Medicinal Plants Used in COVID-19 Pandemic in Buddhabhumi Municipality, Kapilvastu, Nepal

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Research

Abstract

Background: Currently, the Coronavirus disease (COVID-19) pandemic is posing a serious threat to global health. Although approved COVID-19 vaccines have been claimed to provide a high degree of protection against getting seriously ill and dying from the disease, they are not in the approach of all people especially those from the least developed countries like Nepal. Desperation within people has led to increased use of medicinal plants to cure the miscellaneous symptoms of COVID-19 and to prevent infection without proper knowledge of their phytochemical and pharmacological properties.

Methods: Based on the online and interpersonal inquiries with 59 COVID-19 survivors and 111 inhabitants of Buddhabhumi Municipality, Kapilvastu, Nepal, the ethnomedicinal data were collected and summarized using descriptive statistics like frequency, percentage tables, and graphs. For each medicinal plant species, the frequency of citation (FC) and relative frequency of citation (RFC) were calculated along with a radar chart for the top 15 cited species with their phytochemical and pharmacological properties.

Results: This study documented 41 species of medicinal plants belonging to 24 different families and 37 genera were used. Herbs were predominant among other life-forms and leaves were highly used among other plant parts. Turmeric (*Curcuma longa*, with the highest frequency of citation of 0.80) was the most frequently used species. Most of the respondents (44%) obtained medicinal plants from their home gardens. Family, friends, and neighbors were the primary sources of information the respondents followed. Interestingly, all of the 15 most frequently cited medicinal plants were reported to have both antiviral and anti-inflammatory properties and 14 of them were proclaimed to be immunomodulatory.

Conclusion: Therefore, we conclude from the survey and available literatures that medicinal plants play a significant role against viral infections.

Keywords: Anti-inflammatory, Antiviral, Immunomodulatory, Pharmacology, Phytochemical

Background

The worldwide health crisis caused by SARS-CoV-2, the origin of the Coronavirus disease (COVID-19) outbreak, has reminded us that the globe is no longer functioning, presumably business as usual. After the Severe Acute

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Respiratory Syndrome Coronavirus (SARS-CoV) in 2003 (De *et al.* 2016, Lee *et al.* 2003, Pieris *et al.* 2003) and the Middle East Respiratory Syndrome Coronavirus (MERS-CoV) in 2012 (Alagaili et al. 2014, Memish *et al.* 2013, Zaki *et al.* 2012), COVID-19 is the third novel coronavirus to cause a large-scale epidemic in the twenty-first century. The COVID-19 outbreak started in December 2019 (Sheeran *et al.* 2020) and proceeded differently in numerous regions. As of 20th August 2021, 4,400,284 individuals worldwide have lost their lives due to COVID infection (WHO 2021). COVID-19 has triggered several endeavors to prevent disease transmission in addition to preventive measures (Lake 2020, Salathe *et al.* 2020). Few vaccines have been permitted for emergency use and to provide a high degree of protection against getting seriously ill and dying from the disease (Li *et al.* 2021). However, not everyone has access to those vaccines (Saad-Roy *et al.* 2020). Particularly, people from the least developed countries like Nepal have limited access to vaccines. Besides, as the vaccines were developed over a very short period, their long-term efficacy and side effects are yet to be confirmed (Forni & Mantovani 2021). In this context, provided herbal medicines have been used for the treatment of viral infections since time immemorial (Wang *et al.* 2020), medicinal plants are useful as an alternative for symptomatic treatment and boosting the immune system (Sharma *et al.* 2017).

Lifestyle, nutrition, age, gender, health conditions, and environmental variables all have a pivotal role in susceptibility to COVID-19 severity (Gasmi *et al.* 2020). There is a lot of testimony to support the efficacy of medicinal plants in treating viral infections (Zhang *et al.* 2020). Still, it is challenging to state how well medicinal plants work since they're usually combined with allopathy (Vandebroek *et al.* 2020). Traditional Chinese herbal medicine was revealed to be an efficient therapy to prevent and cure COVID-19, which proudly endorses herbal medication as an alternative remedy (Benarba & Pandiella 2020, Hossain *et al.* 2020, Li *et al.* 2020). Screening analysis of hundreds of Chinese medicinal herbs revealed the presence of anti-SARS-CoV property in the plant extracts (Vandebroek *et al.* 2020). Many bioactive compounds have been tested for their antiviral activity against human viruses (Adhikari *et al.* 2021, Bosquet *et al.* 2021). Despite having little knowledge about the chemical properties of medicinal plants, they are prescribed because of their claimed efficacy and availability (Mohammad *et al.* 2018). Consequently, the demand for medicinal plants is increasing and has become an appropriate alternative treatment option (Pandey *et al.* 2020, Vandebroek *et al.* 2020).

Currently, Nepal is experiencing the second wave of COVID-19 and the cases are skyrocketing. As of 22nd August 2021, 10,509 individuals have lost their lives due to the COVID-19 infection in Nepal, and the death number is still soaring (MOHP 2021). Given the limited access to modern medicine, i.e., only 17% of city-dwellers have access to modern medicine (Adhikari *et al.* 2019) and about 5.1% of the country's population have been vaccinated till 13th June (Reuters 2021), an increasing number of people are exploring alternatives of medicinal plant-based therapeutics. With the rise in unsubstantiated efficacy claims circulating on social media, many misinterpretations of the use of medicinal plants to treat or prevent COVID-19 are spreading throughout Nepal. Nepal is considered the native land of medicinal plants (Pandit & Singh 2020) and has a tradition of using them (Kunwar *et al.* 2010), but the irony is that the study and documentation of medicinal plants used during the COVID-19 period in Nepal are limited. In this context, this study aims to document (1) the medicinal plants being used for COVID-19 treatment and prevention (2) the parts of the plants used; (3) their source; (4) the source of information people follows to use them; (5) people's perception about the efficacy of medicinal plants in curing COVID-19 symptoms or preventing infections; and (6) the phytochemical and pharmacological properties of the medicinal plants being used. By doing so, this study will not only explore information that can be used by the general public, and prospective COVID-19 patients but also contribute to the knowledge base that can be used by the global scientific community to formulate novel drugs and select clinical trials for COVID-19 control and prevention.

Materials and Methods

Study area

This study focused on Buddhabhumi Municipality which is one of the most severely affected municipality by COVID-19 in the Kapilvastu district (Health Office Kapilvastu 2021) of Nepal. In terms of area, it is the largest (366.67 sq km) of the ten municipalities in the Kapilvastu District. It is inhabited by 64,949 individuals (11,509 households) (Central Bureau of Statistics 2018). As of 16th Apr, 2021, out of 250 infected individuals, 240 have recovered from COVID-19 infection in the municipality (Health Office Kapilvastu 2021). The map of the study area is presented here (Figure 1)

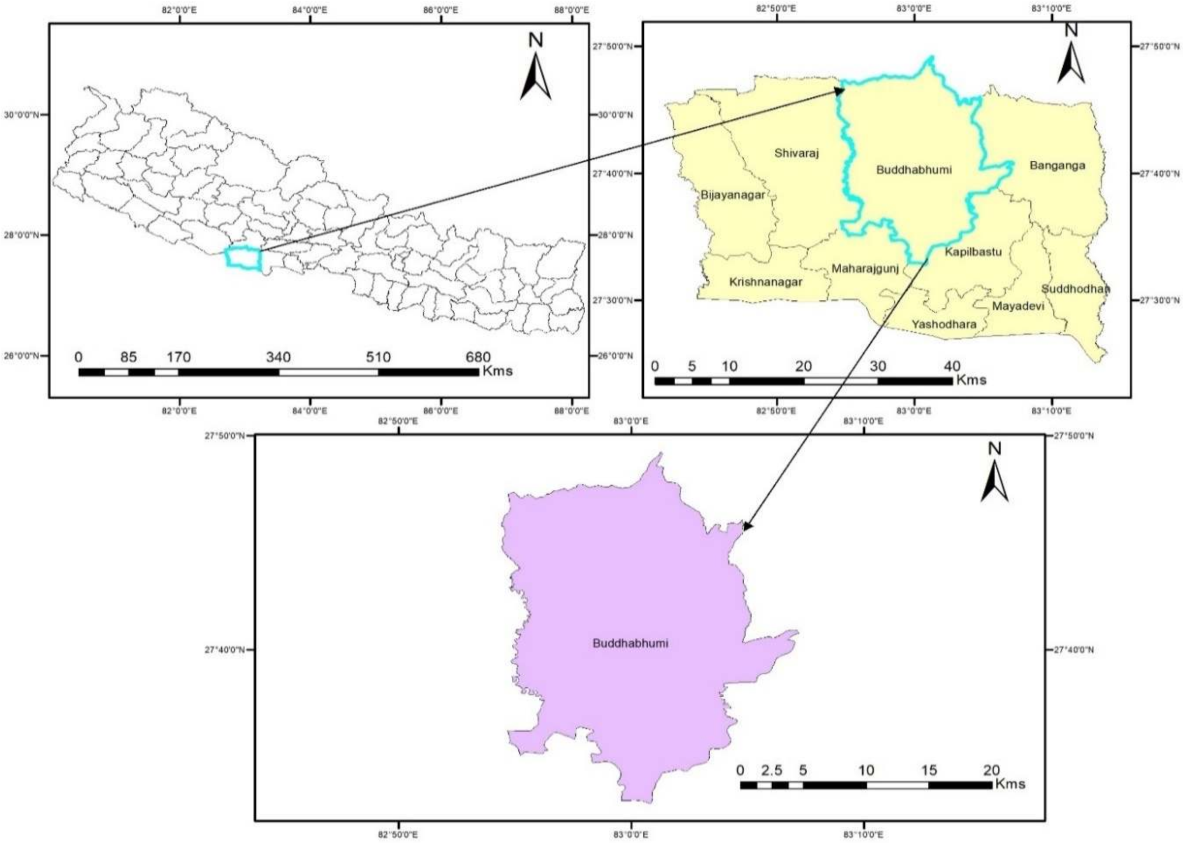

Figure 1. Study area map of Buddhabhumi Municipality. The top left panel shows the location of the Kapilvastu district - the study district and the top right panel shows that of Budhhabhumi Municipality - the studied municipality.

Methods of data collection

Given the current mobility restrictions, we used online inquiries to compile the necessary data. A set of questionnaire forms including close- and open-ended questions was designed in Google Forms Developer. Initially, the Google Form was tested among 25 individuals to validate and comprehend response rates. Throughout our research, we adhered to the norms of the International Society of Ethnobiology and included a written consent message for everyone we reached out with (International Society of Ethnobiology 2006). The Google Form was circulated to 150 individuals of Buddhabhumi Municipality through social media between 5 - 19th May 2021. Out of which, 90 individuals (60%) from 10 wards of the municipality filled out the form and provided information as per the questions mentioned there. In addition to the Google survey, another 60 individuals whose contact details were obtained from the Municipality office were telephoned to collect the data. Furthermore, 20 individuals were interviewed in person, of course following the COVID-19 health standards, using a printed questionnaire. Altogether, 170 individuals were surveyed which covers both COVID-19 survivors (59) and not infected individuals (111). The sample COVID-19 survivors represent 24.58% of the total COVID-19 survivors in the Buddhabhumi Municipality. Of the total 170 respondents, 63.52% were males and 36.48% were females. Most of them were from age class 18-30 years (35.29%) and had completed their higher secondary level education (27.64%).

Identification of Species

The documented plant information was collected from the informants and validated their presence and use in COVID-19 treatment with the local healers. We followed TROPICOS (https://www.tropicos.org/) for the identification of scientific names, the authority of species, and their family of local species used by the respondents.

Statistical Analysis

The collected data were entered into MS Excel 2007 and summarized using descriptive statistics like frequency, percentage tables, and graphs. For each medicinal plant species, the frequency of citation (FC) and relative frequency of citation (RFC) was calculated using the following formula developed by Tardio & Pardo-de-Santayana 2008:

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

Wwhere *RFC*=relative frequency of citation; *FC*=number of respondents who reported the use of medicinal plant species; and *N*=total number of respondents took part in the survey

Based on the RFC, the top 15 medicinal plant species were identified. For the top 15 medicinal plant species, their families, phytochemical, and pharmacological details are listed based on the published literature to verify their use against viral infection.

Methodological limitation

Considering the current situation with limited mobility, we combined an online survey with some interpersonal interviews in this study. Since only the middle-aged educated respondents could access and respond to the online Google Form, it might have introduced some bias.

Results

Medicinal plants used

Of the 170 respondents, 150 (88%) respondents reported that they used medicinal plants during the COVID-19 pandemic (Figure 2). Of the 150 respondents that used medicinal plants, 87 (51%) used only medicinal plants, 63 (37%) others used them along with allopathic medicine while 6 (4%) used allopathic medicine alone and 14 (8%) used none of them. The majority 49 (29%) of the respondents used 8 to 12 species of medicinal plants (Figure 3). In total, 41 species of medicinal plants belonging to 24 families and 37 genera were used (Table 1). Among them, the most common families were Zingiberaceae (4 species), Apiaceae (4 species), Rutaceae (3 species), Lamiaceae (3 species), and Piperaceae (3 species). Similarly, the most dominant genera were *Piper* (3 species), *Cinnamomum* (2 species), *Allium* (2 species), and *Curcuma* (2 species). The majority of the medicinal plant species were herbs 19 (46%), followed by trees 14 (34%), climbers 4 (10%), and shrubs 4 (10%). For species, *Curcuma longa* (0.80) was the most cited species and *Camellia sinensis* (0.01) was the least cited species (Table 1).

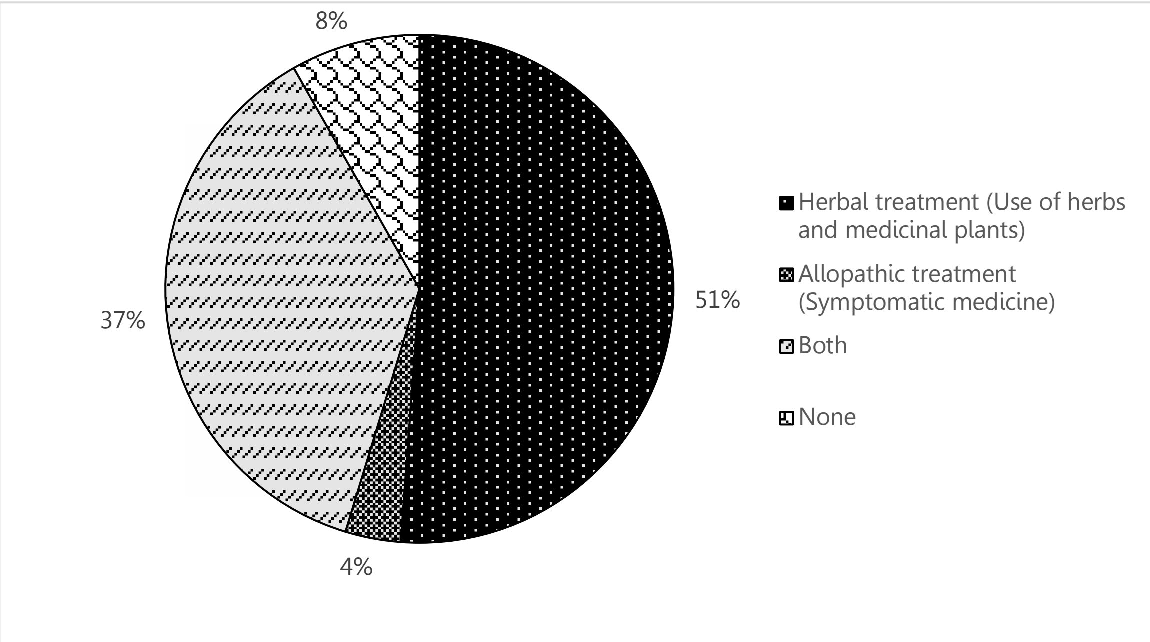

Figure 2. Curative and preventive treatment options followed by the respondents during the COVID-19 period.

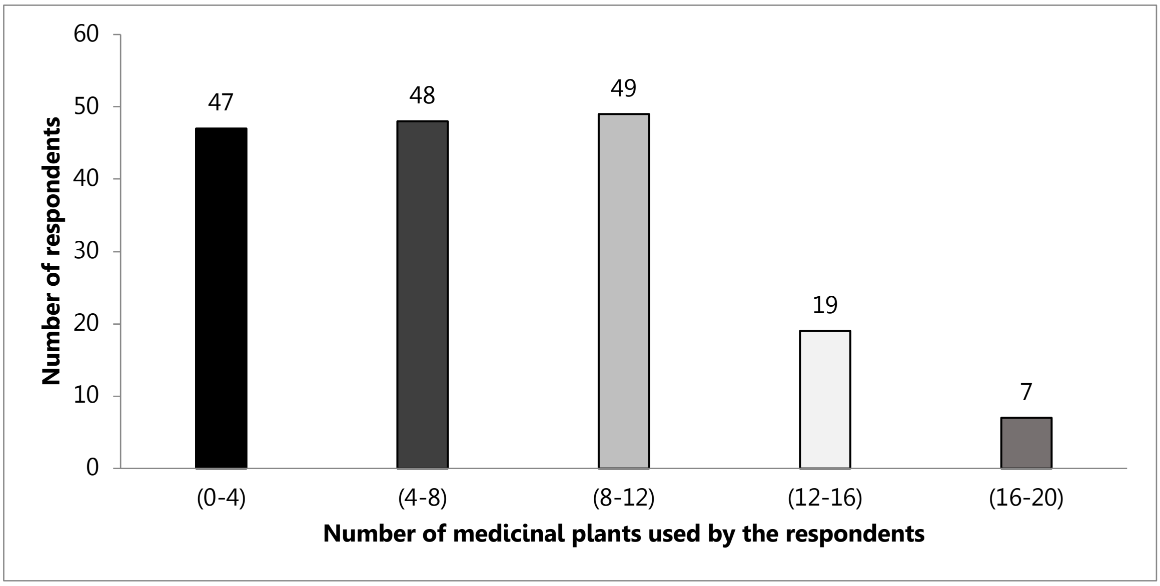

Figure 3. Number of medicinal plants used by the respondents during the COVID-19 period.

Parts of the medicinal plants used, their modes and frequency of use

For some medicinal plant species, entire plants were used, while for some others, specific parts were used. Leaves (37%) were among the most predominantly used parts, followed by rhizome (22%), seed (20%), fruit (17%), Bark (10%), Stem and whole plant (5%), Root and Flower (2%) (Table 1). The most frequently applied process was decoction (to boil plant parts i.e., leaves, rhizome with water) and drink (Table 1). The frequency of medicinal plant use during the period of COVID-19 varied from often 42 (25%) to rarely 20 (12%) (Figure 4).

Table 1. List of medicinal plants used during the COVID-19 pandemic. Scientific names, their respective English names, local names, parts used, mode of use, frequency of citation (FC), and relative frequency of citation (RFC) are shown. Species are grouped by their families.

Scientific name	English name	Local name	Habit	Parts used	Mode of use	FC	RFC
Acanthaceae							
Justicia adhatoda L.	Malabur nut	Asuro	S	L	Decoction	29	0.17
Acoraceae							
Acorus calamus L.	Sweet flag	Bojho	H	R	Steam	9	0.05
Amaryllidaceae							
Allium cepa L.	Onion	Pyaaj	H	R	Cook, Soup	13	0.08
Allium sativum L.	Garlic	Lasun	H	Bu	Soup, Paste	20	0.12
Anacardiaceae							
Mangifera indica L.	Mango	Amp	T	L, B	Decoction	13	0.08
Apiaceae							
Centella asiatica (L.) Urb.	Water pennywort	Ghodtapre / Toprejhar	H	R	Decoction	18	0.11
Coriandrum sativum L.	Coriander	Dhaniya	H	Se, L	Decoction, Paste	8	0.05
Cuminum cyminum L.	Cumin	Jeera	H	Se	Decoction	8	0.05
Trachyspermum ammi (L.) Sprague	Thyme seed	Jwano	H	Se	Decoction	111	0.65
Apocynaceae							
Ceropegia pubescens Wall.	Yellow Himalayan ceropegia	Mirke laharo / simi laharo	H	St	Decoction	3	0.02
Asteraceae							
Artemesia indica Willd.	Indianworm / mugwort	Titepati	H	L	Decoction	31	0.18

Scientific name	English name	Local name	Habit	Parts used	Mode of use	FC	RFC
Spilanthes acmella (L.) L.	Toothache plant	Ban maratthi	H	Fl	Decoction	18	0.11
Combretaceae							
Terminalia chebula Retz.	Chebulie myrobalan/yellow myrobalan	Harro	T	F, B	Decoction	19	0.11
Equisetaceae							
Equisetum debile Roxb. ex Vaucher	Branched horsetail	Kurkure	H	R	Decoction	2	0.01
Fabaceae							
Trigonella foenum-graecum L.	Fenugreek	Meethi	H	Se, L	Paste	9	0.05
Lamiaceae							
Ocimum tenuiflorum L.	Holy basil	Tulsi	H	L, Se	Decoction	131	0.77
Mentha arvensis L.	Pepper mint	Pudina	H	W	Decoction, Paste	7	0.04
Pogostemon benghalensis (Burm. f.) Kuntze	Bengal Shrub-Mint	Rudilo	T	L	Decoction	55	0.32
Lauraceae							
Cinnamomum tamala (Buch. -Ham.) T. Nees & Nee	Indian bay leaf	Tejpat	T	L	Decoction	25	0.15
Cinnamomum zelyanicum Blume	Cinnamon bar	Dalchini	T	B	Decoction	19	0.11
Meliaceae							
Azadirachta indica A. Juss.	Neem tree	Neem	T	L, B	Decoction	38	0.22
Menispermaceae							
Cissampelos pareira L.	Velvet leaf	Gujargano	C	R	Decoction	4	0.02
Tinospora cordifolia (Willd.) Miers	Heart-leaved moonseed	Gurjo / Giloy / Guduchi	C	St	Decoction	135	0.79
Myristicaceae							
Myristica fragrans Houtt.	Nutmeg	Jaiphal	T	Se	Decoction	3	0.02
Myrtaceae							
Psidium guajava L.	Guava	Belauti / Amba	T	L	Decoction	56	0.33
Syzygium aromaticum (L.) Merr. & L.M. Perry	Clove	Lwang	T	F	Raw, Paste	16	0.09
Phyllanthaceae							
Phyllanthus emblica L.	Indian gooseberry	Amala	T	F	Chew, Powder taken with honey	23	0.14
Piperaceae							
Piper cubeba L. f.	Java pepper	Sheetel chini	T	W	Decoction	9	0.05
Piper longum L.	Long pepper	Pipla	C	F	Decoction	29	0.17
Piper nigrum L.	Black pepper	Marich	C	F	Decoction	74	0.44
Poaceae							
Cynodon dactylon (L.) Pers.	Bermuda/Devile grass	Dubo	H	R	Decoction	3	0.02
Rutaceae							
Aegle marmelos (L.) Correa	Indian bael	Bel	T	L	Decoction	29	0.17
Citrus limon (L.) Osbeck	Lemon	Kagati	T	F, L	Decoction	89	0.52
Zanthoxylum armatum DC.	Nepal pepper/prickly ash	Timur	S	F	Soup, Paste	28	0.16
Sapindaceae							
Litchi chinensis Sonn.	Litchi	Lychee	T	L	Decoction	3	0.02

Scientific name	English name	Local name	Habit	Parts used	Mode of use	FC	RFC
Solanaceae							
Withania somnifera (L) Dunal	Winter cherry	Ashwagandha	S	Rt, Se, L	Decoction, Powder taken with milk	25	0.15
Theaceae							
Camellia sinensis (L) Kuntze	Tea	Chiya	S	L	Raw	2	0.01
Zingiberacea							
Amomum cardamomum L.	Green cardamomum	Sukmel	H	Se	Decoction	2	0.01
Curcuma caesia Roxb.	Black turmeric	Kalo haledo	H	R	Decoction	2	0.01
Curcuma longa L.	Turmeric	Haldi/Beshar	H	R	Decoction, Powder taken with milk	136	0.80
Zingiber officinale Roscoe	Ginger	Aduwa	H	R	Decoction, Paste	73	0.43

Habit: H= Herb, S= Shrub, C= Climber, T= Tree; **Parts used:** L= Leaf, R=Rhizome, Se=Seed, F=Fruits, St=Stem, Fl= Flower, W=Whole plant, B=Bark, Bu=Bulb, Rt=Root

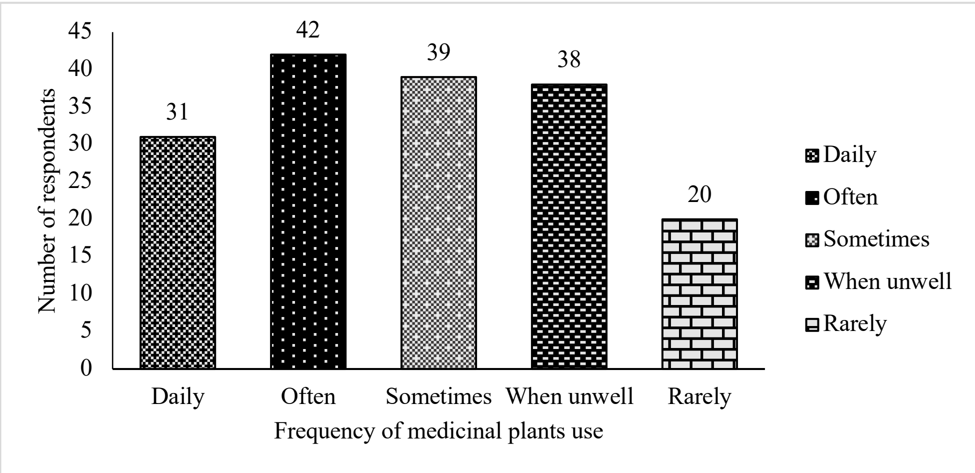

Figure 4. Frequency of use of medicinal plants.

Sources of medicinal plants

The majority of the respondents stated they used medicinal plants available in their home gardens 192 (44 %), others either purchased them from the nearest market 159 (37%), herbal shop 17 (4%) or collected them from the nearest forest areas 64 (15%) (Figure 5).

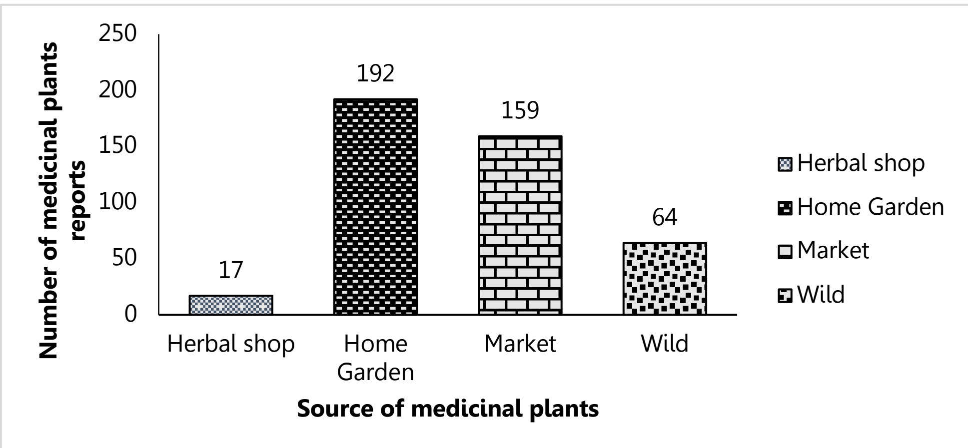

Figure 5. Source of medicinal plants.

Information sources of people followed to use medicinal plants

The majority (162) of the respondents received information about the possibility of using medicinal plants to cure or prevent COVID-19 infection from their family/friends/neighbors followed by the internet (66) (Figure 6). Others relied on other different sources such as books, TV/radio, local health workers, or other sources for information.

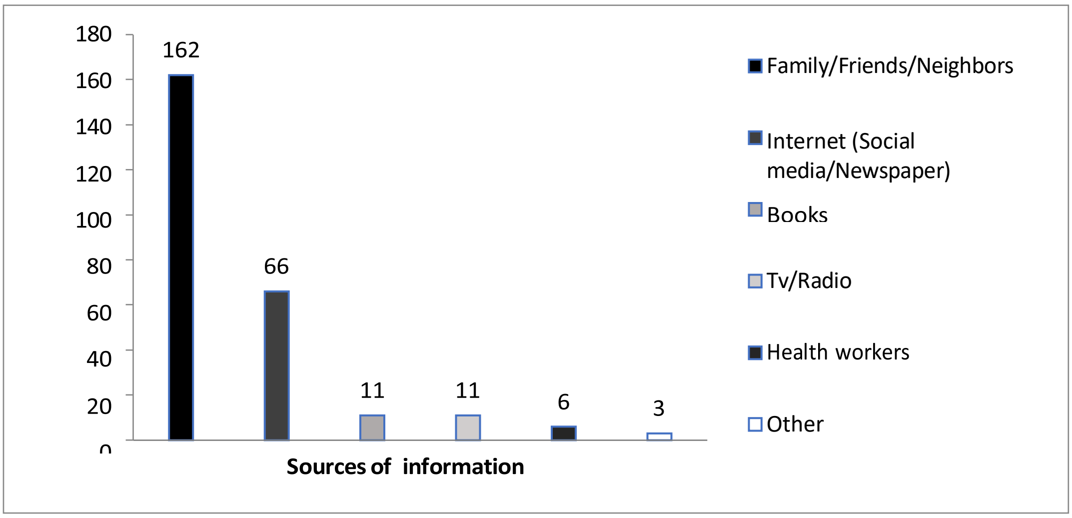

Figure 6. Sources of information that people followed to use medicinal plants.

People's perception about the efficacy of medicinal plants in preventing COVID-19 infection

Of the 59 COVID-19 survivors, 90% (53) of the survivors reported that they used medicinal plants for treating COVID-19 symptoms and 81% (43) of those COVID-19 survivors reported that medicinal plants helped to cure the COVID-19 related symptoms. The survivors consumed medicinal plants primarily for 11 to 15 days to recover from COVID-19 (Figure 7). Paying it forward, each of the 22 (42%) of the satisfied COVID-19 survivors had suggested more than ten individuals in their networks to use medicinal plants (Figure 8). Of the 170 respondents, the majority (66%) of the respondents expressed their belief that medicinal plants can enhance their immunity against viruses, but they were doubtful about their efficacy in preventing COVID-19 infection. In contrast, 18% of the respondents expressed their belief that medicinal plants can cure COVID-19 related symptoms and cure infection (Figure 9).

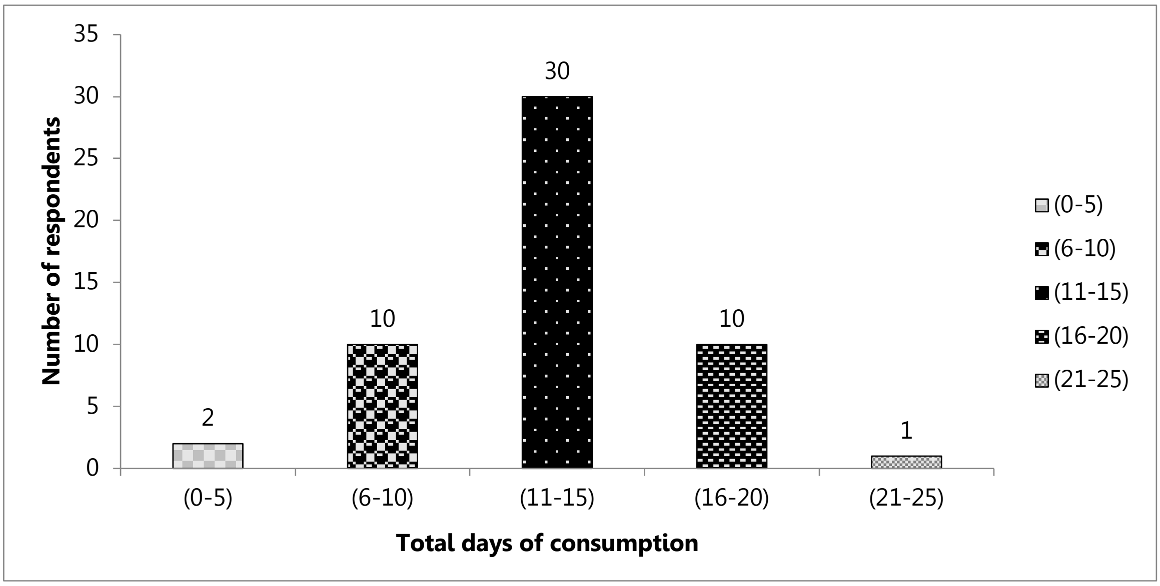

Figure 7. A number of days of consumption of medicinal plants by the 59 COVID-19 survivors.

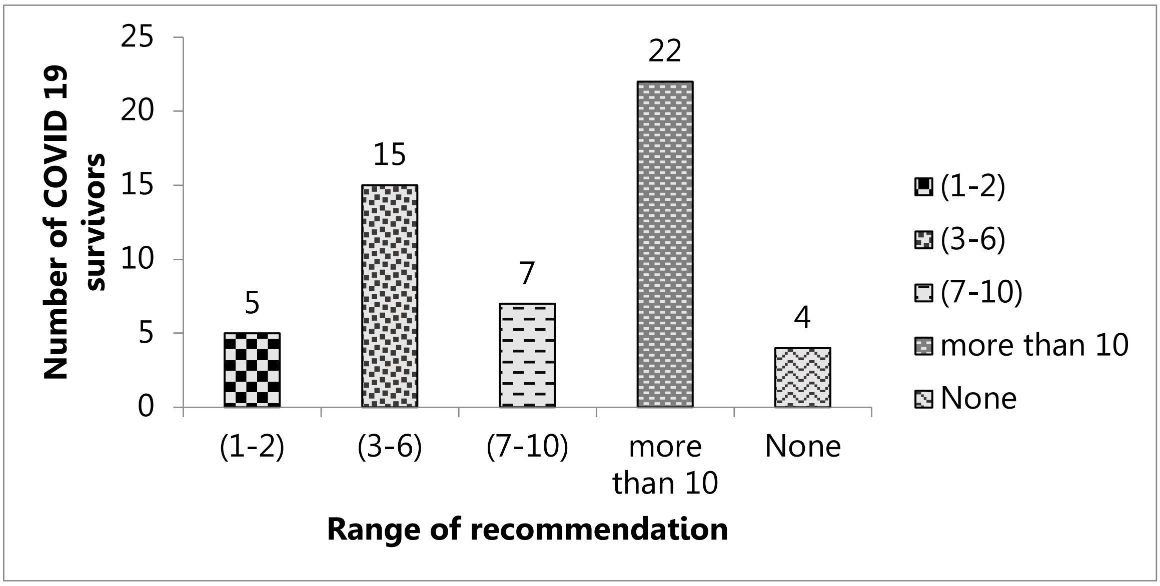

Figure 8. Number of recommended individuals to use medicinal plants by COVID-19 survivors

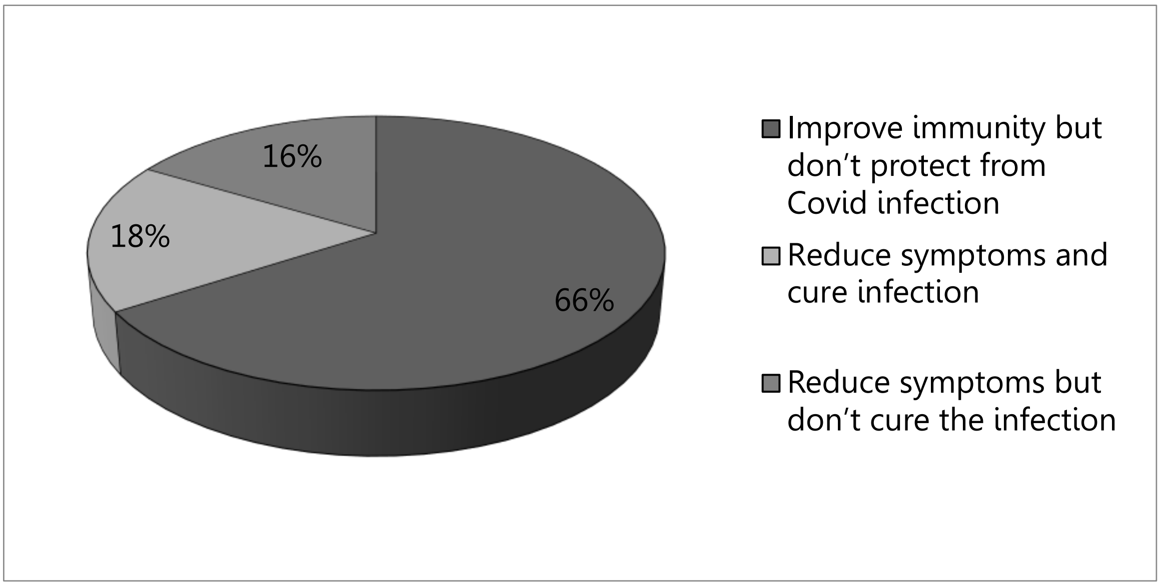

Figure 9. Perceived efficacy of medicinal plants.

Relative frequency of citation

The relative frequency of citations of the top-ranked 15 species among respondents ranged from 0.16 to 0.80 (Figure 10). Among them, *Curcuma longa* (0.80) was the most cited species and *Zanthoxylum armatum* (0.16) was the least cited species.

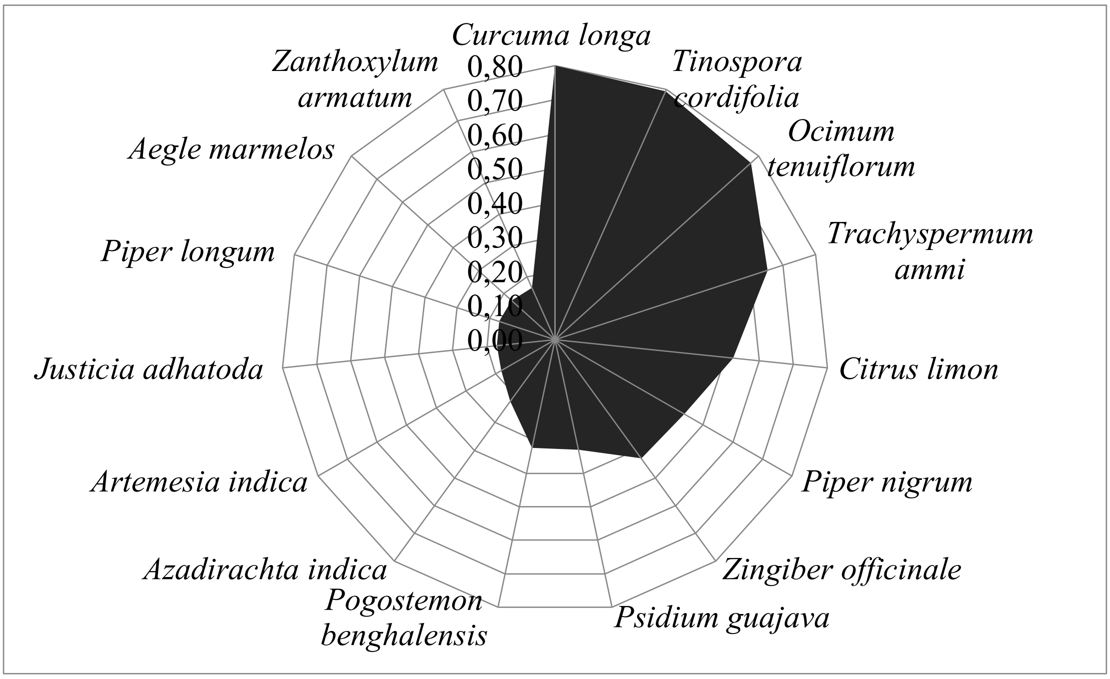

Figure 10. Radar chart showing the relative frequency of citation of the 15 most frequently cited medicinal plant species.

Phytochemical and pharmacological properties of the top 15 medicinal plants used by the respondents

To ensure the efficacy of the medicinal plant in curing COVID-19 symptoms and preventing COVID-19 infection, the top 15 medicinal plant species with the highest relative frequency of citations were selected (Figure 10) and their phytochemical and pharmacological properties were analyzed based on the published pieces of literature. Such analysis showed that all the top 15 medicinal plant species had antiviral and anti-inflammatory properties and 14 of them also had immunomodulatory properties (Table 2). In addition, all top 15 medicinal plant species had been used in past for the treatment of SARS-CoV, Herpes Simplex Virus, Chickungunya Viruses, Zika Virus, Ebola Virus, HIV, SARS-CoV-2, Influenza Virus, Dengue Virus, Hepatitis B Virus, Japanese Encephalitis, and Coxsackieviruses.

Table 2. Phytochemical and pharmacological properties of the 15 most frequently cited medicinal plant species. Scientific names of the species and their respective constituent phytochemicals, pharmacological properties, existing/past antiviral uses, and references are shown.

Plant Species	Constituent phytochemicals	Pharmacological properties	Existing/past antiviral uses
Curcuma longa L.	Curcumin, Curcuminoids, Sesquiterpenes (Adhikari *et al.* 2021, Anand *et al.* 2021, Gyawali *et al.* 2020, Sharifi-Rad *et al.* 2020, Singh *et al.* 2021)	Antioxidant, Anti-inflammatory, Anti-cancer, Antimicrobial, Antiviral, Immunomodulatory (Anand *et al.* 2021, Gyawali *et al.* 2020, Sharifi-Rad *et al.* 2020, Singh *et al.* 2021)	SARS-CoV, Herpes simplex virus, Chickungunya virus, Zika virus, HIV (Gyawali *et al.* 2020, Singh *et al.* 2021)
Tinospora cordifolia (Willd.) Miers	Alkaloids, Diterpenoid lactones, Sesquiterpenoids, Tinocordifolin (Ghatpande *et al.* 2019, Gyawali *et al.* 2020, Tiwari *et al.* 2018)	Anticancer, Antiviral Antioxidant, Antidiabetic, Anti-inflammatory, Immunomodulatory, Antimicrobial (Ghatpande *et al.* 2019, Gyawali *et al.* 2020, Singh *et al.* 2021, Tiwari *et al.* 2018)	SARS-CoV-2, Chickungunya virus, HIV (Gyawali *et al.* 2020, Singh *et al.* 2021)

Ocimum tenuiflorum L.	Phenols, fatty acid, luteolin, saponins, tannins, linalool (Bano *et al.* 2017, Da silva *et al.* 2020, Gyawali *et al.* 2020)	Antimicrobial, Antibacterial, Antiviral, Antifungal, Antidiabetic, Anticancer, Anti- inflammatory, Immunomodulatory (Da silva *et al.* 2020, Gulati *et al.* 2002, Gyawali *et al.* 2020, Kumar *et al.* 2012, Romeilah *et al.* 2010, Singh *et al.* 2021)	SARS-CoV-2, H9N2 virus, Coxsackie virus (Singh *et al.* 2021)
Azadirachta indica A. Juss.	Azadirachtin, Nimbidin, Nimbin, Nimbolide, Nimbic acid (Baharek *et al.* 2014)	Antimalarial, Antiviral, Antibacterial, Antifungal, Anti-inflammatory, Immunomodulatory (Baharek *et al.* 2014, Da silva *et al.* 2020, Gulati *et al.* 2002, Singh *et al.* 2021)	SARS-CoV-2, Influenza virus, Dengue virus (Singh *et al.* 2021)
Zingiber officinale Roscoe	Gingerol, Shogaols, Paradol, Zingerone (Gyawali *et al.* 2020, Mishra *et al.* 2012)	Anticancer, Anti-inflammatory, Antioxidant, Antimicrobial, Immunomodulatory, Antiviral (Da silva *et al.* 2020, Gulati *et al.* 2002, Gyawali *et al.* 2020 Mishra *et al.* 2012, Singh *et al.* 2021)	SARS-CoV-2, Influenza virus, Herpes simplex virus, Chickungunya virus (Singh *et al.* 2021)
Trachyspermum ammi (L.) Sprague	Thymol, Thymene, Limonene, Glycosides (Kumar & Khurana 2018)	Antibacterial, Antiviral, Antidiarrheal, Antifungal, Antioxidant, Anti-inflammatory, Immunomodulatory (Gupta *et al.* 2021, Kumar & Khurana 2018)	Japanese encephalitis virus (Ruwali *et al.* 2018)
Citrus limon (L.) Osbeck	Flavonoids, Limonoids, Phenolic acids (Klimek-szczykutowicz *et al.* 2020)	Anticancer, Antioxidant, Anti-inflammatory, Antimicrobial, Antiparasitic, Antifungal, Antiviral, Immunomodulatory (Anastasiou & Buchbauer 2017, Klimek-szczykutowicz *et al.* 2020)	Herpes simplex virus (Klimek-szczykutowicz *et al.* 2020)
Piper nigrum L.	Piperine, Piperamine, Piperamide, Pipericide (Damanhouri 2014)	Antimicrobial, Antioxidant, Anticancer, Anti-inflammatory, Antidepressant, Antiviral, Immunomodulatory (Anastasiou & Buchbauer 2017, Damanhouri 2014, Singh *et al.* 2021)	Hepatitis B, Dengue virus, Ebola virus (Singh *et al.* 2021)
Psidium guajava L.	Gallic acid, Catechin, Kaempferol, Chlorogenic acid, Quercetin, Myricetin (Kumar *et al.* 2021)	Anticancer, Antidiabetic, Antioxidant, Antimicrobial, Antidiarrhea, Anti-inflammatory, Immunomodulatory, Antiviral (Mittal & Gupta 2010, Sriwilaijaroen *et al.* 2012)	Influenza A virus (Sriwilaijaroen *et al.* 2012)

Piper longum L.	Piperine, Methyl piperine, Sesamin, Pulvutilol, (Zaveri *et al.* 2010)	Antioxidant, Antifungal, Antimicrobial, Anti-inflammatory, Anticancer, Antiviral, Immunomodulatory (Priya & Saravana 2017, Sharma 2019, Zaveri *et al.* 2010)	Vesicular stomatitis Indiana virus, Human para influenza viruses (Priya & Saravana 2017)
Pogostemon benghalensis (Burm. f.) Kuntze	Phenolics, Steroids, Tannins, Flavonoids, Terpenoids (Dahiya *et al.* 2020)	Antioxidant, Antibacterial, Antiviral, Antifungal, Anticancer, Anti-inflammatory (Dahiya *et al.* 2020)	Herpes simplex virus, Sindbis virus, Polio virus (Dahiya *et al.* 2020)
Zanthoxylum armatum DC.	Berberine, Dictamnine, limonene, linalool, Kaempferol (Paul *et al.* 2018)	Anti-inflammatory, Antibacterial, Antifungal, Antioxidant, Antiviral, Immunomodulatory (Alam *et al.* 2020, Bharti & Bhusan 2017, Gyawali *et al.* 2020, Paul *et al.* 2018)	Herpes simplex virus, Influenza virus (Gyawali *et al.* 2020)
Aegle marmelos (L.) Correa	Alkaloids, Coumarins, Flavonoids, Marmelide, Tannins (Manandhar *et al.* 2018)	Antioxidant, Antidiabetic, Antimicrobial, Antiviral, Anticancer, Anti-inflammatory, Immunomodulatory (Badam *et al.* 2002, Govinda & Asdaq 2011, Manandhar *et al.* 2018)	Human coxsackieviruses B1-B6 (Badam *et al.* 2002)
Justicia adhatoda L.	Adhatodine, Anisotine, Vasicoline, Vasicolinone (Kaur *et al.* 2013)	Anti-inflammatory, Antimicrobial, Antibacterial, Antioxidant, Antiviral, Immunomodulatory (Kaur *et al.* 2013, Singh *et al.* 2017)	Herpes simplex virus-1 and 2 (Singh *et al.* 2017)
Artemesia indica Willd.	Flavonoids, Coumarins, Sesquiterpene, Lactones, Alkaloids (Bisht *et al.* 2021)	Antioxidant, Antimicrobial, Antifungal, Antibacterial, Anticancer, Anti-inflammatory, Antiviral, Immunomodulatory (Bisht *et al.* 2021, Kshirsagar & Rao 2021, Ruwali *et al.* 2018)	Hepatitis B and C viruses, HIV-1, Influenza virus A (Kshirsagar & Rao 2021

Discussion

COVID-19 infection is highly contagious (Gasmi *et al.* 2020), and there is no effective antiviral treatment to combat the disease until date (Singh *et al.* 2021). Few vaccines have been approved for emergency use and have been claimed to provide a high degree of protection against getting seriously ill and dying from the disease (*Li et al.* 2021). However, not everyone has access to those vaccines (Forni & Mantovani 2021). This has driven increased interest in exploring alternatives of medicinal plant-based therapeutics globally. In this context, our study highlights the importance and perceived efficacy of medicinal plants in the treatment and prevention of COVID-19.

The use of phytomedicine has been an integral aspect of the traditional health care system for thousands of years (Ghoran *et al.* 2021). The usage of medicinal plants among patients has gained popularity, and considerable literature has reported on their usage in the case of new infectious diseases such as SARS and MERS (Khadka *et al.* 2021). Our study recorded 41 species of medicinal plants belonging to 24 different families and 37 genera being used extensively by the inhabitants of Buddhabhumi Municipality for the treatment and prevention of COVID-19. The majority of the species are similar to the species recorded by analogous but extensive studies from Nepal (Khadka *et al.* 2021) and other countries such as India (Srivastava *et al.* 2020), China (Shahrajabian *et al.* 2020, Xu & Zhang 2020), Bangladesh (Bhuiyan *et al.* 2020), Morocco (Alami *et al.* 2020), Peru (Villena-Tejada *et al.* 2021), Brazil, Jamaica, Bolivia, Romania, Belarus, Lithuania, Poland, Georgia, Turkey, Pakistan, Cambodia, and South Africa (Pieroni *et al.* 2020). However, the recording of 41 species of medicinal plants from a municipality of Nepal is much higher compared to 60 species recorded by Khadka *et al.* (2021), from across the country. This hints towards the increasing popularity of medicinal plants among infected and non-infected people.

Our study documented species such as *Curcuma longa, Coriandrum sativum, Allium sativum,* and *Cuminum cyminum* that are recommended for cooking to combat COVID-19 and species like *Ocimum tenuiflorum, Zingiber officinale, Piper nigrum,* and *Cinnamomum tamala* that are recommended for decoction (Gupta *et al.* 2021). Additionally, species like *Tinospora cordifolia, Curcuma longa, Zingiber officinale, Ocimum tenuiflorum, Zanthoxylum armatum, Phyllanthus emblica, Allium sativum, Withania somnifera,* and *Piper cubeba* that our study documented have already been recommended as remedies for COVID-19 by Gyawali *et al.* (2020). Medicinal herbs have always been part of Nepalese home gardens (Pokhrel 2015) and are traditionally used in many therapeutic practices (Babich *et al.* 2020). Our study confirms that herbs are among the most frequently used medicinal plants and most of the medicinal plants that are being used are sourced from the respondents' home gardens. Nevertheless, a minority of the respondents reported that they are getting medicinal plants from the nearest forest areas. A disordered accumulation of medicinal plants, especially underground parts, and whole plants could pose a threat to nature conservation (Hussain *et al.* 2013). Leaves are storehouses of active secondary metabolites (Ghorbani 2005), and our study has confirmed that leaves are among the most highly used plant parts.

Many of the medicinal plant species documented by our study are already part of the list of alternative medicines to boost the immunity power included in the Ayurveda and Alternative Medicine Guidelines of Preventive Measures and Management Protocol for COVID-19 in Nepal published by the Department of Ayurveda & Alternative Medicine (DAAM), Ministry of Health & Population, Nepal (MOHP 2020). The majority of the respondents expressed their belief that medicinal plants can enhance their immunity against viruses is in line with the aforementioned guidelines of the DAAM.

The eccentricity of the population has increased the use of medicinal plants with antiviral and anti-inflammatory properties to enhance the immune system or cure respiratory diseases (Maldonado *et al.* 2020). Research on ethnopharmacology is full of possibilities, yet challenging, since a single plant may contain a wide range of phytochemicals (Lim *et al.* 2021). The phytochemical and pharmacological screening of the top 15 medicinal plant species documented in this study showed that all the top 15 medicinal plant species had antiviral and anti-inflammatory properties, whereas 14 of them also had immunomodulatory properties. Additionally, the 15 most frequently cited species have been reported to be used or be used for the SARS-CoV, Herpes Simplex Virus, Chickungunya Viruses, Zika Virus, Ebola Virus, HIV, SARS-CoV-2, Influenza Virus, Dengue Virus, Hepatitis B Virus, Japanese Encephalitis, and Coxsackieviruses, etc. Evidence from the research conducted on SARS-COV and COVID-19 has shown that a fragile immune system is one of the major contributing factors for COVID complications (Curbelo *et al.* 2017; Promptetchara *et al.* 2020, Taghizadeh-Hesary & Akbari 2020). Therefore, improving the immune system could avoid COVID-19 infection and complications (Fedoung *et al.* 2021). Phytochemicals such as curcumin, gingerol, zingerol, flavonoids, catechins, quercetin, kaempferol, alkaloids, saponins, and tannins present in the 15 most frequently cited medicinal plants were proven to be antiviral bioactive compounds by the studies of Adhikari *et al.* (2021), Anand *et al.* (2021), Ghoran *et al.* (2021). Moreover, global studies have demonstrated that many medicinal plants have antiviral activity against coronavirus and their primary mechanism seems to be through inhibition of viral replication (Jassim & Naji 2003). In China, traditional Chinese medicinal herbs have been used for the effective treatment of SARS. Given their phytochemical and pharmacological properties, the 15 most frequently cited medicinal plant species could be the best candidates in herbal drug formulations for the treatment of COVID-19 in the future. The significance of medicinal plants to counteract SARS-CoV patented from 2008– 2013 for their anti-SARS-CoV activities is reflected in a review article by Kumar *et al.* (2013). Provided the Government of Nepal and the Government of India (GoI) have formally declared that the Traditional System of Medicine (TSM) should be used in conjunction with allopathic medicine in the treatment of COVID-19 patients (Pandit & Singh 2020).

Conclusion

The study found that 41 medicinal plant species from 24 different families and 37 genera are used. Enthralling, all of the 15 most frequently cited medicinal plants were reported to have both antiviral and anti-inflammatory properties and 14 of them were reported to have immunomodulatory properties. They were reported to be effective against various fatal viruses and could be the best candidates in herbal drug formulations for the treatment of COVID-19 in the future. There is a wide range of potential uses of traditional medicines in these challenging times due to their long history of use in the community, ancient references, and scientific evidence about their safety and efficacy. In conclusion, our study suggests that medicinal plants are effective against viral infections such as COVID-

19 and encourages us to get closer to the natural healing process. Although there are still many challenges and questions unanswered, the recovery of COVID-19 infected individuals by using medicinal plants offers a hope that this pandemic can be halted with herbal drug formulations. Regarding using medicinal plants, sources of information are crucial. It is not advisable to rely on informal sources and unsubstantiated efficacy claims on social media. However, instead of relying on formal and authentic sources such as local and national health authorities, people are using medicinal plants, knowingly or unknowingly for the treatment of the miscellaneous symptoms of COVID-19 preventative measure against COVID-19 infection. Therefore, our study appeals to the concerned authorities such as the Ministry of Health (MoHP) and Population, pharmaceutical companies, pharmacologists, ethnobotanists, and phytochemists to take the potential of medicinal plants seriously and immediately initiate further research on these antiviral, anti-inflammatory and immunomodulatory medicinal plants so that we could pave way for the formulation of novel drugs for the effective treatment of COVID-19.

Declarations

List of abbreviations: Habit: H= Herb, S= Shrub, C= Climber, T= Tree
Parts used: L= Leaf, R=Rhizome, Se=Seed, F=Fruits, St=Stem, Fl= Flower, W=Whole plant, B=Bark, Bu=Bulb, Rt=Root

Ethics approval and consent to participate: We strictly followed the ethical guidelines of the International Society of Ethnobiology (http://www.ethnobiology.net/). The consent message was written to each recipient and placed clearly on the top of the form.

Consent for publication: Not applicable

Availability of data and materials: The data set generated for the current study is available upon request.

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Authors' contributions: The authors were involved in concept development and defining intellectual content. VTC conducted the literature research, data collection and prepared a manuscript draft. PJ analyzed the data collected, reviewed, and edited the manuscript. SKM conducted editing, proofreading, and reviewing the manuscript for finalization. The published version of the manuscript has been read and approved by all authors.

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