Ethnobotanical Survey on the Knowledge and Use of Medicinal Plants for Malaria Management among University Students

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Abstract

Malaria remains a public health problem in Tanzania, escalated by the emergence of both parasite and vector resistance. Plant-based traditional medicines have been widely utilized as alternatives to malaria management. However, proper documentation is minimal, especially among the younger generation. This study assessed the knowledge of medicinal plants for malaria management among 532 Dar es Salaam University College of Education students. Overall, twenty-four plant species, most belonging to the family Asteraceae, were identified with *Azaradichta indica* being the most dominant species. These results reveal a substantial knowledge of medicinal plants for malaria management among university students.

Keywords: Malaria, Medicinal plants, Ethnomedicine, Antimalaria, Tanzania.

Introduction

Malaria is among the significant health problems in tropical and subtropical areas including Tanzania, with adverse social and economic consequences (WHO 2021a). The management and control of malaria disease rely on two intervention strategies, namely malaria parasite control by antimalarial drugs and vector control using insecticide-based interventions (WHO 2019). Currently, artemisinin combination therapies (ACTs) are the antimalarials used for managing uncomplicated malaria (WHO 2021b). On the other hand, vector control depends on long-lasting insecticidal nets (LLINs) and indoor residual spray (IRS) methods. These strategies have substantially reduced malaria by 60% from 2000 to 2019, globally (WHO 2020). However, since 2017 malaria cases and deaths have slightly resurged (WHO

2021a), this can be attributed to antimalarial drug resistance in malaria parasites, and insecticide resistance in vectors (WHO 2018a). Furthermore, the situation is worsening as there are currently limited options for these antimalarial products (drugs and insecticides) developed (WHO 2018b). Therefore, the acceleration of new antimalarial product development should be the main agenda in the current quest for malaria elimination.

Plants have been essential sources of modern drugs used to treat various diseases, including malaria (Ozioma and Chinwe 2019). Historically, the discovery of the first potent antimalaria drug 'quinine' and the modern 'artemisinin', now the potent component of artemisinin, are from medicinal plants (Ceravolo et al. 2021). Thus, medicinal

plants are promising and wealthier sources of new antimalarial product development.

Medicinal plants have been used in different cultures to treat diseases, including malaria (WHO 2013). Sub-Saharan countries, including Tanzania, are among the highest users of medicinal plants in the treatment of various diseases (Ozioma and Chinwe 2019). Even in the current era of conventional or modern medicine, most communities in both urban and rural areas still depend on medicinal plants to treat malaria and other diseases (Bekono et al. 2020). The reasons for the use of medicinal plants are due to historical and cultural acceptance (WHO 2000), loss of potency of most modern drugs due to the development of resistance (Innocent et al. 2022), distance to health facilities, and high cost of the treatment in hospital (WHO 2002). In addition, medicinal plants are easily accessible and believed to be effective with no or minimal side effects compared to modern drugs. Furthermore, due to their cultural linkage, most people in rural communities have greater trust in medicinal plants than in modern drugs (Andarge et al. 2015). As a result, over 50 years ago, the World Health Organization, began advocating the validation efficacy, safety and promotion of the development of new traditional medicine products in the health system of the member states (WHO 2002).

Africa is a leading continent in the diversity of medicinal plant species used as herbal treatments for malaria (Ceravolo et al. 2021). Among African countries, Tanzania has various potential medicinal plants for malaria treatment. Several studies conducted in various regions of Mainland Tanzania including, Pwani, Morogoro, Iringa, Kigoma, Tanga, Kagera, and Lindi (Malebo et al. 2015, Nondo et al. 2015, 2016, Kingo and Maregesi 2020, Christopher et al. 2023) recorded about 100 species of medicinal plants with antiplasmodial activity that are used for malarial treatment. These findings show the necessity of annotating the medicinal plant species for malaria treatment in other parts of the country. However, there is a scarcity of documentation of plant species and indigenous knowledge on the medicinal plants for malaria treatment (Ozioma and Chinwe 2019).

Currently, the indigenous knowledge of medicinal plants in different communities in developing countries is waning as this kind of knowledge has been passed from one generation to another orally (Kamau et al. 2016) These studies have highlighted that youths, particularly those with formal education, have been losing interest in traditional medicine and considering them inferior compared to modern or conventional treatment. Declining interest in traditional medicine among educated youths, particularly in medicinal plants, threatens the development of medicinal plant products and their conservation. In Tanzania, the enrolment rate in higher education has been rapidly increasing; thus, it is vital to understand the magnitude of knowledge and practice of medicinal plants among higher learning students in the country. This data helps decide how to integrate medicinal plant knowledge with formal education. Therefore, this study investigated and documented the indigenous knowledge of medicinal plants used to treat malaria among first-year students in the Dar es Salaam University College of Education (DUCE), hailing from different parts of the country.

Materials and Methods
Study area
The study was conducted at the Dar es Salaam University College of Education (DUCE), which is located between latitude 39.2736°S and longitude 6. 8478°E. DUCE is among the constituent colleges of the University of Dar es Salaam in Tanzania, which enrols approximately 2000 students each year from various regions of Tanzania.

Study design and informant selection
The study was a cross-sectional quantitative survey among the newly enrolled students of DUCE in the 2020/2021 academic year. This survey was conducted between the end of November and December 2020. The informants were recruited using a voluntary response sampling in which the newly

enrolled cohort was sensitized about the project and then requested to join the study. The inclusion criterion was students of 18 years and above.

Sample size

The anticipated population for the study was approximately 2000 students. With a confidence level of 95%, a margin error of *p* = 0.04, and a 10% increment to allow for mid-survey dropout, the sample size was calculated using the Yamane (1967) formula shown below.

$$n = \frac{N}{1 + N\,(e)^2}$$

Thus, 532 newly enrolled students at University were recruited for the study.

Data collection

Before data collection, informants were sensitized to the project, and the objectives were stipulated. Consented participants were individually interviewed, using a pre-tested semi-structured questionnaire designed to collect demographic information and knowledge on plants used for malaria treatment.

Data analysis

The data were entered in Microsoft Excel® spreadsheets. Descriptive statistics including relative frequencies, percentages, and averages of the variables, frequency tables and graphs were made. The importance of each plant in the treatment of malaria was assessed by the relative frequency of citation (RFC) calculated using the following

Table *1*). However, 9 (1.7%) respondents did not indicate sex information, and therefore, were excluded in the calculations related to sex. The age of the informants

formula: RCF = FC / N, where FC was the number of people who mentioned the use of the species and N was the total number of individuals.

Preference ranking

Preference ranking was used to rank the popularity of medicinal plants used for the treatment of malaria among the informants. Each informant ranked the best three (3) plants based on their knowledge of medicinal plants. The highest value was ranked five (5) and the lowest was three (3) for the least popular medicinal plant. Finally, the values were summed and ranked and a frequency table was made.

Research clearance

The research clearance for the study was obtained from the Research Ethics Committee of the University of Dar es Salaam with project number DUCE-20104. Verbal consent was obtained from all of the informants before their enrolment in the study.

Results
Demographic characteristics

The study was conducted among the newly enrolled students at the DUCE in the academic year 2020/2021. The study randomly recruited a total of 532 participants from all twenty-six (26) regions of Mainland Tanzania. The proportion of female respondents was slightly higher than that of males (

ranged from 18 to 30 years with a mean age of 21 years (SD ± 1.56), whereas more than half of the participants 319 (60%) were above 20 years old (

Table *1*).

Table 1: Social-demographic characteristics of the participants

Variable	Category	Frequency (%)
Sex	Female	282 (54)
	Male	241 (46)
Age	18-20	213 (40)
	>20	319 (60)

Proportions of medicinal plant users

Overall, 20.3% (108/532) of respondents reported using medicinal plants to treat malaria upon experiencing malaria-like symptoms. The proportion of female users was slightly higher, 57.3% (59/103), than that of male users 44/103 (42.7%). Most users, 88.9% (96/108) of medicinal plants for malaria treatment, were aged between 18 and 24 years. The users of medicinal plants for malaria treatment hailed from 92.3% (24/26) of regions of Mainland Tanzania except for the Kigoma and Songwe regions.

Plant diversity and origin

Respondents mentioned 24 plant species belonging to 18 families as potential medicines for treatment of malaria infections. The most prevalent family was Asteraceae 4 (16.67%), followed by Myrtaceae and Tiliaceae 2 (8.33%). Other families were represented by only one species, as shown in Table 2. Trees were the most dominant medicinal plants for malaria treatment mentioned by the participants, with eight plants species (34.78%), followed by shrubs 7 (29.17%), herbs 4 (16.67%), climbers two species (8.33%) and graminoids two species (8.33%) as indicated in Table 2. In addition, leaves were the most plant parts used for the preparation of herbal remedies 15 (62.5%), followed by roots and whole plants, each with two plant species (8.33%). Out of 24 plant species mentioned by students, *Azaradichta indica* was the most mentioned species by 89 students (16.73%), followed by *Aloe barbadensis* 39 (7.33%) and *Zingiber officinale* 4 (0.75%), *Psidium guajava* and *Moringa oleifera* mentioned twice each, while other plants were mentioned only once. Of the mentioned medicinal plants, 12 (50%) of the species are collected from the wild and nine species (41.67%) are domesticated plants, while two species 2 (8.33%) are found both in the wild and domestic. All the remedies were administered orally, as indicated in Table 2.

Relative frequency of citation

The calculated RFC indicated that the highly cited plant species include *Azadirachta indica* (RFC = 0.55), followed by *Aloe barbadiensis* (RFC = 0.26), *Zingiber officinale* (RFC = 0.03), and *Citrus limon* (RFC = 0.02) indicating that these were the most used plants in treating malaria infection among the respondents (Table 3). Other plants including *Artemisia afra* and *Persea americana* recorded a very low RFC of 0.01 (Figure 1).
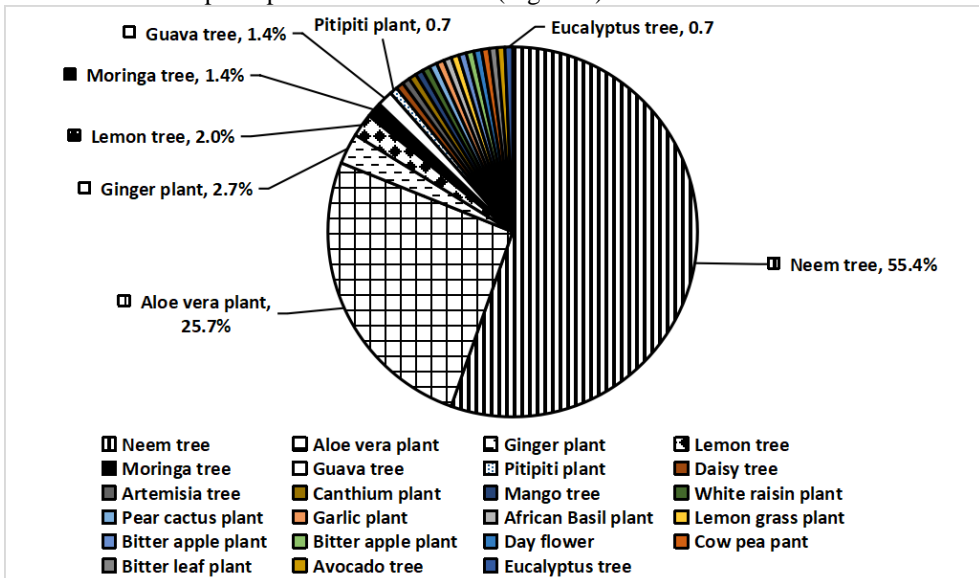
Figure 1:   Proportion of medicinal plants used for the treatment of malaria

Table 2: Medicinal plants used for treating malaria in Tanzania

SN	Local name	Common name	Scientific name	Family	Growth habit	Type of plant	Parts for preparation	Administration route
1	Tangawizi	Ginger plant	*Zingiber officinale* Rosc.	Zingiberaceae	H	D	Rhizome	Oral
2	Mwarobaini	Neem tree	*Azadirachta indica* L.	Meliaceae	T	W	Leaves	Oral
3	Mualovera	Aloe vera plant	*Aloe barbadiensis* Miller.	Liliaceae	H	Both	Leaves	Oral
4	Mlonge	Moringa Tree	*Moringa oleifera* Lam.	Moringaceae	T	D	Leaves	Oral
5	Mlimao	Lemon tree	*Citrus limon* L.	Rutaceae	T	D	Leaves	Oral
6	Long'ono / Ong'ono	Pitipiti plant	*Capparis erythrocarpus* Iser.	Capparidaceae	S	W	Root	Oral
7	Amanyaki / amataghara	Daisy tree	*Senecio mannii* (Hook.f.) C. Jeffrey.	Asteraceae	S	W	Leaves	Oral
8	Fivi	Artemisia tree	*Artemisia afra* Jacq.	Asteraceae	H	W	Leaves	Oral
9	Mshangati/ Omushangati	Canthium plant	*Psydrax parviflora* (Afzel.) Bridson. *ssp. Rubrocostata* (Robyn) Bridson.	Rubiaceae	T	W	Bark and Leaves	Oral
10	Mshunga	Bitter Lettuce plant	*Launaea cornuta* (Hochst. ex Oliv. & Hiem) C. Jeffrey.	Asteraceae	H	W	Whole plant	Oral
11	Mkole	White raisin plant	*Grewia bicolor* Juss.	Tiliaceae	S	W	Leaves	Oral
12	Mkatasi	Pear cactus plant	*Opuntia vulgaris* Mill.	Cactaceae	S	W	Stem	Oral
13	Kitunguu saumu	Garlic plant	*Allium sativum* L.	Amaryllidaceae	B	D	Bulb	Oral
14	Mpera	Guava tree	*Psidium guajava* L.	Myrtaceae	T	D	Leaves	Oral
15	Mzumbasha	African Basil plant	*Tetradenia riparia* (Hochst.) Codd.	Lamiaceae	H	Both	Leaves	Oral
16	Mchaichai	Lemon grass plant	*Cymbopogon citratus;* (DC.) Stapf.	Poaceae	H	D	Leaves	Oral
17	Iminyabulondo /Amataratora	Bitter apple plant	*Solanum incanum* L.	Solanaceae	S	W	Bark and roots	Oral
18	Mgukwe	Giant raisin plant	*Grewia hexamita* Burret.	Tiliaceae	S	W	Leaves	Oral
19	Umuyembe	Mango tree	*Mangifera indica* L.	Anacardiaceae	T	D	Leaves	Oral
20	Korongo	Day flower plant	*Commelina sp.*	Commelinaceae	C	W	Leaves	Oral
21	Mkunde	Cow pea pant	*Vigna unguiculata*(L.) Walp.	Fabaceae	C	D	Whole plant	Oral
22	Mbirizi	Bitter leaf plant	*Vernonia amygdalina* Del.	Asteraceae	S	W	Leaves	Oral
23	Mparachichi	Avocado tree	*Persea americana* Mill.	Lauraceae	T	D	Fruits and leaves	Oral
24	Uumboto / Mkaratusi	Eucalyptus tree	*Eucalyptus globulus* Labil.	Myrtaceae	T	D	Leaves and Bark	Oral

**Growth habitat, H = Hub, T = Tree S = Shrub Plant type D = Domesticated, W = Wild.

Table 3: RFC of medicinal plants used in the treatment of malaria in Tanzania n = 24 species

	Local name	Common name	Scientific name	Family name	Frequency (Np)	RFC
1	Mwarobaini	Neem tree	*Azadirachta indica* L	Meliaceae	82	0.55
2	Mualovera	Aloe vera plant	*Aloe barbadiensis* Miller.	Liliaceae	39	0.26
3	Tangawizi	Ginger plant	*Zingiber officinale* Rosc.	Zingiberaceae	4	0.03
4	Mlimao	Lemon tree	*Citrus limon* L.	Rutaceae	3	0.02
5	Mlonge	Moringa tree	*Moringa oleifera* Lam.	Moringaceae	2	0.01
6	Mpera	Guava tree	*Psidium guajava* L.	Myrtaceae	2	0.01
7	Long'ono/Ong'ono	Pitipiti plant	*Capparis erythrocarpus* Iser.	Capparidaceae	1	0.01
8	Amanyaki/ Amataghara	Daisy tree	*Senecio mannii* (Hook.f.) C. Jeffrey.	Asteraceae	1	0.01
9	Fivi	Artemisia tree	*Artemisia afra* Jacq.	Asteraceae	1	0.01
10	Mshangati/ Omushangati	Canthium plant	*Psydrax parviflora* (Afzel.) Bridson *ssp.Rubrocostata* (Robyn) Bridson	Rubiaceae	1	0.01
11	Umuyembe	Mango tree	*Mangifera indica* L.	Anacardiaceae	1	0.01
12	Mkole	White raisin plant	*Grewia bicolor* Juss.	Tiliaceae	1	0.01
13	Mkatasi	Pear cactus plant	*Opuntia vulgaris* Mill.	Cactaceae	1	0.01
14	Kitunguu saumu	Garlic plant	*Allium sativum L.*	Amaryllidaceae	1	0.01
15	Mzumbasha	African Basil plant	*Tetradenia riparia* (Hochst.) Codd.	Lamiaceae	1	0.01
16	Mchaichai	Lemon grass plant	*Cymbopogon citratus;* (DC.) Stapf.	Poaceae	1	0.01
17	Iminyabulondo/ Amataratora	Bitter apple plant	*Solanum incanum* L.	Solanaceae	1	0.01
18	Mgukwe	Bitter apple plant	*Grewia hexamita* Burret	Tiliaceae	1	0.01
19	Korongo	Day flower plant	*Commelina sp.*	Commelinaceae	1	0.01
20	Mkunde	Cow pea pant	*Vigna unguiculata* (L.) Walp.	Fabaceae	1	0.01
21	Mbirizi	Bitter leaf plant	*Vernonia amygdalina* Del.	Asteraceae	1	0.01
22	Mparachichi	Avocado tree	*Persea americana* Mill.	Lauraceae	1	0.01
23	Uumboto/ Mkaratusi	Eucalyptus tree	*Eucalyptus globulus* Labil.	Myrtaceae	1	0.01
24	Mshunga	Bitter Lettuce plant	Launaea cornuta (Hochst. ex Oliv. & Hiem) C. Jeffrey	Asteraceae	1	0.01

Plant parts used and route of administration

The study findings revealed more than half of the respondents use the leaf part of the mentioned medicinal for malaria treatment. A small proportion of respondents use other parts of the plants such as fruits whole plant stems, bulbs, tree barks, and roots as indicated in Figure 2. Similarly, the study records show that all mentioned medicinal plants are administered via the oral route (Table 2).
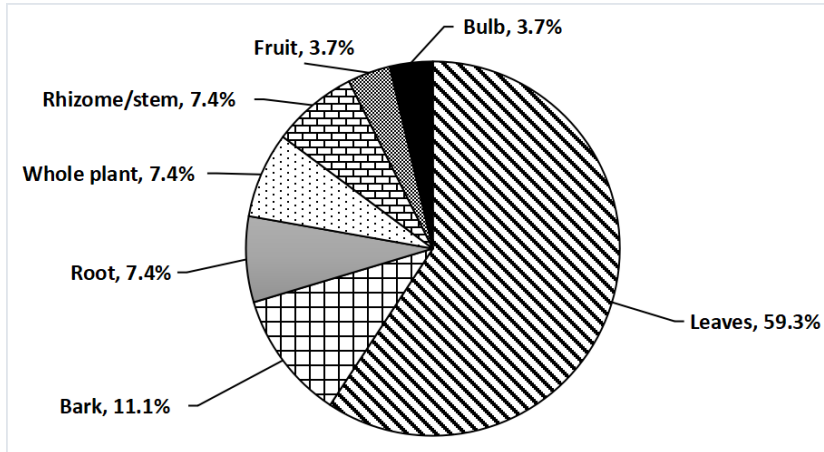

Figure 2: Plant parts used for making medicine for malaria management.

Preference ranking

Since the respondents represented more than 90% of the regions of mainland Tanzania, they were asked to rank the top three plants used for malaria treatment at their domicile. Only nine (9) recruits could mention all three (3) options. Ranking indicated that the most plant used for the treatment of malaria infection was *Azadirachta indica, Aloe barbadiensis* and *Citrus limon* were ranked 1st, 2nd and 3rd positions, respectively. Other plants ranked from position 4 to 6th position are indicated in Table 4.

Table 4: Preference ranking of medicinal plants used for malaria treatment (n = 8)

	Aloe barbadiensis Mill.	*Azadirachta Indica* L.	*Citrus limon* L.	*Cymbopogon citratus* (DC.) Stapf.	*Psidium guajava* L.	*Moringa oleifera* Lam.	*Psydrax parviflora* (Afzel.)	*Vigna unguiculata* (L.) Walp.
R1	5	4	-	-	-	3	-	-
R2	3	5	-	4	-	-	-	-
R3	-	5	-	-	4	-	3	-
R5	5	4	3	-	-	-	-	-
R6	5	4	3	-	-	-	-	-
R7	4	5	-	3	-	-	-	-
R8	4	5	-	-	-	-	-	3
R9	4	5	3	-	-	-	-	-
Total	30	37	9	7	4	3	3	3
Rank	2	1	3	4	5	6	6	6

Discussion

This study aimed to assess the knowledge and practices of students of the Dar es Salaam University College of Education (DUCE) on plants used for managing malaria. Our findings showed that one out of five (20%) of the enrolled participants reported using medicinal plants for malaria

management. In contrast to the current results, the ethnobotanical study on medicinal plants conducted in communities with lower education elsewhere in Tanzania revealed that about half (50%) of the participants had knowledge of medicinal plants (Kibonde 2020). These results indicate a higher knowledge of medicinal plants among less educated individuals compared to educated youths in the country. The plausible explanation for this low ethnobotanical knowledge among educated youths might be due to the disconnection between ethnobotanical knowledge and what they learn at school (Voeks and Leony 2004). Nonetheless, the study conducted among university students in Nigeria revealed more than half (54%) of students reported using medicinal plants for managing malaria (Nworu et al. 2015), this two-fold higher use of medicinal plants among university students in Tanzania and Nigeria implies that the ethnobotanical knowledge among educated youths also differs between countries and regions depending on the emphasis given to the traditional medicines to them (Wassie et al. 2015). Additionally, the recorded low use of medicinal plants among Tanzanian youths might be influenced by modern culture and the low emphasis of our cultural practices on the use of medicinal plants. Thus, there is a need to emphasize the safe use of medicinal plants for the treatment of malaria and other ailments in the Tanzania communities through strengthened social behaviour communication change and advocacy strategies.

The majority of users of medicinal plants for the management of malaria were female students (57.3%). Similar results were recorded elsewhere in Tanzania where female participants were the predominant users of medicinal plants (Kitula 2007, Charwi et al. 2023). This might be due to culture and practices where women are more engaged in caregiving to sick people than male members. However, these results are different from the studies done in communities elsewhere in Uganda (Tugume et al. 2016) and Ethiopia (Tahir et al. 2022) where men were the dominant key informants compared to women. Contrary, another study (Torres-Avilez et al. 2016) recorded no significant difference in the level of knowledge of medicinal plants globally.

In the current study, most medicinal plant users for managing malaria were youths aged between 18 and 24 years, implying that the youths have acquired and practice indigenous knowledge of medicinal plants most likely from their elders. This study is contrary to another research conducted in Tanzania, where the mean age of key informants was 53 years, indicating older people were more knowledgeable of plant-based traditional medicine than the youths (Salinitro et al. 2017). Similarly, in another ethnobotanical survey, the key informers aged 45 years and above had more knowledge than the younger informants aged 15–20 and 21–45 years (Amir et al. 2019). These results reveal that the generational wealth of information on medicinal plants is currently being passed on to the younger generations.

The current study recorded a high diversity of plants used to manage malaria. The Asteraceae family (16.67%) was the most dominant medicinal plant used for malaria management. This family is known for being cosmopolitan (Tugume et al. 2016) as it is a widely distributed plant family in tropical areas with a high abundance and diversity of species; and has excellent healing properties. Over one-third of plants used were trees (34.78%) and shrubs (29.17%). These commonly used growth forms for malaria treatment can be attributed to the availability of trees in both dry and wet seasons compared to other growth forms (Kacholi and Amir 2022). In addition, leaves were the most used plant parts (62.5%) compared to the whole plant, root, bark, fruits, and mixtures of plant parts. Leaves were the most used plant parts due to their easy accessibility, easy preparation of remedies, presence of high amounts of bioactive compounds and allows for preventing plants from extinction (Asnake et al. 2016).

The results showed that *Azaradichta indica* was the most mentioned plant species with high frequency and preference (16.73%) on the management of malaria, followed by

Aloe barbadensis 39 (7.33%) and *Zingiber officinale* 4 (0.75%), *Psidium guajava* and *Moringa oleifera*. These mentioned plant species were also documented as a regimen for malaria in the western part of Tanzania (Kingo and Maregesi 2020). Similarly, *Azadirachta indica*, *Zingiber officinale* and *Psidium guajava* plants were also named as useful medicinal plants for malaria in Southwest Nigeria (Khalid et al. 1989). This study was consistent with other studies which reported the *Azadirachta indica* being useful in the treatment of malaria in Kenya (Nguta et al. 2010) and Ethiopia (Million et al. 2022) The preference for *Azaradichta indica* could be attributed to its antiplasmodial activity (Kirira et al. 2006) and active compounds such as limonoid, gedunin and nimbinin for antimalarial activity (Khalid et al. 1989). The leaf extract of *A. indica* contains antimalarial activities which are superior compared to chloroquine (Ngokere et al. 2014) and has shown appreciable bioactivity in suppressing *plasmodium* parasites (Habluetzel et al. 2019). On the other hand, the genus Aloe (Asphodelaceae) L. and *Aloe barbadensis* in particular were indicated as useful plant species for the management of malaria (Amir et al. 2019). Other mentioned medicinal plants which have already been identified to have antiplasmodial activity include *Zingiber officinale* 4(0.75%) (Airaodion et al. 2021), *Psidium guajava* (Akkawi et al. 2021) and *Moringa oleifera* (Ogundapo et al. 2015).

Consequently, the ability of the youths at DUCE who hailed from 90% of the regions in Mainland Tanzania, to give at least a herbal prescription for malaria reveals the diverse use of medicinal plants for malaria management throughout the Country. Therefore, the findings from the current study suggest that indigenous medicinal plants used for the management of malaria among communities in Tanzania are potential sources for the development of new antimalarial drugs.

Conclusion
This study has highlighted medicinal plants claimed to be used for the management of malaria among the youths at the university level. A total of 24 plant species have been identified for managing malaria among the respondents. These medicinal plants may probably contain yet undiscovered antimalarial properties, which can serve as templates for the production of cheap anti-malaria drugs from indigenous plants in Tanzania. This calls for a multidisciplinary approach to develop potentially effective antimalarial drugs while noting dangerous drugs and traditional practices that should be discarded.

Declarations

Data and material availability: All data is archived by the authors and is available upon reasonable request.

Competing interests: The authors declare that there is no competing interest.

Author's contributions: FM and DJ conceptualized and designed the study. FM, DJ and NM conducted data collection, analysis, and interpretation. FM drafted the initial manuscript, and DJ and NM improved it. All the authors read, reviewed, and approved the final version of the manuscript.

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