Ethnobotanical study of medicinal plants used in management of COVID-19 in Dar es Salaam and Morogoro Regions, Tanzania

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Ethnobotany Research and Applications 29:2 (2024) - http://dx.doi.org/10.32859/era.29.2.1-16
Manuscript received: 28/08/2023 – Revised manuscript received: 21/03/2024 - Published: 23/03/2024

Research

Abstract

Background: The increase in drug resistance has resulted in significant health challenges in managing respiratory tract infections, including the COVID-19 pandemic, which has made people rely on medicinal plants (MPs) for its management. This study aimed to document MPs used for the management of COVID-19 during the disease outbreak in Tanzania.

Methods: The study was carried out in Dar es Salaam and Morogoro regions. A semi-structured interview and field observations were used to gather information from 120 informants. The study focused on plant parts used, preparation, administration and sources of MPs. Descriptions and inferential statistics were performed for data analysis.

Results: Twenty-one MPs belonging to 12 families and 16 genera were documented. Out of these recorded MPs only five were native species and the remaining 16 were exotic. The most cited plant species were *Zingiber officinale* Roscoe (Zingiberaceae), *Allium sativum* L. (Amaryllidaceae), *Citrus x aurantiifolia* (Christm.) Swingle (Rutaceae), *Cymbopogon citratus* (DC.) Stapf (Poaceae), and *Eucalyptus globulus* Labill. (Myrtaceae) each with relative frequency of citation of one. The families with higher number of MPs were Lamiaceae (28.6%) and Myrtaceae (14.3%). Herb (47.6%) and leaves (57.1%) were the most utilized growth form and plant part, respectively. Decoction (76.0%) and oral (73.0%) were the most used method of preparing and administering the remedies, respectively. Market (38.0%) was the most common source of MPs in both study areas. Traditional knowledge was mainly acquired from family members (75.8%).

Conclusion: The findings indicate both regions had a reasonable number of MPs used to manage COVID-19. The effectiveness of MPs should be validated further through research on phytochemistry, toxicity and clinical evaluation.

Keywords: Ethnomedicine, medicinal plants, pandemic, respiratory disorder, traditional medicine

Background

Traditional medical knowledge has increased worldwide due to global healthcare demand and the significant role MPs play in treating, preventing and managing various diseases. About 80% of the world population uses MPs to prevent and treat diseases, and the demand is increasing in middle and low-income countries (Ekor 2014, Khadka *et al*. 2021). In East Africa, the use of MPs for treating various diseases accounted for more than 80% of the inhabitants (Tugume *et al.* 2016). This number can expand since the cost of modern medicine increases (Ekor 2014). In addition, the increasing growth of the human population, the resistance of drugs to pathogens and the inaccessibility to modern medicines due to low incomes have increased the demand for MPs (Augustino & Gillah 2005, Chebaibi *et al.* 2022). MPs are readily available and cheaper than modern medicines (Charwi *et al.* 2023, El Alami *et al.* 2020).

The use of MPs was enormous during the COVID-19 outbreak, which made many people depend on MPs for the prevention of diseases or managing the diseases after being affected (Khadka *et al.* 2021, Odebumni *et al*. 2022, Rosa & Santos 2020). COVID-19 is one of the respiratory diseases, and the respiratory system is vulnerable to several infections caused principally by bacteria or viruses (Innocent *et al.* 2022). It continues to be a significant health challenge worldwide, especially due to the fast development of drug resistance to disease-causing micro-organisms such as bacteria (Innocent *et al.* 2022, Zhang *et al.* 2014). The most common respiratory system problems are bronchitis, common cold, whooping cough, influenza, sinusitis, asthma, and the current COVID-19 infection (Innocent *et al*. 2022). The COVID-19 is an ongoing pandemic caused by coronavirus 2 (SARS-CoV-2). The first outbreak of COVID-19 was reported in Wuhan, China, in December 2019 and continued to spread to Europe and later to other continents, including Africa. In Tanzania, the disease was reported for the first time in the Arusha region in March 2020 (Tarimo and Wu 2020). This disease has claimed the lives of hundreds of people, and millions have been affected worldwide (Rosa & Santos 2020). Since then, 691,446,859 confirmed cases of COVID-19 and 6,899,243 deaths worldwide have been recorded (Worldometer 2023) and in Tanzania, a total of 43,078 cases and 846 deaths were confirmed (Tarimo and Wu 2020). Although there are effective vaccinations used to protect people from getting COVID-19 (Mathieu *et al.* 2021, Polack *et al*. 2020), there is no approved modern medicine with efficacy to combat COVID-19. However, claims of useful and powerful MPs against COVID-19 emerged from different parts of the world, including China (Chan *et al.* 2020), Morocco (Chebaibi *et al.* 2022, El Alami *et al.* 2020), Cameroon (Tsouh Fokou & Youmsi Fokouo 2020), Nepal (Khadka *et al.* 2021) and India (Vellingiri *et al.* 2020).

During the COVID-19 outbreak, the majority of Tanzanians relied on MPs for treatment of the disease due to the lack of proper medication. Therefore, this study aimed to document MPs used to manage COVID-19 by the locals in Dar es Salaam and Morogoro regions during the outbreak. The obtained information will helps to understand the MPs used during the COVID-19 pandemic time, and the documentation will inform the future generation on the MPs used.

Materials and Methods

Study area

This study was conducted in Dar es Salaam and Morogoro regions. The Dar es Salaam region is located at 6°46' S and 39°10' E on the coast of Tanzania, while the Morogoro region is located at 6°49' S and 37°40' E. The selection of the two regions was due to their proximity, Dar es Salaam being the largest commercial city with the highest population of 5.4 million people, and Morogoro region with 3.2 million people being principally touristic and agricultural production (URT 2022). Moreover, both regions are focal points for receiving visitors and business people from various parts within and outside the country. Each region was represented by two districts, namely Temeke and Ubungo districts (Dar es Salaam) and Morogoro urban and Kilombero districts (Morogoro region), as shown in Figure 1. The selected districts were chosen due the availability of MPs in the area, and the presence of traditional medicinal practitioners who were identified by the help of local leaders and elders. The climate of the two regions is tropical sub-humid with bimodal rainfall. Short rains start in November to December while the longer rains starts in March and ends in May. The mean annual rainfall and temperature of Morogoro and Dar es Salaam are 890mm and 26.6^{o}C while Dar es Salaam 1150 mm and 26.5^{o}C.

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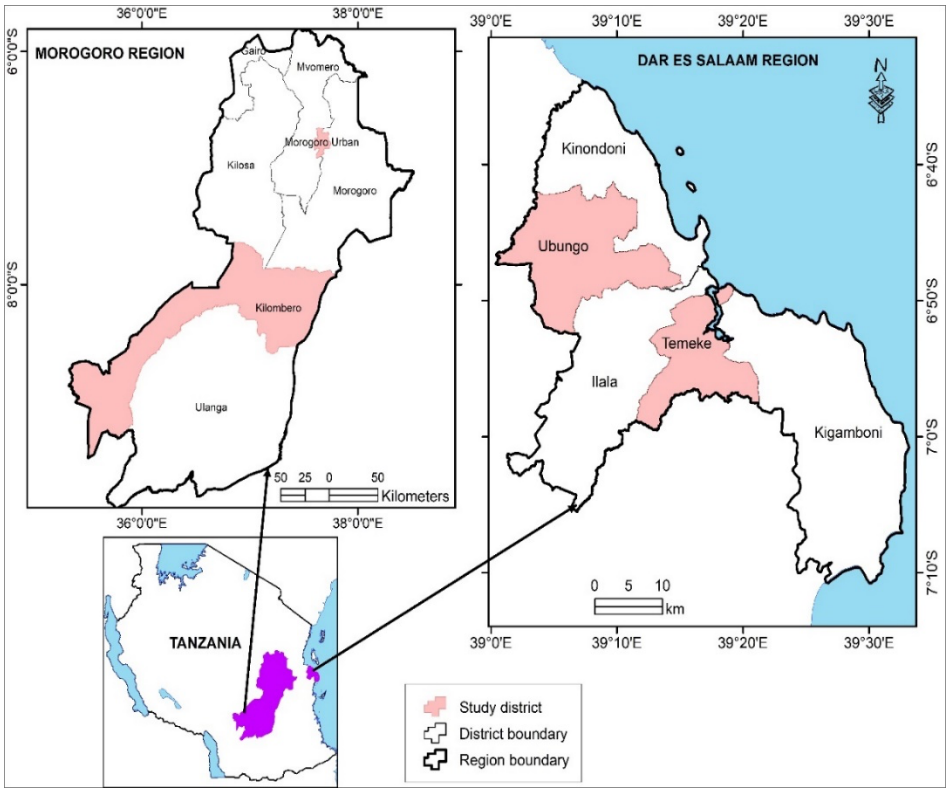

Figure 1. Map showing study regions and sites

Ethnobotanical survey and plant identification

The study was conducted from September 2021 to February 2022 in four districts of Dar es Salaam and Morogoro regions. A total of 120 respondents were involved in the study, out of which 48 were key informants who were knowledgeable in the use of MPs. Each district was represented by 30 respondents, 12 of whom were key informants, six male and six female selected through assistance of local leaders and elders. Other 18 respondents were selected randomly to make a total of 30. Semi-structured interviews following Martin (2010) and field observations were used to gather information on MPs used for the management of COVID-19. Information on the' part(s), sources, preparation methods, administration routes and sources of knowledge on the use of MPs were asked in Swahili language and later translated into the English language. The informant's consent was obtained from the participant before starting the interviews. Prior identification of MPs was done in the field by botanist. Finally, all identified voucher specimens were deposited at the Dar es Salam University College of Education herbarium. The scientific names were verified using the database from https://www.theplantlist.org and https://www. ipni.org.

Data Analysis

Microsoft Excel version 2016 and Statistical Package for Social Sciences (SPSS) version 23 were used to organised and analyse the collected data. The t-test was used to check for differences in plant knowledge within gender. One-way analysis of variance (ANOVA) at (p≤ 5%) was used to check differences in plants medicinal knowledge in the studied groups (age and education level). Relative Frequency of Citation (RFC) was calculated as per the formula indicated below.

$$RFC = \frac{FC}{N}$$

Where FC is the number of respondents who mentioned the use of species and N is the total number of respondents who took part in the survey (Tardio and Pardo-de-Santayana, 2008).

Results

Social demographic data

Of all the respondents involved in this study, 50.8% were female, and 49.2% were male, with ages ranging between 18-78 years with an average of 48 years. The majority of respondents (49.2%) were in the age group of 31-54, followed by the age

group of 18-30 (35.8%), and 15% of the respondents were above 55 years. In terms of education level, 59.2% of the respondents had primary education, 25.8% secondary education, 10.0% tertiary education, and 5.0% had no opportunity for formal education (Table 1).

In terms of MPs knowledge, there was no significant difference within gender ($t = 1.980$, $p = 0.984$), but the knowledge differed appreciably within age group ($F = 36.14$, $p = 0.000$) and education levels ($F = 20.20$, $p = 0.000$). The age groups of 18-30 and 31-54 years did not differ significantly in terms of MPs knowledge, while the age group of 55 and above showed significantly higher MPs knowledge than other groups ($p < 0.05$). In terms of education level, illiterate respondents were revealed to have significantly higher MPs knowledge than the rest of the categories ($p< 0.05$), which did not differ appreciably (Table 1).

Table1. Social demographic information

Informants	Categories	No. of respondents	% of respondents	No of species
Gender	Female	61	50.8	4.3±1.7
	Male	59	49.2	4.3±1.4
Age	18-30 years	43	35.8	3.2±1.0[a]
	31-54 years	59	49.2	4.7±1.2[ab]
	55 and above	18	15.0	5.9±1.6[b]
Education	Illiterate	06	5.0	6±0.9a
	Primary Education	71	59.2	4.9±1.4[a]
	Secondary Education	31	25.8	3.1±1.0[a]
	Tertiary Education	12	10.0	3.4±1.0[a]

Note: Differences in the superscript letters indicate significant differences between the two means at a 5% significant level

Transfer of traditional medicinal plant knowledge

The highest traditional medicinal plant knowledge of MPs for COVID-19 was acquired from closely related family members, including mother (22.5%), grandmother (20.8%), grandfather (17.5%) and father (15.0%), while other sources included media (10.80%), wives (7.5%) and knowledge from friends (5.9%).

Medicinal plants diversity

The ethnobotanical survey revealed 21 medicinal plant species belonging to 12 families and 16 genera that were used as traditional remedies for the prevention and management of COVID-19 in the study areas. Out of the recorded MPs, only five species were native to Tanzania, while sixteen were introduced. The native species were *Cymbopogon citratus* (DC.) Stapf. (Poaceae), *Ocimum gratissimum* L. (Lamiaceae), *Ocimum suave* Willd. (Lamiaceae), *Plectranthus amboinicus* (Lour.) Spreng (Lamiaceae) and *Plectranthus barbatus* Andr. (Lamiaceae). The dominant family was Lamiaceae (28.6%), followed by Myrtaceae (14.3%), Rutaceae and Amaryllidaceae (9.5% each) and the other eight families had only one species (Table 2).

Source of medicinal plants

Most respondents reported obtaining MPs from markets (38.0%) followed by home gardens (26.0%), farmland (21.0%), and wild (15.0%) (Figure 2)

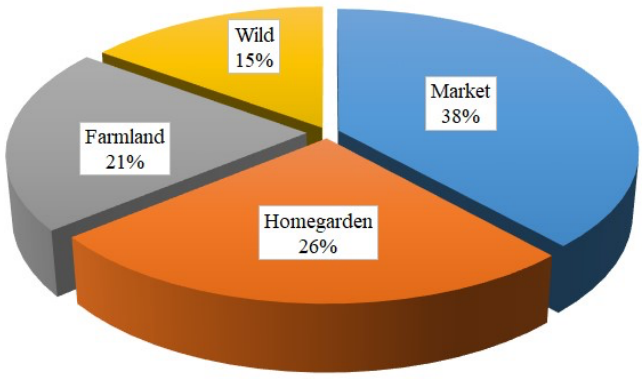

Figure 2. Sources of medicinal plants

Plant parts used medicinally

The comparison of the parts of MPs used to treat COVID-19 revealed that leaves (57.1% of the recorded species) were the most dominant plant part, followed by fruits (19.0%) and bulbs (9.5%), while bark, roots, and flowers were represented by 4.8% each (Table 2).

Growth form, mode of preparation and route of administration of medicinal plants

The collected MPs had diverse growth forms. Herb constituted a large portion of 47.6%, followed by trees (42.9%), and shrubs (9.5%). Regarding the methods of preparation, decoction (76.0%) outweighed other methods, followed by chewing (10.0%) and infusions (7.0%), while the least were baking and juicing (3.5% each). The result showed that the remedies were mainly administered through two routes: oral (73.0%) and steam inhalation (27.0%) (Figure 3). Detailed information on the plant part used, habit, mode of preparation and route administration are provided in Table 2.

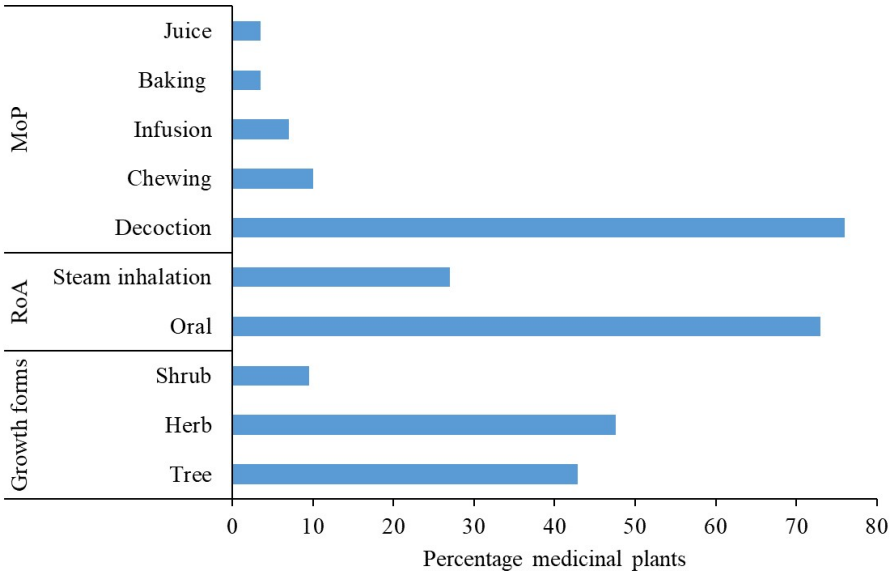

Figure 3. Growth form, mode of preparation (MoP) and route of administration (RoA) of medicinal plants

Relative frequency of citation (RFC)

The MPs with the highest RFC were *Zingiber officinale* Roscoe (Zingiberaceae), *Eucalyptus globulus* Labill. (Myrtaceae) *Cymbopogon citratus* (DC.) Stapf (Poaceae), *Citrus x aurantiifolia* (Christm.) Swingle (Rutaceae) and *Allium sativum* L.(Amaryllidaceae), each with an RFC of one. These were followed by *Azadirachta indica* A.Juss. (Meliaceae) (0.95), *Citrus limon* (L.) Osbeck (Rutaceae) (0.93), *Tetradenia riparia* (Hochst.) Codd (Lamiaceae) (0.9), *Allium cepa* L. (Amaryllidaceae) (0.74) and *O. gratissimum* L.(Lamiaceae) (0.7). The least RFC were the species of *Ananas comosus* (L.) Merr. (Bromeliaceae) (0.05) and *Syzygium aromaticum* (L.) Merr. & L.M. Perry (Myrtaceae) (0.1) (Table 2).

Table 2. Medicinal plants for management of COVID-19 with their respective scientific name, family, habit, part used, mode of preparation (MoP), dosage, route of administration (RoA), Frequency of citation (FC), Relative Frequency of Citation (RFC) and country with similar use

Scientific name and status in Tanzania	Family	Growth form	Vernacular and English name	Parts used	Preparation and dosage	RoA	FC	RFC	Voucher no.	Countries with similar use to treat COVID-19
Allium cepa L. **Exotic**	Amaryllidaceae	Herb	kitunguu maji (onion)	Bulb	Chewing a raw onion twice a day for three days. Boil three red onions in one litre of water, add three tablespoons of honey, and drink twice a day for two weeks.	Oral Oral	89	0.74	NGM01	Algeria (Brahmi *et al.* 2022), Cameroon (Tsouh Fokou &Youmsi Fokouo 2020), Morocco (El Alami *et al*. 2020), Nepal (Khadka *et al*. 2021), Nigeria (Odebunmi *et al.* 2022), Brazil (Ferreira 2020) Cuba (Rivas et al.2022), Turkey (Güneş *et a*l. 2018).
Allium sativum L. **Exotic**	Amaryllidaceae	Herb	kitunguu swaumu (garlic)	Bulb	Chew two pieces twice a day. Blend a mixture of five clove of *A. sativum*, and two *A. cepa*, two pieces of *Z. officinale* rhizome, two hot *Capsicum annuum* and two *C.aurantiifolia* without the seeds. Add one litre of boiled water and mix. Use one tablespoon twice a day for 14 days.	Oral Oral	120	1	NGM02	Algeria (Brahmi *et al.* 2022), Cameroon (Tsouth Fokou &Youmsi Fokouo 2020), Morocco (El Alami *et al*. 2020), Nepal (Khadka *et al*. 2021), Nigeria (Odebunmi *et al.* 2022), Brazil (Ferreira 2020, Turkey (Nadiroğlu *et al.* 2019).
Ananas comosus (L.) Merr. **Exotic**	Bromeliaceae	Herb	nanasi (pineapple)	Fruit	Raw juice; take a glass twice a day.	Oral	6	0.05	NGM03	Cameroon (Tsouh Fokou & Youmsi Fokouo 2020)
Azadirachta indica A.Juss. **Exotic**	Meliaceae	Tree	mwarobaini (neem)	Leaves	Fresh leaves of *A. indica, E. globulus* are all boiled in water; drink then inhale it twice a day when sick or once a week for prevention.	Oral Steam inhalation	114	0.95	NGM04	Nepal (Khadka *et al*. 2021), Nigeria (Odebunmi *et al.* 2022)

Scientific name and status in Tanzania	Family	Growth form	Vernacular and English name	Parts used	Preparation and dosage	RoA	FC	RFC	Voucher no.	Countries with similar use to treat COVID-19
Capsicum annuum L. **Exotic**	Solanaceae	Herb	pilipili kichaa (pepper)	Fruit	Fruit of *Capsicum annuum* blended with *A. sativum* and *Z. officinale* and water. Drink twice a day.	Oral	67	0.56	NGM05	Nepal (Khadka *et al*. 2021), Nigeria (Odebunmi *et al.* 2022)
Cinnamomum verum J.Presl. **Exotic**	Lauraceae	Tree	mdalasini (cinnamon)	Bark	Prepare a herbal tea using six cloves seeds of *S. aromaticum*, bark of *C. verum*, fresh leaves of *M. oleifera* and one spoon of honey in a cup. Drink a cup twice a day for one week.	Oral	37	0.31	NGM06	Algeria (Brahmi *et al.* 2022), Nepal (Khadka *et al*. 2021)
Citrus x aurantiifolia (Christm.) Swingle **Exotic**	Rutaceae	Tree	ndimu (lime)	Fruit	Fresh fruits are squeezed to get juice and drink juice twice a day. Fresh leaves are cleaned and boiled in water and inhale the steam while covering with blanket. Do it twice a day.	Oral Steam inhalation	120	1	NGM07	Cameroon (Tsouh Fokou & Youmsi Fokouo 2020), Nepal (Khadka *et al*. 2021), Nigeria (Odebunmi *et al.* 2022), Brazil (Ferreira 2020)
Citrus limon (L.) Osbeck **Exotic**	Rutaceae	Tree	Limao (lemon)	Fruit	Make a hot tea of fresh fruits of *C.limon* and *Z. officinale*. Drink while it is warm twice a day	Oral	112	0.93	NGM08	Algeria (Brahmi *et al.* 2022), Ethiopia (Umeta Chali *et al.* 2021), Nigeria (Odebunmi *et al.* 2022), Brazil (Ferreira, 2020)
Cymbopogon citratus (DC.) Stapf **Native**	Poaceae	Herb	mchaichai (lemon grass)	Leaves	Prepare a tea of fresh leaves of *C. citratus* and ground *Z. officinale.* Drink a cup twice in a day for seven days. Fresh leaves of *C. citratus, E. globulus,* and fruits of *C. limon* are mixed and boiled in water; inhale the hot mixture twice a day.	Oral Steam inhalation	120	1	NGM09	Cameroon (Tsouh Fokou &Youmsi Fokouo 2020), Nepal (Khadka *et al*. 2021), Nigeria (Odebunmi *et al.* 2022.

Scientific name and status in Tanzania	Family	Growth form	Vernacular and English name	Parts used	Preparation and dosage	RoA	FC	RFC	Voucher no.	Countries with similar use to treat COVID-19
Eucalyptus globulus Labill. **Exotic**	Myrtaceae	Tree	mkaratusi (eucalyptus)	Leaves	Prepare a decoction by boiling fresh leaves of *E. globulus, M. oleifera* and *Ocimum* sp. in five litres of water and drink a cup of the mixture, and inhale twice a day for one week.	Oral Steam inhalation	120	1	NGM10	Algeria (Brahmi *et al.* 2022), Cameroon (Tsouh Fokou &Youmsi Fokouo 2020), Morocco (El Alami *et al*. 2020), Nigeria (Odebunmi *et al.* 2022), Brazil (Ferreira 2020)
Mangifera indica L. **Exotic**	Anacardiaceae	Tree	mwembe (mango)	Leaves	Fresh leaves of *M. indica, E. globulus* and *T. riparia* boiled in five litres of water; drink a cup of the mixture and do steam inhalation.	Oral Steam inhalation	43	0.36	NGM11	Cameroon (Tsouh Fokou &Youmsi Fokouo 2020), Nigeria (Odebunmi *et al.* 2022).
Moringa oleifera Lam. **Exotic**	Moringaceae	Tree	mlonge (drumstick tree)	Leaves	Fresh young leaves of *M. oleifera* boiled in one litre of water, add two spoons of honey to make herbal tea, and drink a cup twice a day.	Oral	26	0.22	NGM12	Cameroon (Tsouh Fokou &Youmsi Fokouo 2020)
Ocimum tenuiflorum L. **Exotic**	Lamiaceae	Herb	mvumbashi (holy basil)	Leaves	Decoction made by boiling fresh leaves of *O.tenuiflorum*, *P. guajava* and *M. indica* in five litres of water. Drink the decoction and inhale the steam therapy once a day for one week.	Oral Steam inhalation	23	0.19	NGM13	Not found
Ocimum gratissimum L. **Native**	Lamiaceae	Shrub	mvumbashi (basil cloves)	Leaves	Fresh leaves chewed for a few minutes and spit out. Fresh leaves boiled in water and drink twice a day.	Oral	84	0.7	NGM14	Not found
Ocimum suave Willd. **Native**	Lamiaceae	Herb	mvumbashi (wild basil)	Leaves	Fresh leaves are boiled in water with *M. oleifera* leaves; drink the decoction and do hot steam inhalation.	Oral Steam inhalation	79	0.66	NGM15	Not found

Scientific name and status in Tanzania	Family	Growth form	Vernacular and English name	Parts used	Preparation and dosage	RoA	FC	RFC	Voucher no.	Countries with similar use to treat COVID-19
Plectranthus amboinicus (Lour.) Spreng **Native**	Lamiaceae	Herb	(Indian borage)	Leaves	Fresh leaves are soaked in water and drank twice a day for one week.	Oral	48	0.4	NGM16	Cuba (Rivas *et al.*2022) Brazil (Ferreira 2020)
Plectranthus barbatus Andr. **Native**	Lamiaceae	Herb	(Indian coleus)	Leaves	Fresh leaves are put in a boiled cup of water and let it infuse for five to ten minutes; add honey. Drink the infusion for five days.	Oral	57	0.48	NGM17	Brazil (Ferreira 2020)
					Bake five leaves on fire for 15 seconds, remove them, then squeeze while inhaling twice a day	Steam inhalation				
Psidium guajava L. **Exotic**	Myrtaceae	Tree	mpera (guava)	Leaves	Fresh leaves are ground and boiled in water, drink half of a cup of decoction twice a day.	Oral	58	0.48	NGM18	Cameroon (Tsouh Fokou &Youmsi Fokouo 2020), Nigeria (Odebunmi *et al.* 2022),
					Fresh leaves of *P.guajava*, *M. oleifera* and *T. riparia* each, mixed and boiled in 5 litres of water. Do hot steam inhalation.	Steam inhalation				
Syzygium aromaticum (L.) Merr. & L. M. Perry **Exotic**	Myrtaceae	Tree	karafuu (cloves)	Flower bud	Soak six cloves in a cup of clean water overnight, then drink in the morning before eating anything for 15 days.	Oral	12	0.1	NGM19	Algeria (Brahmi *et al.* 2022), Cameroon (Tsouh Fokou &Youmsi Fokouo 2020), Ethiopia (Umeta Chali *et al.* 2021), Nigeria (Odebunmi *et al.* 2022
Tetradenia riparia (Hochst.) Codd. **Exotic**	Lamiaceae	Shrub	mvumbashi (ginger bush)	Leaves	Fresh leaves of *T. riparia* are chewed for a few minutes and spit out. Chew twice to thrice a day for 14 days.	Oral	108	0.9	NGM20	
Zingiber officinale Roscoe	Zingiberaceae	Herb	tangawizi (ginger)	Rhizome /root	Fresh rhizome ground and boiled in water. Add a teaspoon	Oral	120	1	NGM21	Algeria (Brahmi *et al.* 2022), Cameroon (Tsouh Fokou &

Scientific name and status in Tanzania	Family	Growth form	Vernacular and English name	Parts used	Preparation and dosage	RoA	FC	RFC	Voucher no.	Countries with similar use to treat COVID-19
Exotic					of honey and drink a cup at least three times a day for seven days. Grind five cloves of *A. sativum* and a piece of *Z. officinale*, then add a cup of boiled water and add a tablespoon of honey. Mix them well and drink one tablespoon twice a day for one week.	Oral				Youmsi Fokouo 2020), Ethiopia (Umeta Chali *et al.* 2021), Morocco (El Alami *et al*. 2020) Nepal (Khadka *et al*. 2021, Nigeria (Odebunmi *et al.* 2022), Brazil (Ferreira 2020), Turkey (Yalçın *et al.* 2021).

Discussion

Social demographic data

The findings indicate slight domination of females over males in the knowledge of MPs used for the management of COVID-19. This could be attributed to the fact that traditionally, women are the ones who spend more time helping sick people and are responsible for the health of their families. According to Olanipekun (2023), women are closer to family welfare than men. Females are responsible for food and healthcare for their families. This finding is agreeing with findings in Tanzania (Charwi *et al.* 2022, Kitula 2007), Uganda (Kamatenesi-Mugisha & Oryem–Origa 2007), Ethiopia (Kidane *et al.* 2018, Megersa & Tamrat 2022) and Nigeria (Odebunmi *et al*. 2022). The difference in the average number of cited species among education level could be contributed by the fact that, those who have only primary education or no opportunity for formal education spent much of their lifetime in their local environment. Thus, they learn more and gain experience of the use of MPs. Mwingira et al. (2023) reported that people who have acquired higher level of education are disconnected with ethnobotanical knowledge. In terms of age, the elders had good knowledge of MPs used for management of COVID-19 than the younger age groups. The difference could be due to accumulated experiences and knowledge of natural resources over time compared to young respondents (Kacholi & Amir 2022, Olanipekun 2023). In addition, young generation prefers contemporary medical healthcare than older ones, hence, disinterested with indigenous medication (Bhat *et al*. 2021, Kacholi & Amir 2022). Therefore, it is important for the older people to share their knowledge with the younger generation, and document MPs for future use.

Ethnobotanical data

In this study, 21 MPs belonging to 12 families and 16 genera were recorded as being used for the management of COVID-19. The present study recorded 21 MPs, slightly higher than the record of Mshana et al (2021) who recorded 19 MPs used in COVID-19 in the Mwanza region, Tanzania. However, the present finding is low compared to other studies conducted in other countries (Table 3), which call for further study surveys to check for more MPs in the country. Most of these species recorded were similar to the other studies of medicinal plants used in the treatment of COVID-19 within and outside the countries, as shown in Table 3.

Table 3. Similar number of species recorded in other ethnobotanical studies

Country	Number of species recorded	Similar MPs with this study	List of similar MPs in this study
Tanzania (Mshana *et al.* 2021)	19	12	*A. cepa, A. sativum, A. indica., C. limon, C. citratus, E. globulus, M. indica, O. gratissimum, P. guajava, S. aromaticum, T. riparia Z. officinale,*
Tanzania (Mlozi 2022)	7	5	*A. cepa, A. sativum, C. annum, Z. officinale, C. aurantiifolia*
Nigeria (Odebunmi *et al.* 2022)	26	12	*A. cepa, A. sativum, A. indica*, *C. annuum, C. limon, C. aurantiifolia, C. citratus, E. globulus, M. indica, P. guajava, S. aromaticum, Z. officinale*
Ethiopia (Umeta Chali *et al.* 2021)	32	06	*A. cepa, A. sativum, C. aurantiifolia, C.verum, S .aromaticum, Z. officinale*,
Cameroon (Tsouh Fokou and Youmsi Fokouo 2020)	29	11	*A. cepa, A. comosus,A. sativum,, C. aurantiifolia, C. citratus, E. globulus, M. indica , M. oleifera , P. guajava , S .aromaticum, Z. officinale*
Algeria (Brahmi *et al.* 2022)	23	08	*A. cepa, A. sativum, C. verum, C. limon, E. globulus, O. basilicum, S. aromaticum, Z. officinale*
Morocco (El Alami *et al.* 2020)	23	04	*A. cepa, A. sativum, E. globulus, Z. officinale*
Nepal (Khadka *et al.* 2021)	60	11	*A. cepa, A. indica, A. sativum, C. papaya, C. aurantiifolia, C. annuum C. citratus, O. basilicum, P. guajava, S. aromaticum, Z. officinale*

In all these countries, five species, namely, *A. cepa*, *A. sativum, C. aurantiifolia, E. globulus* and *Z. officinale* were the most cited plants for the management of COVID-19. The relevance and acceptance of these species in the management of COVID-19 was also realized in this study through discussion with the locals and in their value of RFC where all had scored one except

A. cepa whose RFC value was 0.74. (Table 2) which is the indication of importance and acceptance of the species in the area. According to Eidi *et al*. (2006) and Fredotovic & Puizina (2019), *A. sativum* is rich in nutrients, which helps boost body immunity, prevent respiratory tract infections and have anti-stress properties. It also contains compounds of sulfoxide, bioactive compounds such as polyphenols and proteins, which are antiviral and have immunostimulatory capacity (Anywar *et al.* 2006). It possesses antioxidant, antibacterial, anti-inflammatory and anticancer activities (Fredotovic &Puizina 2019).

The presence of Quercetin chemical in *A. cepa* helps to inhibit SARS-CoV-2 effect in the body (Ahmed &Hughes 2022). It has flavonoids, saponins and organosulfur compounds (Bisakowski *et al.* 2007) which make it to possess antioxidant, antiviral, antibacterial, antiproliferative and anti-inflammatory properties (Fredotovic & Pulzina 2019). *Z. officinale* is known for having antimicrobial, anti-inflammatory, hepatoprotective, antioxidant, antidiabetic and hypocholesterolemic properties (AbdEl-Wahab *et al.* 2009, Chang *et al.* 2013, Jolad *et al.* 2004). It has a chemical compound called Kaempferol which inhibit SARS-CoV helicase activity (Ahmed & Hughes 2022), and contain 8-Gingerol and 10- Gingerol, which are active compound against COVID-19 (Rajagopal *et al*.2020). *E. globulus* has essential oils and active compounds such as Eucalyptol, Limonene, Aromadendrene, Eucalyptol and Isoledene (Abdossi *et al*.2015) which make it antiviral, antifungal, antimicrobial, antiviral, antioxidant and antinociceptive activities (Hayat *et al.* 2015). The presence of Cineole compound in *Eucalyptus* help in relieves coughs, congestion, loosens phlegm and other breathing disorders such as COVID-19 and asthma (Mlozi 2022).

The prevalence of the Lamiaceae family is due to its widespread and richness in terms of the number of species (Silva et al. 2021). The observation of this study is also in line with the findings of an ethnobotanical study conducted in Morocco (El Alami *et al*. 2020), Nepal (Khadka *et al.* 2021) and Turkey (Akbulut 2021) which reported the family being dominant in treating COVID-19. Similarly, the family was the most dominant in Spain (Gras *et al.* 2021), Ethiopia (Teka & Maryo 2023), Kenya (Uritu *et al*. 2018) South Africa, (Semenya & Maroyi 2018), Turkey (Selvi *et al.*2022) for treating various ailments. The family contains different essential oils together with their terpenes' components, which have antiviral activity against SARS-CoV-2 and other respiratory tract disorders (Ćavar Zeljković *et al.* 2022, Le-Trilling *et al.* 2022).

Source, life forms and part used

In this study, most MPs were obtained from market places. This is due to the fact that some MPs do not grow well in the study area due to weather conditions and edaphic factors. Some of the species that are mostly found in the markets are *A. sativum*, *S. aromaticum, Z. officinale, and C. verum.* A. *sativum*, *C. verum* and Z. *officinale* require high elevation areas of 1200- 2000m and cool temperatures. The findings were comparable with Khadka *et al.* (2021) and Umeta Chali *et al.* (2021) who found the same results. Although the home garden was the second source of MPs, the locals should be encouraged to cultivate MPs for their sustainability, easy accessibility, diversity of MPs and for ensuring enough supply for commercial purposes. Moreover, elders who are key knowledgeable holders of MPs avoid looking for MPs far from where they live and hence grow them in their home gardens (Agize *et al.* 2022).

The predominance of herbs and trees in the management of COVID-19 in the area can be attributed to their easy accessibility, knowledge, familiarity, and abundance of these growth forms (Amri & Kisangau 2012). This is in line with the results by Amsalu *et al.* (2018), Kacholi & Amir (2022), Charwi *et al*. (2023) and Semenya & Maroyi (2018). The study also indicates that leaves were the most used part. A very high use of leaves as MPs was also reported elsewhere in Tanzania (Mshana *et al*. 2021, Charwi *et al.* 2023), Ethiopia (Umeta Chali *et al.* 2021), and South Africa (Semenya & Maroyi 2018). Leaves are preferred for the formulation of remedies because of their easy accessibility, easy processing, and abundance of organic elements, which have medicinal effects (Amsalu *et al.* 2018, Charwi *et al*. 2023). Additionally, unlike roots and bark, leaves are preferred because of their less detrimental effects on the mother plant (Chandrodyam 2016). Hence, this study suggests for need to educate the locals on the importance of the use of leaves as part of conservation strategies of medicinal plants.

Method of preparation and administration

Decoction was commonly used in preparing remedies as it speeds up the extraction of active compounds from the plant materials, but it also disinfects and removes poisonous compounds in the plant material Sheridan *et al*. (2012). The preferential use of decoction was also reported in other ethnobotanical studies on COVID-19 (Mshana *et al*. 2021, Umeta Chali *et al*. 2021, El Alami *et al*. 2020). In addition, the oral route was preferred because it is the most convenient, innocuous and least expensive. Ahmed & Hughes (2020), Tsouh Fokou & Youmsi Fokouo (2022) in their ethnobotanical studies on COVID-19 management, reported similar observations.

Novelty of the study

Out of 21 MPs reported in the present study for management of COVID-19, two species of *Ocimum suave* and *Ocimum tenuiflorum* were not reported in the cited literature within and outside the country.

Conclusion

The findings indicate that the two regions researched had a considerable diversity of medicinal plants for the management of COVID-19. The results of this study corresponded well with other studies on COVID-19 done within and outside the country. Unfortunately, no phytochemical and toxicity study has been done in this study, and no clinical evaluation made. Hence, this study recommends further research to examine the phytochemical and pharmacological aspects of the recorded medicinal plants. Furthermore, the study suggests for toxicological study and clinical evaluation in order to determine their effectiveness in the prevention of COVID-19.

Declarations

List of abbreviations: COVID-19- Corona Virus Disease 2019, FC-Frequency of citation, MPs – Medicinal Plants, RFC- Relative frequency of citation,

Ethical approval and consent to participants: All participants provided oral prior informed consent.

Data and material availability: Voucher specimens deposited at Dar es Salaam University College of Education, Department of Biological Sciences Herbarium (DUCE herbarium)

Conflict of interest: The author declares there is no conflict of interest.

Author's contributions: NGM conceptualized and designed the overall study, including fieldwork conduction, plant materials collection, processed the data and interpreted the results, drafted the manuscripts, read, reviewed the manuscripts and approved the final manuscript.

Funding: This work did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Acknowledgements

The author would like to thank all the participants for sharing their valuable time and information, which made this work successful.

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