academicJournals

Vol. 9(6), pp. 179-192, 10 February, 2015
DOI: 10.5897/JMPR2014.5685
Article Number: 915206C50871
ISSN 1996-0875

http://www.academicjournals.org/JMPR

Journal of Medicinal Plants Research

Full Length Research Paper

Ethnobotanical survey and *in vitro* antiplasmodial activity of medicinal plants used to treat malaria in Kagera and Lindi regions, Tanzania

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Received 10 November, 2014; Accepted 5 February, 2015

Tanzania has over 12,000 plant species, some of which are endemic and have potential to yield useful medicines. This study seeks to document such plants used as traditional medicines for treatment of malaria in Kagera region of northwestern Tanzania and Lindi region in south eastern Tanzania. The study also reports on the antiplasmodial activity against chloroquine-resistant *Plasmodium falciparum* (Dd2) strain of some of the documented plants using the parasite lactate dehydrogenase method. A total of 108 plant species, among which the families Compositae (14; 12.96%), Fabaceae (12; 11.11%), Euphorbiaceae (8; 7.41%), Melastomataceae (6; 5.56%) and Myrtaceae (4; 3.70%) were documented. Sixteen (16; 44.4%) of 36 extracts from 31 plant species that were tested inhibited malaria parasites growth by more than 50%. *Bersema abyssinica* stem bark extract was the most active with 86.67% inhibition rate followed by *Bridelia micrantha* stem bark extract with 71.87% inhibition rate. These results confirm the potential for plants used in traditional medicine to yield active antimalarial compounds. Further *in vitro* and *in vivo* screening supported by bioassay-guided isolation of active compounds from plants showing good safety margin is suggested.

Key words: Ethnobotanical survey, medicinal plants, malaria, treatment, *in vitro* antiplasmodial, Tanzania.

INTRODUCTION

Human malaria is caused by five *Plasmodium* species namely; *P. falciparum*, *P. vivax*, *P. ovale*, *P. malariae* and *P. knowlesi,* but *Plasmodium falciparum* is the most widespread and virulent species (World Health

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Organization (WHO), 2013; Cox-sigh and Singh, 2008). Malaria in Tanzania is mainly caused by *P. falciparum* with *Anopheles gambiae* complex being the main vector United States Agency for International Development (USAID, 2014). Tanzania has high malaria prevalence and it is among six African countries that have many reported cases of malaria, with an estimated 10 to 12 million cases and 60,000 to 80,000 malaria-related deaths per year (USAID, 2014; WHO, 2012). Although the Tanzania HIV/AIDS and Malaria Indicator Survey (2011/2012) reported a decrease in the prevalence of malaria in Tanzania, the trend remains unchanged. Prevalence is still high in rural areas and the Lake Victoria zone as compared to other parts of the country Tanzania Commission for AIDS (TACAIDS, 2013).

Malaria is a curable disease that is treated by both modern drugs and herbal medicines (Kinung'hi et al., 2010; Gessler et al., 1995). However, the emergence of *P. falciparum* strains resistant to almost all classes of antimalarial drugs dictates that efforts be increased to develop new antimalarial drug candidates (Dondorp et al., 2009; Wongsrichanalai et al., 2002). Since most antimalarial drugs that are currently being used like quinine and artemisinin derivatives originate from traditionally used medicinal plants (Wells, 2011), this source has a great potential to provide new antimalarial molecules.

Tanzania is estimated to have over 12,000 higher plant species, of which 10% are used for medicinal purposes, and may yield active antimalarial compounds (Mahunnah et al., 2012). Previous reports confirm that some of these plants are used in traditional medicine for treatment of malaria (Gessler et al., 1995), and malaria is leading among diseases that are popularly treated with medicinal plants (Moshi et al., 2009; Mahunnah, 1987). Some of these plants have been reported in previous studies (Moshi et al., 2009; Gessler et al., 1995; Mahunnah, 1987), but many have not been documented and only a few have been tested for antimalarial activity. Therefore, this study reports plant species used for treatment of malaria in Kagera and Lindi regions of Tanzania and results of some of the plants that were screened for *in vitro* antiplasmodial activity.

MATERIALS AND METHODS

Documentation, identification and collection of the medicinal plants used for treatment of malaria

Disease-specific ethnobotanical survey was conducted in six villages in Kagera region (North-west of Tanzania) and one village in Lindi region (South east of Tanzania). In Kagera region the study was conducted in November, 2012 in Buzi Bukombe, Buzi Kishura and Kwamkenge villages in Bukoba rural district, Buleza village in Muleba disctrict, Rwambaizi village in Karagwe district, and Kashozi village in Misenyi district. The study in Lindi region was conducted in July, 2012 in Mchakama village located in Kilwa district. Information was collected from well known and experienced traditional healers and herbalists who were informants in a previous ethnomedical study (Moshi et al., 2009). Before collecting information all the participants were informed about the study objectives and agreed to participate by signing an informed consent form. Vernacular names of the plants, part(s) used, method for preparation, route of administration and possible signs of toxicity were documented. Preliminary identification was done by a Botanist, Mr. Haji. O. Selemani, in the field and further authenticated in the Herbarium. Voucher specimens are deposited in the Herbaria at Muhimbili University of Health and Allied Sciences and at the Botany Department, University of Dar es Salaam. The selection of the plants to be tested for antimalarial activity was based on absence in the literature of previous antimalarial testing, reported antimalarial use in other countries or emphasis made by the traditional healers regarding efficacy for malaria treatment. This study received ethical clearance (Ref. No. MU/DRP/AEC/Vol.XIII/01st August 2011) from the Muhimbili University of Health and Allied Sciences Institutional Review Board.

Preparation of extracts

Dry powdered plant materials were macerated in 80% ethanol, at room temperature, for 24 h and then filtered through cotton wool to separate the liquid crude extracts from the solid materials. The solid plant materials were macerated again in the same solvent for another 24 h and the extracts obtained from the first and the second extractions were mixed before drying. The liquid crude extracts were concentrated under *vacuo* by using Heldolph® rotary evaporator (Heldolph instruments GmbH, Schwabach, Germany) to obtain viscous extracts which were further dried by using a freeze drier (Edwards High Vacuum International, Crawley Sussex, England).

In vitro antiplasmodial screening

Malaria parasites

Blood stage chloroquine-resistant *P. falciparum* Dd2 strains (*Pf* Dd2; MRA-156 deposited by TE Wellems, Lot# 59443398) were used. The parasites were donated to the University of Buea in Cameroon by BEI-resources (MR4/ATCC® Manassas, VA, USA).

Malaria culture medium

RPMI-1640 (Lot# RNBC 8874) culture medium with L-glutamine and 20 mM HEPES (Sigma®, Steinheim, Germany) was used.

In vitro culture of malaria parasites

P. falciparum Dd2 laboratory strains were maintained in culture according to the method of Trager and Jensen (Trager and Jensen, 1976) with modifications (Zofou et al., 2013). The parasites were grown in O^+ red blood cells (RBCs) maintained in complete malaria culture medium composed of RPMI-1640 medium supplemented with 2 mg/ml $NaHCO_3$, 10 µg/ml hypoxanthine, 2 mg/ml glucose, 1% albumax II as source of proteins, lipids and 10 µg/ml gentamicin. The cultures were incubated at 5% CO_2, 5% O_2, 90%

N_2 in a humidified incubator set at 37°C (SHEL LAB® Sheldon Mfg Inc, OR, USA). All materials were purchased from SIGMA (Sigma®, Steinheim, Germany) except Albumax II (GIBCO™, Invitrogen) and gentamicin (ROTEX MEDICA, Trittau - Germany) which were supplied locally in Cameroon.

Preparation of plant extracts and standard drug

Stock solutions of 400 µg/ml for each crude extract was prepared by first dissolving 4 mg of crude extract into 100 µl dimethyl sulfoxide (Sigma®) followed by addition of RPMI-1640 medium to 10 ml. Artemether (Sigma®) was first dissolved in dimethyl sulfoxide and then diluted with RPMI-1640 medium to 5 µg/ml. All solutions were sterilized by using 0.22 µm syringe-adapted filters (Corning®, NY, USA) and stored at 4°C until use.

In vitro antiplasmodial activity assay

In vitro antiplasmodial activity was assessed using the parasite lactate dehydrogenase (pLDH) assay (Makler et al., 1993). Non-synchronized 1% parasitized red blood cells (pRBCs) at 2% haematocrit (hct) in 96 well cell culture plates (Costar®, Corning, NY, USA) were incubated in triplicates with 100 µg/ml crude extracts or with 1.25 µg/ml artemether. Wells with parasitized cells but without extract or drug served as negative controls (100% parasite growth) and wells without parasitized cells but with red blood cells only at 2% hct served as blank controls. The plates were incubated for 48 h at 37°C in a humidified incubator set at 5% CO_2, 5% O_2, 90% N_2. After incubation for 48 h parasite growth was confirmed by the aid of a light/UV fluorescence microscope (TENSION®, China) with Acridine orange filter (λmax Abs = 490 nm; λmax Em = 525 nm) and a counting device (Lennox Grain Analysis NG NG21, SPI®, USA) before the plates were frozen overnight at -20°C. In the pLDH assay the plates were thawed at room temperature to hemolyse red blood cells, and the 10 µL of malaria culture were incubated with 50 µL Malstat solutions and 12.5 µL nitroblue tetrazolium/phenazine ethosulfate for 1 h in darkness. Parasite growth was determined by measuring the activity of pLDH enzymes at 650 nm using a microplate reader (Emax-Molecular Devices Corporation, California, USA) and the optical density (OD) values obtained were used to calculate antiplasmodial activity. The average OD value of the blank control (2%hct RBC only) was subtracted from all OD values. The antiplasmodial activity was expressed as percentage inhibition rate of parasites growth.

$$\%\text{Growth inhibition rate (\%IR)} = \frac{(\text{OD negative control} - \text{OD treated})}{\text{OD negative control}} \times 100$$

RESULTS

Documentation and identification of medicinal plants used for treatment of malaria in Kagera and Lindi regions, Tanzania

A total of 108 plants species distributed into 41 plant families were documented and identified in six villages in Tanzania (Table 1). Fourteen plant species (12.96%) belonged to the family Compositae, 12 plant spp (11.11%) belonged to Fabaceae, 8 plant spp (7.41%) belonged to Euphorbiaceae, 6 plant spp (5.56%) belonged to Melastomataceae and 4 plant spp (3.70%) belonged to Myrtaceae. The families Anacardiaceae, Graminae, Labiatae, Meliaceae and Rutaceae each had 3 plant spp (2.78%) while other families were represented by 2 or 1 plant spp (Figure 1). The reported medicinal plants were identified as trees (37%), herbaceous plants (34%), shrubs (20%), climbers (5%), grass (2%) and wood climbers (2%) as shown in Figure 2. In addition, all the reported medicinal plants are administered orally, mostly as decoctions. Boiling was the most common method of preparation (Table 1). Leaves were the most used part of the plants, representing 46% of all plant parts reported followed by stem bark (19%), aerial parts (15%), roots (8%), whole plants (4%), seeds (4%), fruits (3%) and whole stem (1%) as shown in Figure 3.

In vitro antiplasmodial activity of the extracts

The results reported in Table 2 show that 16 (44.4%) out of the 36 extracts of 31 plant species that were tested inhibited the growth of the chloroquine-resistant Dd2 malaria parasite strains by more than 50%. The extract of *Bersema abyssinica* stem barks was the most active with 86.67% inhibition rate followed by the extract of *Bridelia micrantha* stem barks which inhibited parasite growth by 71.87%. The ethanol extracts of *Anthocleista grandiflora* stem barks*, Funtumia Africana* stem bark and leaves, and extracts from leaves of *Vernonia glabra, Ipomoea rubens*, *Pycnanthus angolensis*, *Eriobotrya japonica* and *Oxyanthus speciosus* were the least active with growth inhibition rate of less than 30% against the chloroquine-resistant Dd2 strains (Table 2).

DISCUSSION

The results of the current study support results of previous ethnobotanical studies done in Tanzania and outside Tanzania. In previous studies *Abrus precatorius*, *Adansonia digitata, Azadirachta indica*, *Cassia*

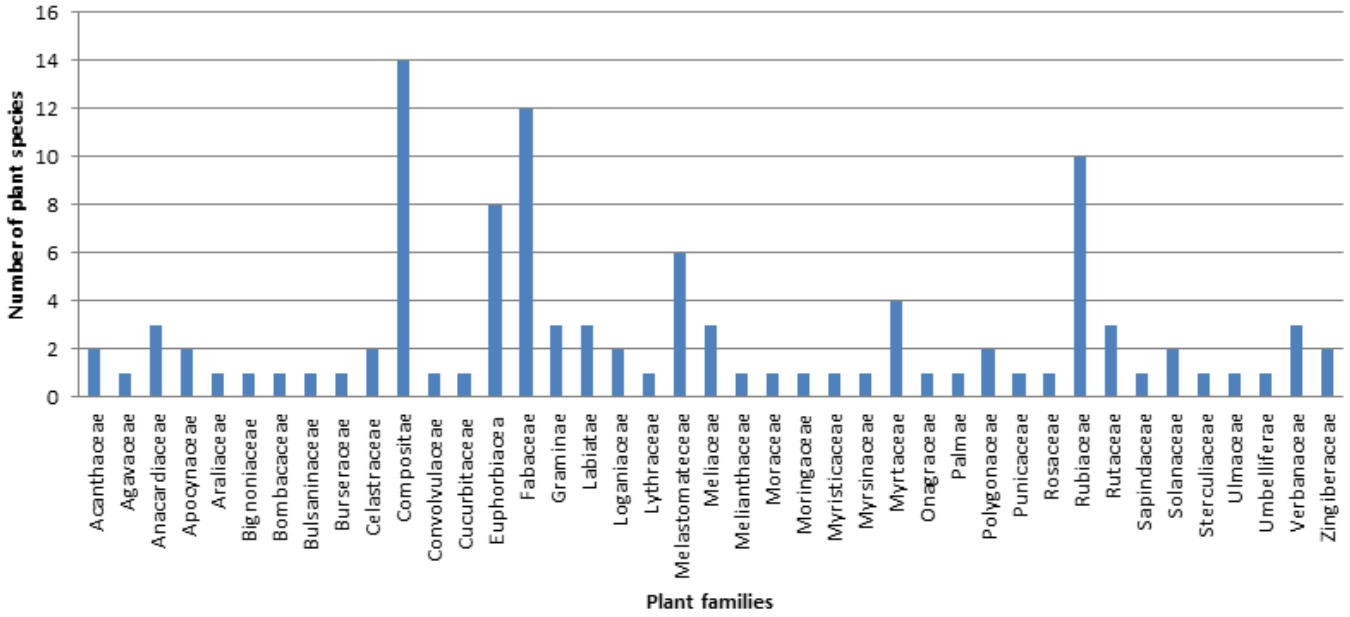

Figure 1. Distribution of plant species into different families

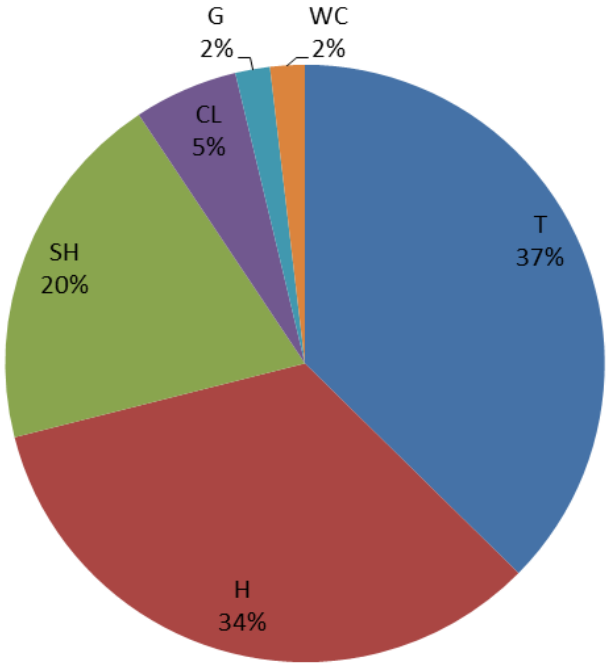

Figure 2. Percentage use of different types of plants. WC = wood climber, G = grass, SH = shrub, CL = climber, T = tree, H = herbs

didymobotrya, *Dombeya shupangae, Ethrina sacleuxii*, *Lantana camara*, *Mangifera indica*, *Maytenus senegalensis*, *Momordica foetida*, *Parinari excelsa*, *Pseudospondias microcarpa*, *Psidium guajava*, *Syzygium*

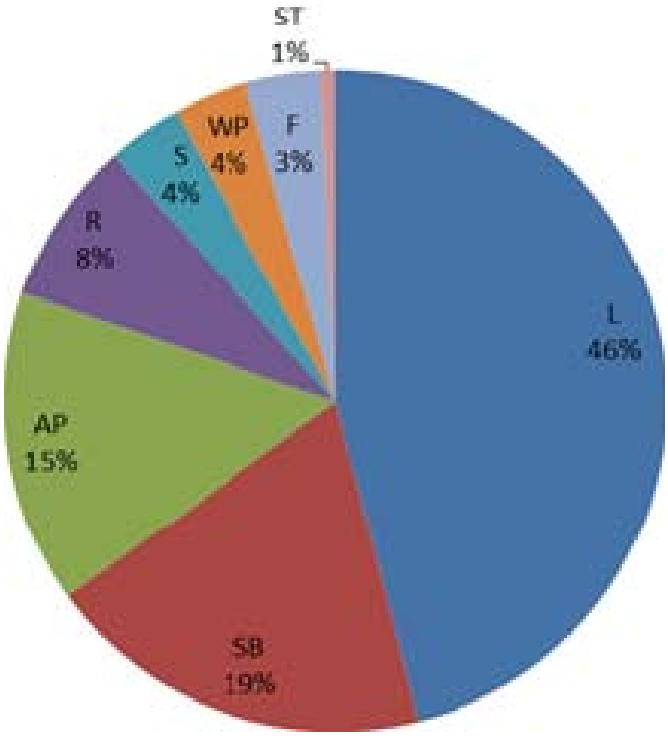

Figure 3. Percentage use of different plant parts. L = leaves, F = fruits, S = seeds, WP = whole plant, R = root, SB = stem bark, ST = whole stem, AP = aerial part.

cordatum, *Todalia asiatica*, *Vangueria infausta*, *Vernonia amygdalina*, and *Zanthoxylum chalybeum* were reported to be used in the treatment of malaria in Tanzania and some of them have shown good *in vitro* antimalarial activity against multi-drug resistant *P. falciparum* K1 malaria parasites (Amri et al., 2012; Augustino et al., 2011; Gessler et al., 1994; Weenen et al., 1990). Similarly, *Erythrina abyssinica*, *Markhamia lutea*, *Teclea nobilis*, *Adansonia digitata*, *Lantana camara*, *Azadirachta indica*, *Zynthoxylum chalybeum, Maytenus senegalensis*, *Vernonia amygdalina*, *Momordica foetida*, *Mangifera indica*, *Moringa oleifera*, *Leonotis nepetifolia*, *Maesa lanceolata, Psidium guajava, Funtumia africana, Canna indica, Cymbopogon citratus* and *Pycnanthus angolensis* are used in traditional medicine for malaria treatment in Kenya, Uganda, Cameroon and Nigeria (Lacroix et al., 2011; Nguta et al., 2010; Tabuti et al., 2008; Titanji et al., 2008; Katuura et al., 2007; Odugbemi et al., 2007).

It is notable that some of the reported plants belong to the families Compositae (13%), Euphorbiaceae (7.4%), Fabaceae (11.1%), and Rubiaceae (9.2%) which are known to contain chemical compounds with good antimalarial properties (Ntie-Kang et al., 2014; Batista et al., 2009). The study has provided useful information that supports traditional healers' claims for antimalarial activity and earlier observations that plants used in traditional medicine are a potential source of new antimalarial lead compounds (Onguéné et al., 2013; Bero et al., 2009).

All the extracts tested for *in vitro* antiplasmodial activity at 100 µg/ml inhibited the growth of malaria parasites to different percentages. *Bersama abyssinica, Bridelia micrantha, Canarium schweinfurthii* and *Antiaris toxicaria* stem bark extracts; *Aspilia natalensis*, *Aspilia mossambicensis* and *Desmodium salicifolium* aerial part extracts; *Maesa lanceolata* and *Rhytignia obscura* leaf extracts; *Pycnanthus angolensis* fruit and *Hallea rubrostipulata* root extracts inhibited parasite growth by more than 60%. The ethanol extract of *B. abyssinica* was the most active with 86.67% inhibition rate against Dd2. In a previous study Kassa et al. (1996) reported that the ethanol extract of *B. abyssinica* stem bark exhibited good *in vitro* antimalarial activity against *P. falciparum* tine-FAC-2/ Ethiopia with IC_{50} = 11 µg/ml. Similarly, a study done in Cameroon by Ngemenya et al. (2005) showed that the methanol extract of *B. abyssinica* leaves exhibited good *in vitro* antiplasmodial activity with an IC_{50} of 2.7 µg/ml. Meanwhile, the chloroform extract of *M. lanceolata* was reported to exhibit very good antiplasmodial

Table 1. Medicinal plants used traditionally in the treatment of malaria in Kagera and Lindi regions, Tanzania

Family	Plant species	Vernacular name	Nature	Part (s) used	Preparation	Voucher number
Acanthaceae	*Acanthus pubescens* (Oliv.) Vatke	Amatoju	SH	R, L	Decoction	RN 01
	Thunbergia alata (Sims)	Wankula	CL	WP	Decoction	RN 02
Agavaceae	*Dracaena steudneri* Engl.	Omugorogoro	T	SB	Decoction	RN 03
Anacardiaceae	*Pseudospondias microcarpa* (A. Rich) Engl	Omuziru	T	L	Decoction	RN 04
	Rhus vulgaris Meikle	Omukanja	SH	R, L, F	Root and leaf Decoction. Ripe fruits eaten	RN 05
	Mangifera indica L.	Omnembe, Mwembe	T	SB	Decoction	RN 06
Apocynaceae	*Funtumia africana* (Benth) Staff	Mwezamaino, Omwelamaino	T	L	Decoction	RN 07
	Holarrhena pubescens (Huch – Ham) G.Don	Nalupande	SH	R	Decoction	4665
Araliaceae	*Schefflera goetzenii* Harms	Olugogome	T	SB, L	Decoction	RN 08
Bignoniaceae	*Markhamia lutea* (Benth) K. Schum	Omushambya	T	SB	Decoction	RN 09
Bombacaceae	*Adansonia digitata* L.	Mbuyu	T	L, F	Leaves are eaten like vegetables. Powder from dry fruits used to make juice	RN10
Bulsaninaceae	*Impatiens gomphophylla* Bak.f	Olwita mkole	H	L	Decoction	RN 11
Burseraceae	*Canarium schweinfurthii* Engl.	Omubafu wa kike/muubani wa kike	T	SB, L	Decoction	RN 12
Celastraceae	*Salacia lovettii* N. Hallé & B. Mathew	Omzindabikaka	T	SB, L	Decoction	RN 13
	Maytenus senegalensis (Lam.) Exel	Omunyaburiko	T	SB, L	Decoction	RN14
Compositae	*Bidens schimperi* Sch. Bip ex Walp	Orwongwa	H	AP	Fresh aerial parts pounded then mixed with clean water, taken orally.	RN 15
	Aspilia mossambicensis (Oliv.) Wild	Eshurwa rusharila, Esisa	H	AP, WP	Fresh aerial parts pounded then mixed with clean water, taken orally.	RN 16
	Gynura scandens O. Hoffm	Ekizimya mulilo	CL	L	Fresh leaves squeezed to get juice. Juice taken orally	RN17
	Vernonia colorata (Wild.) Drake	Ekishura	SH	L	Decoction	RN 18

Table 1. Cont'd

	Vernonia amygdalina Delile	Omubilizi	T	L	Decoction	RN 19
	Crassocephalum mannii (Hook.f) Milne-Redh	Omugango	T	SB, L	Decoction	Voucher not collected
	Crassocephalum vitellinum (Benth) S. Moore	Ekishenda	H	AP, L	Decoction or fresh leaves squeezed to get juice, taken orally.	RN 20
	Aspilia pluriseta (Schweinf)	Lusharila eshurwa	H	AP	Decoction	RN 21
	Bidens pillosa L.	Akakururа	H	AP	Decoction	RN22
	Aspilia natalensis (Sond) Wild	Kanyamoisa	H	L	Decoction. Fresh leaves squeezed and liquid obtained applied in the nose	RN 23
	Melanthera scandens (Schum &Thonn) Roberty	Omlela	H	L	Decoction	RN 24
	Guizotia scabra (Vis.) Chiov	Echihongosheija	H	L	Decoction	RN 25
	Senecio spp	Ekikarabwe	H	L	Decoction	Voucher not collected
	Vernonia glabra (Steetz) Vatke	Msangusangu	H	L	Decoction	4664
Convolvulaceae	*Ipomoea rubens* Choisy	Kataba	CL	L	Decoction	RN 26
Cucurbitaceae	*Momordica foetida* Schum.	Orwihula	SH	WP	Decoction	RN 27
	Alchornea cordifolia (Schum & Thonn) Müell. Arg	Omujululuzi	SH	L	Decoction or young fresh leaves pounded then mixed with water, taken orally	RN 28
	Sapium ellipticum (Hochst.) Pax	Omushasha	T	L, SB	Decoction of leaves or stem bark. Fresh leaves can be used to prepare cold infusion	RN 29
Euphorbiace	*Phyllanthus nummulariifolius* Poir	Karungi	H	AP	Decoction	RN 30
	Ricinodendron heudelotii (Baill) Pax	Kabaka njagala	SH	L	Decoction	RN 31
	Croton macrostachyus Dell	Omwowa	T	SB	Decoction	RN 32
	Bridelia micrantha (Hochst.) Bail	Omushamako	T	R,SB	Decoction	RN 33
	Acalypha indica L.	Obweya	H	L, S	Decoction	RN 34
	Canna indica L.	Maruru	H	S	Seeds grounded, powder used to make warm infusion.	RN 35
	Erythrina abyssinica D.C	Omulinzi	T	SB	Decoction	RN 36
Fabaceae	*Cassia didymobotrya* Fress	Omulembelembe	SH	L	Decoction	RN 37
	Desmodium salicifolium (Poir) DC	Batengeliange/Omukongoranwa	H	AP, L	Decoction	RN 38

Table 1. Cont'd.

	Tephrosia aequilata Bak	Endalabugazi	H	WP	Decoction	Voucher not collected
	Kotschya africana Endl.	Ekyangwe ekiango	H	AP	Decoction	RN 39
	Eriosema parviflorum E. Mey	Mshelere	H	L	Decoction or fresh leaves squeezed to get juice, taken orally	RN 40
	Dalbergia malangensis E.P Sousa	Omugorora	WC	L	Decoction	RN 41
	Macrotyloma axillare (E. Mey) Verdc	Akaihabukuru	CL	AP	Decoction	RN 42
	Indigofera arrecta A. Rich	Omusoroka	H	AP	Decoction or aerial parts pounded then mixed with water, taken orally.	RN 43
	Abrus precatorius L.	Karigoligo	CL	L	Fresh leaves pounded then mixed with water, taken orally.	RN 44
	Erythrina schliebenii Harms	Mlindimila	T	SB	Decoction	4661
	Erythrina sacleuxii Hua	Mlindimila	T	SB	Decoction	4662
Graminae	*Pennisetum purpureum* Schum	Olutete	G	L	Decoction	RN 45
	Vossia cuspidata (Roxb) Grift	Ekishararago	G	L	Decoction	RN 46
	Cymbopogon citratus L.	Mchaichai	G	L	Hot infusion	RN 47
Labiatae	*Platostoma africanum P.* Beauv.	Nyanjaeyera	SH	AP	Dry powder used to make warm infusion	RN 48
	Leonotis nepaetifolia (L.) R. Br	Ekitatelante	H	L	Decoction	RN 49
	Ocimum kilimandscharicum Gürke	Kaswagara	H	S	Powder from dry seeds used to make warm water infusion	RN 50
Loganiaceae	*Anthocleista grandiflora* Gilg	Mgabaigana	T	L, R, SB	Decoction	RN 51
	Strychnos spinosa Lam.	Orurema	SH	L	Dry powder used to make warm infusion or decoction bathed to children	Voucher not collected
Lythraceae	*Lawsonia inermis* L.	Eina	H	L, S	Leaf decoction. Powdered seeds used to make warm infusion	RN 52
Melastomataceae	*Dissotis rotundifolia* (Sm) Triana	Obwehehe/Obwee	H	AP	Decoction or fresh aerial parts pounded then mixed with clean water, taken orally	RN 53
	Melastomastrum capitatum (Vahl) A. & R. Fern)	Katuntun	H	AP	Fresh aerial parts pounded then mixed with clean water. Dry aerial parts used to prepare warm infusion	RN 54

Table 1. Cont'd.

	Dissotis melleri Hook.f.	Ekituntun/Etuntun	H	AP	Aerial parts pounded then mixed with water, taken orally	RN 55
	Melastomastrum segregatum (Benth) A.& R Fern.	Eitulu	H	AP	Decoction or cold infusion.	RN 56
	Dissotis brazzae Cogn	Bulitulo	H	AP	Decoction	RN 57
	Pilea holstii Engl.	Omufura/Eimyo	SH	L	Fresh leaves squeezed then mixed with water, taken orally.	RN 58
	Trichilia emetica Vahl.	Omushunguti, Mushunguti	T	SB, L	Decoction	RN 59
Meliaceae	*Pseudobersama mosssambicensis* (Sim) Verdc	Omusiibi	T	SB, L	Decoction	Voucher not collected
	Azadirachta indica A. Juss.	Mwarobaini	T	L	Decoction	RN 60
Melianthaceae	*Bersama abyssinica*	Omujalya	SH	R, SB, L	Decoction	RN 61
Moraceae	*Antiaris toxicaria* (Pers) Lesch	Omujuju	T	SB, L	Decoction	RN 62
Moringaceae	*Moringa oleifera* (Lam.)	Mlonge	T	L	Decoction. Dry powder used to make warm infusion	RN 63
Myristicaceae	*Pycnanthus angolensis* (Welw.) Warb	Omunonoba	T	SB	Decoction	RN 64
Myrsinaceae	*Maesa lanceolata* Forsk	Omuzilanyama/ Omuhanga	T	RB, SB, L	Decoction	RN 65
	Syzygium guineense (Willd.) DC	Omuchwezi	T	L	Decoction	RN 66
	Syzygium cordatum Krause	Omugege	SH	SB, L	Fresh leaves or stem barks grounded then mixed clean with water, taken orally	RN 67
Myrtaceae	*Syzygium cumini* (L.) Skeels	Mzambarau	T	SB, L, F	Decoction of stem bark or leaf. Ripe fresh fruits eaten	RN 68
	Psidium guajava L.	Mpera	T	L	Fresh leaves pounded then mixed with clean water, used orally	RN 69
Onagraceae	*Ludwigia octovalvis* (Jacq.) Haven *ssp. brevisepala* (Brenan) P.H. Raven	Wejunge	H	L	Decoction	RN 70
Palmae	*Raphia farinifera* (Gaertn) Hyl.	Omubobo	T	ST, R	Decoction	Voucher not collected

Table 1. Cont'd.

Polygonaceae	*Polygonum senegalense* Meisn	Kinyanyanja	H	AP	Decoction or aerial parts pounded then mixed with water, taken orally.	RN 71
	Rumex abyssinica	Akanulilizi	H	AP	Aerial parts pounded then mixed with water, taken orally	RN 72
Punicaceae	*Punica granatum* L.	Omukomamanga	T	F	Outer part of the fruits dried then powdered. Powder used to make warm infusion	RN 73
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl	Musharazi/Omusharazi	T	R, SB, L	Root decoction. Powdered dry stem barks and leaves used to prepare warm infusion. Fresh fruits eaten.	RN 74
Rubiaceae	*Spermacoce princeae* (K. Schum) Verdc	Ekaiza nkoju	H	AP	Decoction	RN 75
	Psydrax parviflora (afzel) Bridson ssp. *Rubrocostata* (Robyn) Bridson	Omushangati	T	SB, L	Decoction of SB or leaves. Fresh leaves squeezed to get juice.	RN 76
	Tricalysia coriacea (Benth.)Hiern	Omushekera	SH	L, F	Fresh leaves pounded then mixed with clean water or fresh leaves boiled	RN 77
	Vangueria infausta Burch	Mtugunda, Amabungo	SH	L	Decoction	Voucher not collected
	Rytigynia obscura Robyns	Omulokola/Lulokola	SH	L	Decoction	RN 78
	Oxyanthus speciosus DC	Omwanikibira	T	L	Decoction	RN 79
	Pentas bussei (K. Krause)	Rusharila kibira	H	AP	Decoction	RN 80
	Pavetta lynesii Bridson	Orwingula, Omuingula	SH	L	Decoction	RN 81
	Chassalia umbraticola Vatke	Mwataibare	SH	SB, L	Decoction	RN 82
	Hallea rubrostipulata (K. Schum) J.F. Leny	Mchunguchugu	T	SB, R	Decoction	4663
Rutaceae	*Zanthoxylum chalybeum* Engl.	Omutaregwairungu	T	SB	Decoction	RN 83
	Toddalia asiatica (L.) Lam	Orukwatango	CL	L	Decoction	Voucher not collected
	Teclea nobilis Delile	Omuzo	T	R	Decoction	RN 84
Sapindaceae	*Lecaniodiscus fraxinifolius* Bak	Omwasha	T	L	Decoction	Voucher not collected
Solanacaeae	*Physalis peruviana* L.	Kitutun kikubwa	H	L	Fresh leaves pounded then mixed with water, used orally	RN 85

Table 1. Cont'd.

	Datura stramonium L.	Ekitaigwa, Amalulu	SH	S	Decoction	RN 86
Sterculiaceae	*Dombeya shupangae* (K. Schum)	Omutangarara, Mtangarara	T	L	Decoction	RN 87
Ulmaceae	*Trema orientalis* Bullock	Omuhuwe	T	SB, L	Dry powder used to prepare warm infusion	Voucher not collected
Umbelliferae	*Centella asiatica* (L.) Urb	Mbatama	H	WP	Decoction	RN 88
Verbenacea	*Clerodendrum cephalanthum* Oliv	Ekishekesheke	WC	L	Decoction	RN 89
	Lantana camara L.	Lukulata	SH	L	Decoction	RN 90
	Lantana trifolia L.	Omuhuchi	SH	AP	Decoction	RN 91
Zingiberaceae	*Aframomum angustifolium* (Sonn.) K. Schum	Orushasha	SH	L	Cold infusion	Voucher not collected
	Costus afer Ker-Gawl	Ekigagi	H	R, AP	Decoction or eaten raw	RN 92

Plant part: R = root, ST = Stem, SB = Stem bark, AP = Aerial parts, L = Leaves, F = Fruits, S = Seeds, WP = Whole plant. Nature of the plant: SH = Shrub, H = Herb, T = Tree, CL = Climber, WC = Wood climber, G = Grass

Table 2. *In vitro* antiplasmodial activity of 80% ethanol crude extracts at 100 µg/ml against *P. falciparum* Dd2 strains.

Plant Family	Plant species	Part tested	Percentage growth inhibition rate (% IR) of crude extracts at 100 µg/ml on *P. falciparum* Dd2 strain
Acanthaceae	*Acanthus pubescens* (Oliv.)	R	41.50 ± 6.32
Apocynaceae	*Funtumia africana* (Benth) Staff	SB	17.51 ± 8.07
	Funtumia africana (Benth) Staff	L	14.21 ± 2.74
Burseraceae	*Canarium schweinfurthii* Engl.	SB	61.94 ± 15.61
Celastraceae	*Salacia lovetii* N. Halle & B. Mathew	L	32.35 ± 3.50
Compositae	*Guizotia scabra* (Vis.) Chiov	WP	49.09 ± 0.03
	Aspilia mosambicensis (Oliv.) Wild	AP	69.34 ± 7.05
	Aspilia natalensis (Sond) Wild	AP	65.23 ± 0.25
	Vernonia glabra (Steetz) Vatke	L	12.44 ± 1.18
Convolvulaceae	*Ipomoea rubens* Choisy	L	27.61 ± 1.83

Table 2. Cont'd.

Euphorbiaceae	*Bridelia micrantha* (Hochst.) Bail	SB	71.87 ± 1.53
	Phyllanthus nummulariifolius Poir	WP	38.88 ± 7.83
	Phyllanthus nummulariifolius Poir	WP	51.31 ± 12.84[a]
Fabaceae	*Erythrina schliebenii* Harms	SB	39.86 ± 13.97
	Dalbergia malangensis E.P Sousa	L	39.78 ± 7.88
	Dalbergia malangensis E.P Sousa	ST	32.37 ± 8.49
	Macrotyloma axillare (E. Mey) Verdc	AP	33.21 ± 1.37
	Desmodium salicifolium (Poir) DC	AP	68.41 ± 13.33
	Erythrina sacleuxii Hua	SB	42.08 ± 5.49
Labiatae	*Leonotis nepaetifolia* (L.) R. Br	AP	54.43 ± 9.07
Loganiaceae	*Anthocleista grandiflora* Gilg	SB	9.18 ± 6.77
Melastomataceae	*Melastomatrum capitatum* (Vahl) A. & R. Fern)	AP	39.06 ± 3.47
	Dissotis brazzae Cogn	AP	52.31 ± 0.55
	Dissotis rotundifolia (Sm) Triana	AP	33.64 ± 0.44
Moraceae	*Antiaris toxicaria* (Pers) Lesch	L	34.72 ± 6.25
	Antiaris toxicaria (Pers) Lesch	SB	61.18 ± 2.02
Melianthaceae	*Bersama abyssinica*	SB	86.67 ± 11.32
Myristicaceae	*Pycnanthus angolensis* (Welw.) Warb	F	65.43 ± 9.62
	Pycnanthus angolensis (Welw.) Warb	SB	40.63 ± 8.10
	Pycnanthus angolensis (Welw.) Warb	L	28.63 ± 5.07
Myrsinaceae	*Maesa lanceolata* Forsk	L	53.46 ± 1.86
Myrtaceae	*Syzygium cordatum* Krause	SB	55.46 ± 13.43
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl	L	20.52 ± 3.35
Rubiaceae	*Hallea rubrostipulata* (K. Schum) J.F.Leny	R	64.54 ± 7.56
	Hallea rubrostipulata (K. Schum) J.F.Leny	SB	53.22 ± 5.58
	Pentas bussei (K. Krause)	AP	59.92 ± 4.41
	Oxyanthus speciosus DC	L	29.19 ± 9.66
	Rhytignia obscura Robyns	L	22.35 ± 5.42
	Artemether (1.25 µg/ml)		91.98 ± 10.46

WP= whole plant; L= leaves; SB= stem bark; ST= stem; AP= aerial parts (stem plus leaves); R= root; F= fruits [a]= aqueous extract

activity with IC50 = 1.6 µg/ml against P. falciparum clinical isolates (Katuura et al., 2007). Most plants tested in this study showed low parasite growth inhibition rate. It is not easy to identify the specific reasons for low activity but factors such as the solvent used for extraction, the method of preparation, storage conditions, and variation in the active constituents due to seasonal or geographical and model of testing may also reduce the efficacy of the extract (Weeneen et al., 1990). Furthermore, Chhabra et al. (1993) reported that preparations of medicinal plants can be used orally, rubbed into scarification, inhaled as fumes, splashed on the eyes, poured into the wound or sniffed. In this study we found that all preparations were administered orally in the form of decoction (boiled water extracts), infusion (hot water extract), juice or taken as raw fruits. In the oral route, the bioactive molecules are exposed to various barriers and enzyme systems before reaching the systemic circulation. This causes some bioactive molecules to be modified by metabolism thus, either enhance or reduce their antiplasmodial activity suggesting that the antiplasmodial activity of metabolically activated compounds may not be evident in *in vitro* assays.

Conclusion

This study reported 108 medicinal plants that are used in the traditional medicine for treatment of malaria and fevers in Kagera and Lindi regions of Tanzania. *In vitro* assays revealed substantial antiplasmodial activities of 15 plants out of 31 plant species tested. Although questionnaire based evidence suggested that decoctions from these plants were not acutely toxic, further toxicity testing will be required to establish their safety profile. Meanwhile these findings support the use of these plants for the traditional treatment of malaria. Further *in vitro* and *in vivo* screening supported by bioassay-guided isolation of active compounds of plants showing good safety margin are suggested.

Conflict of interests

The authors declare that they have no competing interests

ACKNOWLEDGEMENTS

This work was financed by Sida through MUHAS capacity building grants. Authors are very grateful to Sida for the financial support. We are grateful to Mr. Mohamedi Ngalanga, Mr. Didas Ngemera, Mr. Dominic Mushwahili, Mr. Buchadi Tibikunda and Mr. Papianus Rwechungura for showing us the medicinal plants traditionally used for treatment of malaria in their areas. We would like to extend our gratitude to Mr. Haji.O. Selemani (Botanist) for identification of the documented medicinal plants. Extraction of the plant extracts was done at the Institute of Traditional Medicine in Tanzania whereas *in vitro* antimalarial study was done at the Research Foundation in Tropical Diseases and Environment, and at the Biotechnology Unit, University of Buea in Cameroon. We are grateful to MR4/BEI-resources (Manassas, VA, USA) for donating malaria parasites used for this work.

REFERENCES

Amri E, Kisangau DP (2012). Ethnomedicinal study of plants used in villages around Kimboza forest reserve in Morogoro, Tanzania. J. Ethnobiol. Ethnomed. 8:1

Augustino S, Hall JB, Makonda FBS, Ishengoma RC (2011). Medicinal Resources of the Miombo woodlands of Urumwa, Tanzania: Plants and its uses. J. Med. Plants. Res. 5:6352-6372.

Batista R, Silva Ade Jr J, de Oliveira AB (2009). Plant-derived antimalarial agents: new leads and efficient phytomedicines. Part II. Non-alkaloidal natural products. Molecules 14:3037-3072.

Bero J, Frederich M, Quetin-Leclerq J (2009). Antimalarial compounds isolated from plants used in traditional medicine. J. Pharm. Pharmacol. 61:1401-1433.

Chhabra SC, Mahunnah RL, Mshiu EN (1993). Plants used in traditional medicine in eastern Tanzania. VI. Angiosperms (Sapotaceae to Zingiberaceae). J. Ethnopharmacol. 39:83-103.

Cox-singh J, Singh B (2008). Knowlesi malaria: newly emergent and of public health importance ?, Trends Parasitol. 24:406-410.

Dondorp AM, Nosten F, Yi P, Das D, Phyo AP, Tarning J, Maung K, Ariey F, Hampithakpong W, Lee SJ, Ringwald P, Silamut K, Iwong M, Chotivanich K, Lim P, Herdman T, An SS, Yeung S, Singhasivanon P, Day NPJ, Lindergardh N, Socheat D, White NJ (2009). Artemisinin Resistance in *Plasmodium falciparum* Malaria. N. Engl. J. Med. 361:455-467.

Gessler MC, Msuya DE, Nkunya MHH, Mwasumbi LB, Schar A, Heinrich M, Tanner M (1995). Traditional healers in Tanzania: the treatment of malaria with plant remedies J. Ethnopharmacol. 48:131-144.

Gessler MC, Nkunya MH, Mwasumbi LB, Heinrich M, Tanner M (1994). Screening Tanzanian medicinal plants for antimalarial activity. Acta Trop. 56:65-77.

Kassa M, Mohana R, Hunde A (1996). Antimalarial activity of *Bersama Abyssinica* against *Plasmodium Falciparum*. Ethiop. Phar. J. 14:16-21.

Katuura E, Waako P, Tabuti JRS, Bukenya-Ziraba R, Ogwal-Okeng J (2007). Antiplasmodial activity of extracts of selected medicinal plants used by local communities in western Uganda for treatment of malaria. Afr. J. Ecol. 45(S3):94-98.

Kinung'hi SM, Mashauri F, Mwanga JR, Nnko SE, Kaatano GM, Malima R, Mboera LE (2010). Knowledge, attitudes and practices about malaria among communities: comparing epidemic and non-epidemic prone communities of Muleba district, North-western Tanzania. BMC Public Health 10:395.

Lacroix D, Prado S, Kamoga D, Kasenene J, Namukobe J, Krief S, Brunois F (2011). Antiplasmodial and cytotoxic activities of medicinal plants traditionally used in the village of Kiohima, Uganda. J. Ethnopharmacol. 133:850-855.

Mahunnah RL (1987).Traditional plant medicines used by Hayas of North-western Tanzania. J. Econ. Tax. Bot. 10:371-379.

Mahunnah RLA, Uiso FC, Kayombo EJ (2012). Documentation of Traditioanal Medicine in Tanzania: A Traditioanal Medicine Resource Book. Dar es Salaam University Press, Dar es Salaam – Tanzania. p. 8.

Makler MT, Hinrichs DJ (1993). Measurement of the Lactate Dehydrogenase Activity of *Plasmodium falciparum* as an Assessment of paraistaemia. Am. J. Trop. Med. Hyg. 48:205-210.
Moshi MJ, Otieno DF, Mbabazi PK, Weisheit A (2009). The ethnomedicine of the Haya people of Bugabo ward, Kagera Region, north western Tanzania. J. Ethnobiol. Ethnomed. 5:24.
Ngemenya M, Titanji V, Akam T, Yong J, Tane P, Fanso-Free S, Berzins K (2005). Antiplasmodial activity and toxicity of extracts and products from selected medicinal plants used in Cameroon. Acta Trop. 96S:S1-S506.
Nguta JM, Mbaria JM, Gakuya DW, Gathumbi PK, Kiama SG (2010). Traditional antimalarial phytotherapy remedies used by the South Coast community, Kenya. J. Ethnopharmacol. 131:256-267.
Ntie-Kang F, Onguéné PA, Lifongo LL, Ndom JC, Sippl W, Mbaze LM (2014). The potential of anti-malarial compounds derived from African medicinal plants. Part II: a pharmacological evaluation of non-alkaloids and non-terpenoids. Malar. J. 13:81.
Odugbemi TO, Akinsulire OR, Aibinu IE, Fabeku PO (2007). Medicinal plants useful for malaria therapy in Okeigbo, Ondo state, Southwest Nigeria. Afr. J. Tradit. Compl. Alter. Med. 4:191-198.
Onguéné PA, Ntie-kang F, Lifongo LL, Ndom JC, Sippl W, Meva'a ML (2013). The potential of anti-malarial compounds derived from African medicinal plants. Part I: A pharmacological evaluation of alkaloids and terpenoids. Malar. J. 12:449.
Tabuti JRS (2008). Herbal medicines used in the treatment of malaria in Budiope county , Uganda. J. Ethnopharmacol. 116:33-42.
TACAIDS, ZAC, NBS, OCGS, IFC International (2013). Tanzania HIV/AIDS and Malaria Indicator Survey 2011-12. Dares Salaam, Tanzania: TACAIDS, ZAC, NBS, OCGS, and ICF International.
Titanji VP, Zofou D, Ngemenya MN (2008). The Antimalarial Potential of Medicinal Plants used for the Treatment of Malaria in Cameroon folk Medicine. Afr. J. Complement. Alter. Med. 5302-321.
Trager W, Jensen JB (1976). Human malaria parasites in continuous culture. Science. 193:673-5.
United States Agency for International Development (USAID) (2014). President's Malaria Initiative: Tanzania Malaria Operational Plan FY 2014.
Weenen H, Nkunya MH, Bray DH, Mwasumbi LB, Kinabo LS, Kilimali VA (1990). Antimalarial activity of Tanzanian medicinal plants. Planta Med. 56:368-370.
Wells TN (2011). Natural products as starting points for future anti-malarial therapies: going back to our roots ? Malar. J. 10(Suppl1):S3.
WHO (2002). Traditional Medicine Strategy 2002-2005. WHO Press, Geneva, Switzerland. WHO/EDM/TRM/2002.1
Wongsrichanalai C, Pickard AL, Wernsdorfer WH, Meshnick SR (2002). Reviews: Epidemiology of drug-resistant malaria. Lancet Infect. Dis. 2:209-218.
World Health Organization (WHO) (2012). WHO Global Malaria Programme: World Malaria Report 2012. WHO Press, Geneva, Switzerland.
World Health Organization (WHO) (2013). WHO Malaria Factsheet No 94 - 2013. WHO press, Geneva, Swirtzerland.
Zofou D, Tematio EL, Ntie-Kang F, Tene M, Ngemenya MN, Tane P, Titanji VPK (2013). New antimalarial hits from *Dacryodes edulis* (Burseraceae)- Part I: isolation, in vitro activity, in silico "drug-likeness" and pharmacokinetic profiles. PloS One. 8:11