 6.67 and 100% for *Anopheles* and 25–100% for *Culex*.

The most active extracts causing 100% mortality of larvae were *Cm. planchonii*, *P. amarus* and *Cs. populnea* 24 h post-incubation. For these extracts, the LC_{50} were 80–180 ppm against *Anopheles* and 370 ppm against *Culex* (Table 3). *Phyllanthus amarus* and *Cs. populnea* killed resistant *An. gambiae*, with KT_{50} ranged between 41 and 42 min. *Cochlospermum planchonii* caused death of *Anopheles* and *Culex* with KT_{50} values of 125 and 145 min respectively.

Incubation with extract of *Cm. planchonii* (Table 3) and related fractions (hexane, and chloroform) resulted in death of larvae of both *Anopheles* and *Culex*, at LC_{50} values ranging between 80 and 370 ppm (Table 4).

Following exposure to *Cs. populnea* extract, sensitive and resistant larvae of *An. gambiae* died at LC_{50} values of 80 and 180 ppm respectively. Its hexane fraction was more active (LC_{50} = 180 ppm) than the chloroform fraction, LC_{50} = 370 ppm (Table 4). The TLC phytochemical analysis revealed at least trace amount of monoterpenoids, polyphenols and alkaloids (Table 5).

In this study *P. amarus* exhibited high larvicidal potential against *An. gambiae* (LC_{50} = 80–180 ppm). Incubation with derivatives (hexane and chloroform) caused death of larvae at LC_{50} = 180–370 ppm between 12–24 h (Table 4). No effect was observed with aqueous and tannin fractions. Preliminary phytochemical studies have shown presence of monoterpenoids, flavonoids, anthrones and anthraquinones (Table 5).

DISCUSSION

Plant phytochemicals have more specific effects and could be usefully integrated with other control measures to design comprehensive, appropriate and effective management protocols with less collateral harm to the environment and non-target species[20].

Exposures to studied plants resulted in death of susceptible and resistant larvae of *An. gambiae*. For the active plant species, the mortality rates range between 6.67 and 100% for *Anopheles* and 25–100% for *Culex* after 24

Table 3. LC_{50} and LC_{95} (ppm) of ethanol extracts of active plant species on III and IV instar larvae of *Anopheles gambiae* and *Culex quinquefasciatus*

Plant species	Plant parts	*Anopheles gambiae*				*Culex quinquefasciatus*	
		Sensitive strain Kissumu		Resistant strain		Resistant strain	
		LC_{50}	LC_{95}	LC_{50}	LC_{95}	LC_{50}	LC_{95}
Cochlospermum planchonii	Roots	80	22.22	180	342	370	703
Phyllanthus amarus	Whole plant	80	22.22	180	342	ND	ND
Heliotropium indicum	Leaves	180	342	370	703	ND	ND
Cissus populnea	Roots	80	22.22	180	342	ND	ND
Vitex grandifolia	Leaves	180	22.22	370	703	ND	ND
Vitex grandifolia	Stem bark	180	342	370	703	ND	ND

ND = Not determined.

Table 4. LC_{95} and LC_{50} (ppm) of chloroform and hexane fractions

Plant species	Mosquitos species	Hexane fraction		Chloroform fraction	
		LC_{95}	LC_{50}	LC_{95}	LC_{50}
Cochlospermum planchonii	*Anopheles gambiae*	342	180	703	370
Cochlospermum planchonii	*Culex quinquefasciatus*	342	180	703	370
Cissus populnea	*Anopheles gambiae*	342	180	703	370
Phyllanthus amarus	*Anopheles gambiae*	342	180	703	370

Table 5. Possible compounds present in fractions of the most active plants

Plant fractions	Pre-derivatization				Post-derivatization										Possible types of compounds
	Rf	Visible	254 nm	366 nm	Godin			Folin-Ciocalteu		Dragendorff		KOH			
					Visible	366 nm	Rf	Visible	Rf	Visible	Rf	Visible	366 nm	Rf	
Cissus populnea (Chloroform)	0.65		Visible	Blue											ND
					Blue	0.53									Monoterpenoids
					Violet	0.56									Monoterpenoids
								Blue	0.59						Polyphenols
													Yellow	0.0	Anthrones
Cissus populnea (Hexane)	0.65		Visible	Blue											ND
					Violet		0.8								Monoterpenoids
					Violet		0.56								Monoterpenoids
					Blue		0.36								Monoterpenoids
								Blue	0.80						Polyphenols
								Blue	0.59						Polyphenols
										Orange	0.59				Alkaloids
Phyllanthus amarus (Chloroform)	0.65		Visible	Violet											ND
	0.70			Orange											ND
	0.08			Orange											ND
					Blue		0.56								Monoterpenoids
								Blue	0.53						Polyphenols
													Red	0.71	Anthraquinones
													Yellow	0.0	Anthrones
Phyllanthus amarus (Hexane)	0.65	Green	Visible	Orange											ND
				Orange											ND
					Violet		0.79								Monoterpenoids
						Orange	0.69								Flavonoids
						Yellow	0.56								Flavonoids
								Blue	0.80						Polyphenols
								Blue	0.59						Polyphenols
								Blue	0.53						Polyphenols
													Red	0.71	Anthraquinones

ND : Not determined.

h exposure. In a previous study, *Schinus terebinthifolia* essential oil displayed activity after 72 h, the mean mortality percentage ranged from 0.5 to 96.75% for *Cx. quinquefasciatus* and 13.75 to 97.91% for *An. gambiae*[12].

Cochlospermum planchonii, *Cs. populnea* and *P. amarus* extracts caused cent percent mortality of larvae 24 h post-incubation, with LC_{50} of 80–180 ppm and LC_{95} values of 22.22–342 ppm. Other active species such as *A. cordifolia*, *H. indicum* and *V. grandifolia* exhibited activity with LC_{50} and LC_{95} values ranging between 180–370 and 342–703 ppm respectively. Following partition of crude extracts and larvicidal assays, only hexane and chloroform fractions exhibited activity against larvae, with LC_{50} and LC_{95} values of 180 and 342 ppm respectively for hexane. Chloroform fraction showed LC_{50} and LC_{95} values of 370 and 703 ppm respectively. The results revealed that increased larval mortality was observed with increased concentration of the extracts tested against *An. gambiae* and *Cx. quinquefasciatus*. Similar finding was obtained against *An. stephensi* with the leaf of *Adansonia digitata*[4]. Chloroform extract of the plant showed LC_{50} and LC_{90} values of 88.55 and 168.14 ppm respectively, while its hexane extract showed LC_{50} and LC_{90} of 111.32 and 178.63 ppm respectively in 24 h. However, in the present study, hexane fractions displayed stronger potential than chloroform fractions against *An. gambiae* and *Cx. quinquefasciatus*.

The KT_{50} values ranged between 41–125 and 145 min against resistant *An. gambiae* and *Cx. quinquefasciatus* respectively. Previous study demonstrated that the time required to knock down 50% of the wild adult *An. gambiae* in Tanzania was 11.29 min for *S. terebinthifolia* essential oil[12].

The larvicidal activity of some studied plants such as *Cm. planchonii*, *H. indicum* and *A. cordifolia* was reported against *Ae. aegypti*[14]. The ethanolic extracts of these species caused death of larvae 30 min and 24 h post-incubation respectively at single concentration tested of

500 µg/ml. The present study gave further data on the potential use of these plants against malaria, yellow fever, filarial and dengue vector control.

The active plants contain phytochemicals such as monoterpenoids and flavonoids. The fresh rhizomes of *Cm. planchonii* yield essential oils, with a high rate of oxygenated compounds (86.4% of ketones and esters)[21]. *Cissus populnea* and *P. amarus* also contained essential oils[22, 23]. Several authors have demonstrated strong responses of mosquito odour receptors to volatiles produced by plants. Essential oils were found to be larvicidal against *Anopheles* and *Culex*[17, 24, 25]. The finding of the present study is in line with the high potential of non-polar (dichloromethane, chloroform and hexane) extracts[4, 19] demonstrated against mosquito larvae.

The selection of plants based on their botanical family or genus can be valuable criteria for identifying high larvicidals. Of the 7 active species, 2 were Euphorbiaceae. Several species of this family were reported to be larvicidal against mosquitos. *Ricinus communis*[26], *Acalypha indica*[27], and *Acalypha alnifolia*[1] have shown activity against resistant and susceptible *Anopheles* and *Culex* larvae. *Alchornea cordifolia*, *Bridelia aubrevillei* and *B. grandis* caused death of *Ae. aegypti*[18]. Thus, Euphorbiaceae is a promising family for vector control.

Vitex grandifolia displayed activity on resistant and susceptible larvae of *Anopheles*; disappointingly in this study, the species lacked activity against *Cx. quinquefasciatus.* Other species of the same genus, *V. trifolia*, *V. peduncularis* and *V. altissima* exhibited activity on IV instar larvae of *Cx. quinquefasciatus*[28]. The extract of *V. negundo* was repellent against adult mosquitoes[29]. Therefore, there is no doubt that *Vitex* spp are of great interest in control of mosquitoes.

This is the first hand report of the larvicidal activity of studied plants discussing whether some are well-known for treating malaria. Phytochemical investigations, repellent study and field evaluation are ongoing.

CONCLUSION

In the present study, the larvicidal potential of 45 plants from West Africa was evaluated against sensitive and resistant *An. gambiae* and *Cx. quinquefasciatus*. Some of these plants exhibited high larvicidal activity. The results show that some of plants traditionally used in West Africa could gain place in control of African malaria vectors. The efficacy exhibited by these plants has given an opportunity for further investigation on eggs and adult mosquitoes and to evaluate them in small-scale field trials.

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