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
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 (Adhkari 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 (Adhkari 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 follow 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)
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:
Where \( RFC = \frac{FC}{N} \)

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.](image-url)
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 | Pyaj | 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 lahoro / simi lahoro | H, St | Decoction | 3 | 0.02 |
| Asteraceae      | Artemisia 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     | F          | 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 zeylanicum Blume     | Cinnamon bar                  | Dalchini  | T     | B          | Decoction   | 19  | 0.11|
| Melliaceae                      |                               |            |       |            |             |     |     |
| 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 (Wild.) 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.
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.
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, 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,     | Antioxidant, Anti-inflammatory, Anti-cancer, Antimicrobial, Antiviral, Immunomodulatory (Anand   | SARS-CoV, Herpes simplex virus, Chickungunya virus, Zika virus, HIV (Gyawali *et al.* 2020, Singh   |
|                                    | Gyawali *et al.* 2020, Sharifi-Rad *et al.* 2020, Singh *et al.* 2021)                   | (Anand *et al.* 2021, Gyawali *et al.* 2020, Sharifi-Rad *et al.* 2020, Singh *et al.* 2021) | *et al.* 2021)                                                                            |
| *Tinospora cordifolia* (Willd.) Miers | Alkaloids, Diterpenoid lactones, Sesquiterpenoids, Tinocordifolin (Ghatpande *et al.* 2019, | Anticancer, Antiviral Antioxidant, Anti-diabetic, 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)                      |
|                                    | Gyawali *et al.* 2020, Tiwari *et al.* 2018)                                               |                                                                                           |                                                                                           |
| Plant Name | Constituents | Properties |
|------------|--------------|------------|
| *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) |
| *Azadirachta indica* A. Juss. | Azadirachtin, Nimbidin, Nimbins, Nimbidol, Nimbidic 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) |
| *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) |
| *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) |
| *Citrus limon* (L.) Osbeck | Flavonoids, Limonoids, Phenolic acids (Klimek-szczukutowicz *et al.* 2020) | Anticancer, Antioxidant, Anti-inflammatory, Antimicrobial, Antiparasitic, Antifungal, Antiviral, Immunomodulatory (Anastasiou & Buchbauer 2017, Klimek-szczukutowicz *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) |
| *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) |

SARS-CoV-2, H9N2 virus, Coxsackie virus (Singh *et al.* 2021)
SARS-CoV-2, Influenza virus, Dengue virus (Singh *et al.* 2021)
SARS-CoV-2, Influenza virus, Herpes simplex virus, Chickungunya virus (Singh *et al.* 2021)
Japanese encephalitis virus (Ruwali *et al.* 2018)
Herpes simplex virus (Klimek-szczukutowicz *et al.* 2020)
Hepatitis B, Dengue virus, Ebola virus (Singh *et al.* 2021)
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, Anticancer, Anti-inflammatory (Dahiya et al. 2020, Bharti & Bhusan 2017, 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)
- 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, Shahrarajabian et al. 2020, Xu & Zhang 2020, 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 (Shahrarajabian 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 2021).
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, Promptetchar 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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