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A review on therapeutic potential of Indian medicinal plants against COVID-19 pandemic

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Abstract

COVID-19 has changed the way of living and altered the lifestyle in many ways since 2019 and its various mutant forms were responsible for millions of deaths globally. According to the reports, this virus was more dangerous to the people with weak immune systems, who already had certain illnesses. Therefore, the World Health Organization and the Ministry of Ayush recommend easy-to-access immunity-boosting foods, regular exercise and yoga to lead a healthy lifestyle and fight against COVID infection. As most of the plants are powerful sources of several phytochemicals with biological activity and this list includes a variety of medicinal or therapeutic plant species such as ashwagandha, aloe vera, garlic, neem, giloy, harar, lemon grass and many more. The various parts of these plants contain beneficial elements such as phenols, flavonoids, tannins and vitamins that strengthen the immune system and improve health. In India, there are different climatic zones where various herbs and medicinal plants can be grown abundantly in different regions. These medicinal plant species and herbs do not directly cure COVID infection but play a significant role in controlling the disease conditions which are similar to this infection like cold, cough, fever, diabetes, obesity, heart problems and especially respiratory problems. A healthy immune system has the ability to mitigate the disease's adverse effects. Thus, increasing immunity through the use of these herbs and medicinal plants can assist us in future in reducing the severity of various diseases, including COVID infection.

1. Introduction

In December 2019, Wuhan (China) reported a spate of acute respiratory illnesses that have subsequently spread to more than 165 nations and triggered economic crises all over the world (Yuki *et al.*, 2020). The agent of infection for this viral outbreak was discovered as the new type of coronavirus, a virus having positive-sense with single-stranded RNA (+ssRNA) which consist of projections on its surface that give it a crown-like look (Richman *et al.*, 2016). The virus's spike protein binds on the surface of type II pneumocytes through angiotensin converting enzyme-2 (ACE-2) receptors in the alveolar lining followed by internalization and release of +ssRNA. Coronaviruses are zoonotic due to their animal origin and have the ability to infect humans through recombination, mutation and adaptation (Lau *et al.*, 2020; WHO, 2020). This deadly virus comes from Coronaviridae family and phylum Nidovirales and has the ability to spread by close human contact or respiratory droplets (Harapan *et al.*, 2020; Chan *et al.*, 2020). On the basis of its wider spreadability and thousands of fatalities throughout the world, on March 12, 2020 COVID-19 has been declared as a pandemic by World Health Organization (Ciotti *et al.*, 2020). In patients, it causes

pneumonia, multiple organ failure and severe ARDS (Acute Respiratory Distress Syndrome) symptoms, but in elderly people, even worse symptoms like cardiac issues, multiple-organ failure, shortness of breath, respiratory failure and acute kidney injury occurs (De and De, 2020). People who have comorbid conditions such as coronary heart diseases, high blood pressure, diabetes, obstructive pulmonary diseases, *etc.*, are more vulnerable to infection (Zhou *et al.*, 2020).

Food and nutrition have a crucial interest in safe-guarding human health and preventing a wide range of diseases since appropriate immune system function depends on adequate nourishment (Lange, 2017). The majority of different medications that are both curative and therapeutic aid come from plants. During COVID pandemic, Ministry of Ayush enlisted the list of some plants to fight against this deadly virus which includes tulsi, aonla, haldi, ashwagandha in different forms and formulation. Garlic, turmeric, licorice, black pepper, pomegranate and other functional food plants have all been linked to antiviral and immunomodulatory activities (Yang *et al.*, 2020). Vitamins, polyphenols, dietary fibre, folate, polysaccharides, lipids and peptides are considered to be crucial for the body because they increase immunity against viruses (Calder *et al.*, 2020; Castro *et al.*, 2020).

Numerous plants with medicinal properties have been found in India, and these plants derived medicines are used to cure a number of illnesses and strengthen the defense mechanism of our body (Fakhri *et al.*, 2020). As these plants contain various bioactive compounds

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and secondary metabolites, Ayurveda, the conventional Indian medical system, has suggested the use of specific herbs, plant-based formulations and decoctions to boost immunity and improve our body's ability to fight illnesses (Gangal *et al.*, 2020). The plant's antiviral chemicals can block viral replication by interfering with

viral enzymes, preventing virus attachment to cells and also prevents genome replication (Xu and Zhang, 2020; Thota *et al.*, 2020). This review discusses the medicinal and therapeutic value of several plants found in India which helps in the reduction of the potential harmful effects of COVID-19 infection.

Table 1: Medicinal plants available in India

S. No.	Medicinal plants	Common name	Family	Plant part used as medicine	References
1.	<i>Aegle marmelos</i>	Bael	Rutaceae	Fruit	Bhatt <i>et al.</i> (2021)
2.	<i>Aloe vera</i>	Aloe vera, quargandal, ghritkumari, gheekvar, katraazhai	Liliaceae	Leaves, pulp	Qadir (2009)
3.	<i>Andrographis paniculata</i>	Kalamegha, king of the bitters, bhunimba, neem of the earth	Acanthaceae	Leaves, stems	Mishra <i>et al.</i> (2007); Pole (2012)
4.	<i>Azadirachta indica</i>	Neem	Meliaceae	Seed, leaves, flower, bark	Rahmani <i>et al.</i> (2018)
5.	<i>Cinnamomum verum</i>	Dalchini, true cinnamon, ceylon cinnamon	Lauraceae	Leaves, bark	Kaul <i>et al.</i> (2003)
6.	<i>Clerodendrum serratum</i>	Bharngi, bhrguja	Verbenaceae	Leaves	Kumar and Nishteswar (2013)
7.	<i>Curcuma longa</i>	Haldi	Zingiberaceae	Rhizome	Gupta <i>et al.</i> (2020)
8.	<i>Cymbopogon citratus</i>	Lemon grass	Poaceae	Leaves	Wifek <i>et al.</i> (2016)
9.	<i>Glycyrrhiza glabra</i>	Licorice, mulethi	Fabaceae	Roots, bark	Parvaiz <i>et al.</i> (2014)
10.	<i>Jatropha curcas</i>	Physic nut, purging nut	Euphorbeaceae	Root, stem, leaves, latex, seed	Islam <i>et al.</i> (2011)
11.	<i>Ocimum basilicum</i>	Sweet basil	Lamiaceae	Leaves, stem, seeds	Shahrajabian <i>et al.</i> (2020)
12.	<i>Ocimum sanctum</i>	Tulsi	Laminaceae or Labiate	Leaves, stem, seed, root	Mohan <i>et al.</i> (2011)
13.	<i>Phyllanthus emblica</i>	Aonla, Indian goose berry or amalaka	Euphorbiaceae	Fruits, bark	Saini <i>et al.</i> (2008)
14.	<i>Picrorhiza kurroa</i>	Kutki	Scrophulariaceae	Leaves	Kumar and Nishteswar (2013)
15.	<i>Swertia chirata</i>	Chirettai, Nepali neem	Gentianaceae	Whole plant	Aleem and Kabir (2018)
16.	<i>Syzygium aromaticum</i>	Clove	Myrtaceae	Flower buds	Mittal <i>et al.</i> (2014)
17.	<i>Terminalia chebula</i>	Harar, black myroblans, haritaki, king of medicines	Combretaceae	Leaves, bark, stem, fruit, seed	Gupta (2012)
18.	<i>Tinospora cordifolia</i>	Guduchi or giloy, amarlata, amrita	Menispermaceae	Roots, stem, leaves, fruits	Choudhary <i>et al.</i> (2013); Srivastava and Saxena (2020)
19.	<i>Withania somnifera</i>	Indian ginseng, ashwagandha, Indian winter cherry	Solanaceae	Roots, leaves	Singh <i>et al.</i> (2010); Dhawan <i>et al.</i> (2021)
20.	<i>Zingiber officinale</i>	Ginger	Zingiberaceae	Rhizome	Shahrajabian <i>et al.</i> (2019)

2. Medicinal plants and herbs in Indian locations

There are over thousands of plant species which are regularly used as a key source of medicine because it is believed that close to 15% of the 70,000 or so plant species known to exist have therapeutic properties (Badola and Aitken, 2003). Most of the Indian medicinal plants can be found in the Aravalis, Tarai regions in the Himalayan foothills, Eastern and Western Ghats, Chotanagpur plateau, Vindhyas and North-Eastern parts of the country. These constitute more than

70% of all therapeutic plants in use today. A few medicinal plants can also be found in water areas including mangroves, temperate regions and alpine habitats containing about 30% of all plants (Kala, 2009). The Table 1 enlists some of the medicinal plants available in India which are having importance in curing wide range of diseases.

3. Impact of medicinal plants on COVID-19

The medicinal plants listed in Table 1 are particularly important due to the presence of bioactive substances such as polyphenols,

secondary metabolites and nutritive compounds. Polyphenols are classified as reducing agents, and when combined with other dietary reducing agents such as vitamin C, E and carotenoids, they are known as effective antioxidants, protecting the body against oxidative stress and illnesses such as cancer, coronary heart diseases and hyperinflammation (Kashyap *et al.*, 2017; Thakur *et al.*, 2020; Hamid *et al.*, 2022). Polyphenols are classified as phenols (gallic acid, ellagic acid), flavonoids (quercetin), tannins (hydrolyzable and condensed tannins), stilbenes, and lignanas. Medicinal plants contain different polyphenolic compounds and helps in disease prevention. Curcumin, a polyphenol found in haldi, is a potent oxidant that aids in the prevention of most viral infections and boosts immunity. Similarly, the presence of chemicals in tulsi leaves like apigenin and ursolic acid makes it a promising therapeutic herb for COVID prevention. These chemicals function as protease enzyme inhibitors which prevent the virus from replicating. Aonla is an immunity enhancer because of its high concentration of vitamin C and polyphenols (Kaushal *et al.*, 2022). To maintain health, one should be aware of the favourable pharmacological effects of numerous plants that may be included in one's regular diet (Hamid *et al.*, 2021). On the basis of availability of medicinal plants in India and their high impact on quenching various disease, the knowledge regarding bioactive components and their involvement in COVID prevention is presented in several sub headings below and summarized in Table 2.

3.1 Bael: *Aegle marmelos* L.

Bael or Bengal quince is a concentrated source of riboflavin and has several medicinal properties including anti-inflammatory, antimicrobial, antipyretic, antifungal, analgesic, platelets formation, hypoglycemic as well as antiproliferative (Neeraj *et al.*, 2017). The compounds like aegelin, marmesinin, marmelide, lupeol, citral, cuminaldehyde, eugenol, skimmianine, cineol, α -sitosterol, flavone, seselin, *etc.*, are among the major bioactive compounds present in bael fruit (Bhatt *et al.*, 2021). Seselin a compound present in bael has shown the inhibitory potential against the main protease and free enzymes of the SARS-CoV-2 (Nivetha *et al.*, 2021). Also, marmelide ($C_{16}H_{14}O_4$) isolated from this plant possess antiviral properties as it affects the initial stages of lifecycle of a virus, including penetration and adsorption (Kim *et al.*, 2016).

3.2 Aloe vera: *Aloe vera* (L.) Burm. f.

Aloe vera is considered as 'wonder plant' or 'miraculous plant' and its gel along with other components (aloe-emodin and aloin) are well known for the antiviral properties as they eliminate the enveloped viruses including HIV, influenza, SARS-CoV-1, *etc.*, by destroying the viral lipid envelope and inhibits its further replication (Daverey and Dutta, 2020; Mpiana *et al.*, 2020). It is a good source of many phytochemicals, namely; anthrones/anthraquinones (aloe-emodin, anthranol, barbaloin, isobarbaloin, emodin, aloetic-acid), chromones, steroids, lipids, triglycerides, triterpenoids, salicylic acid and uric acid (Zandi *et al.*, 2007). The antiviral properties against influenza, hepatitis, HIV and herpes simplex virus-2 are mainly due to the presence of anthraquinones (Li *et al.*, 2014; Parvez *et al.*, 2019; Mpiana *et al.*, 2020).

3.3 Kalamegha: *Andrographis paniculata* (Burm. f.) Nees

Kalamegha or 'king of the bitters' and 'bhunimba' in Sanskrit which means "Neem of the Earth" is used in our ancient medicine to cure cold, fever, diarrhea and also used as a health tonic (Hossain *et al.*,

2014). It contains labdane diterpenoids, flavonoids, steroids and polyphenols. The bioactive compound andrographolide, a diterpene lactone has been reported to cure many viral diseases including chikungunya, dengue, herpes simplex virus type-1 (Seubsasana *et al.*, 2011; Wintachai *et al.*, 2015) and is reported as a potent binder of main protease of SARS-CoV-2 which inhibit its replication (Sangiamsuntorn *et al.*, 2021). Apart from this, it also possesses antidiabetes, anti-inflammatory, anticancer and antiobesity properties (Gupta *et al.*, 2017; Dai *et al.*, 2019). The other compound, namely; 5,4-dihydroxy-7-*O*-D-pyran-glycuronate-butyl-ester (DGE) has also been reported in this fruit which inhibits the infection of SARS-CoV-2 by hindering the activity of protease enzyme (Sukardiman *et al.*, 2020).

3.4 Neem: *Azadirachta indica* Juss

Neem is a medicinal plant of Indian origin that is used to treat chronic and acute ailments (Singh *et al.*, 2021). Several terpenoids have been found in the bark, including nimbin, nimbidin, nimbolide, 6-desacetylnimbinene, limonoids, sistosterol, margocin, nimbione, quercetin and others (Alzohairy, 2016). These bioactive chemicals are said to have anti-inflammatory and antiviral activities (Patel *et al.*, 2018). Furthermore, neem and tulsi bioactive components (methyl eugenol, ursolic acid and oleanolic acid) prevents viral attachment and replication by attaching to the spike glycoprotein, RNA polymerase and its protease enzyme (Kumar, 2020).

3.5 Cinnamon: *Cinnamomum verum* J. Presl

Cinnamon commonly known as dachini, true cinnamon or ceylon cinnamon is a traditional Indian spice used to cure pneumonia and other lungs related infectious disorders (Lai *et al.*, 2018). The major bioactive compounds reported are cinnamaldehyde, eugenol, linalool, α -caryophyllene, *etc.* (Yakhchali *et al.*, 2021) and these phytochemicals are responsible for the various therapeutic properties of dachini like antiviral, antimicrobial, antidiabetic, antifungal, antioxidant, immunomodulatory, antihypertensive, antitumor, *etc.* (Shen *et al.*, 2012). Also, the bioactive compounds tenufolin (TEN) and pavetannin C1 (PAV) has shown good binding efficacy with the main protease and spike proteins of SARS-CoV-2 and could be used as potential COVID-19 inhibitors (Prasanth *et al.*, 2021).

3.6 Bharngi: *Clerodendrum serratum*

Bharngi is an important Ayurvedic plant which is mainly used to cure respiratory conditions. The roots of this plant contain saponins, queretaroic acid, stigmaterol, scutellarein, D-mannitol, oleanolic acid, serratagenic acid, terpenoids, lupeol, ursolic acid, sitosterol, baicalein, ferulic acid, arabinose and caffeic acid (Singh *et al.*, 2012; Gurav *et al.*, 2019) and have expectorant, anti-inflammatory, antispasmodic, anthelmintic, carminative, digestive and sudorific action. This medication was frequently utilized in ancient times for a variety of ailments, including breathlessness, cough, asthma, fever, wound, swelling and various neurological disorders (Singh *et al.*, 2012; Kumar and Nishteswar, 2013).

3.7 Haldi: *Curcuma longa* L.

Turmeric is a crucial part of our culture and because of its wide range of therapeutic properties for centuries, it has been employed in ancient Ayurvedic medicine including Unani and Siddha (Gupta *et al.*, 2020). In Ayurveda, haldi is abundantly used to cure runny nose, cough and sinusitis (Gyawali *et al.*, (2020). The compounds like

curcumin (diferuloylmethane), DMC (demethoxycurcumin), BDMC (bisdemethoxycurcumin), polyphenols, sesquiterpenes, steroids and volatile oils (tumerone, atlantone, and zingiberone) are among the major bioactive substances isolated from its rhizome (Sahoo *et al.*, 2020). Due to the occurrence of these compounds, turmeric exhibits various pharmacological activities like removal of inflammations, antioxidant, neuroprotective and chemopreventive properties (Mehla *et al.*, 2010). Curcumin is effective against various viral diseases like chikungunya, zika, AIDS, hepatitis B, hepatitis C, dengue, *etc.* (Richart *et al.*, 2018; Prasad and Tyagi, 2015) and as inhibitor of key enzyme for replication, *i.e.*, protease with high potency and replication of SARS-CoV-2 (Wen *et al.*, 2007).

3.8 Lemon grass: *Cymbopogon citratus* (DC) Stapf

Lemon grass is an aromatic medicinal grass used to address a wide variety of diseases such as fever, cough, elephantiasis, flu, leprosy, malaria and digestive issues. This grass contains bioactive chemicals such as anthraquinones, steroids, phlobotannins and cardiac glycosides as well as alkaloids, terpenoids, flavanoids, phenols, saponins and tannins (Ranade and Thiagarajan, 2015). This plant also posses anti-inflammatory, antibacterial, antifungi, antioxidant, antiobesity and antihypertensive properties (Olorunnisola *et al.*, 2014).

3.9 Licorice: *Glycyrrhiza glabra* L.

Licorice commonly known as mulethi, is very well-known plant for its potential antiviral activity against several RNA and DNA viruses (Sinha *et al.*, 2020). It contains various bioactive compounds including triterpenoid saponins, flavonoids, phenols, coumarins and polysaccharides (Jiang *et al.*, 2020). A triterpenoid saponin, *i.e.*, glycyrrhizin or glycyrrhizic acid (GLR), is derived mostly from the roots of the plant has been found to inhibit the replication, adsorption and penetration of SARS-associated coronavirus into cells and is reported to possess antiviral properties against influenza, herpes, hepatitis and SARS viruses (Chen *et al.*, 2004).

3.10 Purging nut: *Jatropha curcas* L.

The medicinal plant, *Jatropha* (purging nut, physic nut) is used to cure a variety of illnesses, including malarial fever, arthritis, gout and jaundice as well as oral infections (Sriprang *et al.*, 2010). According to Oskoueian *et al.* (2011), root extract and latex of this plant includes phenolics, flavonoids and saponins which has significant antioxidant, anticancerous and anti-inflammatory properties. *Jatropha* latex also consists of an alkaloid known as “Jatrophine” whereas, its leaves contain vitexin, apigenin and isovitexin which enable it to be used as an antiseptic against cough and cold, malaria, rheumatic muscle aches and otorrhoea (Patil *et al.*, 2013).

3.11 Vana tulsi: *Ocimum basilicum* L.

Vana tulsi or sweet basil has been used for thousands of years for its antioxidant, anti-inflammatory, antiviral, antipyretic, antidiabetes, insecticidal and cardioprotective properties (Saganuwan, 2010; Rubab *et al.*, 2017). Monoterpenoids (carvone, cineole, linalool, myrcene, fenchone, geraniol and thujone), triterpenoids (ursolic acid), sesquiterpenoids (farnesol and caryophyllene) and flavonoids (apigenin) are the major compounds present in sweet basil (Chiang *et al.*, 2005). Among the various compounds, nevadensin, oleanolic acid, apigenin and ursolic acid have the potential to alter the activity of protease enzyme of SARS-CoV-2 (Matondo *et al.*, 2021).

3.12 Tulsi: *Ocimum sanctum* L.

Tulsi also known as “Queen of herbs” is being used for thousands of years due to its wide therapeutic properties (Umashankar *et al.*, 2021) and it is used to treat diarrhea, pain, cough and fever which are among the common COVID-19 symptoms (Mohan *et al.*, 2011). It has antimicrobial properties against viruses, bacteria and fungi whereas its leaves can help in curing respiratory problems (cough, bronchitis, influenza, asthma and cold) (Pattanayak *et al.*, 2010). It has been proven useful in preventing the spread of various viral diseases, including vaccinia, newcastle and infectious bursal disease (Prakash and Gupta, 2005). Its therapeutic action involves anti-bacterial, antiviral, antifungal, antidiabetic, anti-inflammatory, immunomodulatory, antispasmodic and cardioprotective properties (Jamshidi and Cohen, 2017). The presence of many types of bioactive metabolites in this plant is accountable for the above-mentioned qualities. According to Shree *et al.* (2020), the presence of vicenin, 4-O-glucoside 200-O-p-hydroxybenzoate, isorientin and ursolic acid is responsible for reducing the infection of SARS virus in human. These compounds form a ligand with M^{pro} and does not allow it to bind with the COVID triggering compounds. Similarly, Srivastva *et al.* (2020) have reported apigenin and ursolic acid as the key functional compound for the inhibition of replicating protein.

3.13 Aonla: *Phyllanthus emblica* L.

Indian goose berry or amalaka is second richest source of vitamin C best known for its rejuvenating, anti-ageing and antioxidant properties and also for the treatment of skin disorders and cough (Saini *et al.*, 2008). Being second highest source of Vitamin C, it has indirect antiviral properties as it boosts the body’s innate immunity, antioxidant properties as it reduces the lung inflammation caused due to oxidative stress, immunomodulatory properties as it increases T cell activity by increasing immunoglobulin synthesis and anti-inflammatory characteristics as it helps in lowering down the danger of cytokine storm (Abobaker *et al.*, 2020). The medicinal properties are due to the presence of phyllemblic acid, ellagic acid, gallic acid and flavonoids which is reported to cure cold, cough, diabetes, heart disorders, asthma, digestion problems (Baidya and Sethy, 2020). Also, the compound phyllaemblicin G7 present in aonla has shown the ability to cure COVID-19 (Wu *et al.*, 2020).

3.14 Kutki: *Picrorhiza kurroa* Royle ex Benth.

Picrorhiza kurroa, commonly known as kutki is a perennial herb with extraordinary medicinal properties. Kutkin is the main phytochemical constituent of this medicinal plant, containing iridoid glucosides like picroside I, II, III, IV, kutkiol, kutkoside, kutki sterol, pikurosides, kutkoside, D-mannitol and flavonoids like vanillic acid and apocynin (Kumari *et al.*, 2021). Kutki’s pharmacological effects include microbial actions against bacteria, fungus, viruses and have antioxidant, hepatoprotective, antimutagenic and anticancer capabilities (Masood *et al.*, 2021; Kumari *et al.*, 2021). It is highly valued in Ayurveda and other traditional systems for healing a variety of ailments, including fever, common cold, sore throat, cough, dyspepsia, chronic diarrhea, liver and respiratory tract disorders (Sultan *et al.*, 2016; Kumari *et al.*, 2021).

3.15 Chirettai: *Swertia chirata* (Buch) Ham.

Chirettai is a well-known medicinal plant native to the temperate Himalayas. The pharmacological efficacy is attributed due to major phytoconstituents including swerchirin, swertiamarin, sweroside,

amarogentin, mangiferin, amaroserin, *etc.* (Kumar and Staden, 2016). It is being used due to its therapeutic properties, against viruses, bacteria, fungus and act as antidiabetic, anti-oxidant, anti-cancerous, anti-inflammatory agent, *etc.* (Arya *et al.*, 2011).

3.16 Clove: *Syzygium aromaticum* L.

Clove is an evergreen tree that has been used for over 2000 years in Ayurvedic and Chinese traditional medicine (Vicidomini *et al.*, 2021). The various phenolic compounds present in clove include hydroxycinnamic acids, hydroxyphenylpropens, hydroxybenzoic acids, flavonoids and so on. However, eugenol is responsible for the main antiviral activity and has been shown to be effective against Ebola, influenza A virus (IAV), and other viruses (Neveu *et al.*, 2010; Lane *et al.*, 2019). The presence of these bioactive compounds is responsible for clove's therapeutic properties, which include antimicrobial, antiviral, antifungal and antiseptic properties that have been known for centuries (Bhowmik *et al.*, 2012). Tellimagrandin-II, which inhibits ACE 2 interactions is responsible for the inhibition of SARS-CoV-2 infection.

3.17 Harar: *Terminalia chebula* Retz.

Harar or haritaki, also known as king or mother of medicinal plants (Chandil *et al.*, 2021). It is rich in triterpenoids, phytosterols, phenolic compounds and glycosides which makes it effective in treating various diseases (Choudhary *et al.*, 2021; Hussain, 2021). The presence of various phytochemicals is responsible for its antiviral and antibacterial properties (Lee *et al.*, 2011; Rathinamoorthy and Thilagavathi, 2014). The bioactive compounds like maslinic acid, arjunetin, daucosterol and bellericoside are among the potential inhibitors of the protease proteolytic activity of SARS-CoV-2 and can be used for the treatment of COVID-19 (Ghosh *et al.*, 2022).

3.18 Guduchi: *Tinospora cordifolia* Miers

Guduchi or giloy is a powerful rasayana that rejuvenates the dead cells and boosts innate immunity against COVID-19 infections (Srivastava and Saxena, 2020). It is well known for its immunomodulatory, antidiabetic, antioxidant, antihepatotoxic and cytotoxic effects (Sharma *et al.*, 2012). The presence of a diterpenoid, tinosporin is responsible for the antiviral property of the herb which is useful in combating various viral diseases (Akhtar, 2010). Tinocordiside is reported to be the main phytochemical responsible for inhibition of the main protease of SARS-CoV-2 (Shree *et al.*, 2020).

3.19 Ashwagandha: *Withania somnifera* (L.) Dunal

Indian ginseng frequently referred as ashwagandha, is a herbal plant used in medical field for immunomodulation, stress management, fighting infectious and disease-causing agents, improving mental and physical health (Srivastava and Saxena, 2020). Approximately 35

chemical constituents having biological activity has been reported from this plant especially from its roots (Singh *et al.*, 2010). The phytoconstituents like withanolide D, withaferin-A and withanoside I-VII are responsible for the majority of biological action (Matsuda *et al.*, 2001). Several reports showed its therapeutic properties against diabetes, inflammatory diseases, stress, wide range of microbes and also as immunomodulatory, neuroprotective, antitumor and cardioprotective, which are attributed due to biological activity of these compounds (Venmurthy *et al.*, 2010; Vyas *et al.*, 2011). Several researchers have already approved its antiviral activity against herpes simplex, parainfluenza-3, H1N1 and most importantly against SARS-CoV (Kashyap *et al.*, 2020). In relation to COVID-19, the compound withanoside V act as a hurdle for the replication of main protease enzyme of SARS-CoV-2 (Tripathi *et al.*, 2020). Dhawan *et al.* (2021) discovered that withanolides inhibit ACE2, a receptor that mediates SARS-CoV-2 entry into host cells. They also explained how the presence of withanosides, withanone and withanolide A inhibited the SARS-CoV-2 main protease (M^{pro}). Thus these compounds play a key role in quenching COVID-19 infection as these M^{pro} are responsible for the replication of virus (Kashyap *et al.*, 2020).

3.20 Ginger: *Zingiber officinale* Roscoe

Ginger contains many bioactive chemicals of medicinal importance, including phenolics, alkaloids, steroids, *etc.* (Singh *et al.*, 2021). The pharmacological activities including antiviral, anti-inflammatory, anti-diabetic, antibacterial, anticancer, antioxidant, antihyperalgesic, gastroprotective and neuroprotective are majorly due to presence of phenolic and terpene compounds (Mao *et al.*, 2019; Kiyama, 2020). In relation to COVID-19, bioactive compounds such as gingerenone A, geraniol, gingerol, zingiberene, shogaol, zingiberenol and zingeron have been shown to play a significant role by blocking the spike (S) protein, which is responsible for SARS-CoV-2 entry during infection and also hinders its binding to the ACE 2 receptor (Ahkam *et al.*, 2020; Walls *et al.*, 2020). Gyawali *et al.* (2020) have observed the positive effect of zingiberene against fever, viruses and as antigestation.

3.21 Other medicinal plants

The majority of the plants discussed here are high in phenolic compounds such flavonoids, phenols, tannins, vitamins, alkaloids, glycosides and so on. In Indian circumstances, these plants are readily available. However, there are dozens of additional species with similar traits that could also be investigated for future usage.

Table 2: Important medicinal plants and role of their phytochemicals on human health

S. No.	Medicinal plant	Functional compound	Immunological properties	Diseases quenching	References
1.	<i>Aegle marmelos</i>	Marmelide, marmelosin, seselinaegeline, phenols, flavonoids	Antiviral, body cooling effect, antipyretic, antifungal, anti-inflammatory, wound healing, hypoglycemic, analgesic, antiproliferative	SARS-CoV-2, diabetes, cancer cardio vascular, disease	Kim <i>et al.</i> (2016); Nivetha <i>et al.</i> (2021); Bhatt <i>et al.</i> (2021)
2.	<i>Aloe vera</i>	Aloe-emodin, aloin, anthraquinones/anthrones (aloe-emodin, anthranol, barbaloin, aloetic-acid, isobarbaloin, emodin), chromones, steroids	Immunomodulatory, anti-inflammatory, antimicrobial, UV-protectant	HIV, influenza, SARS-CoV-1, hepatitis, herpes simplex virus-2, asthma, cancer, diabetes	Zandi (2007); Qadir (2009)

3.	<i>Andrographis paniculata</i>	5,4'-dihydroxy-7-O- β -D-pyran-glycuronate butyl ester, labdane diterpenoids, flavonoids, steroids, polyphenols	Antiobesity, antidiabetes, anti-inflammatory, anticancer	Cold, fever, diabetes, diarrhea, chikungunya, dengue, herpes simplex virus type-I	Mishra <i>et al.</i> (2007); Pole (2012); Wintachai <i>et al.</i> (2015); Sukardiman <i>et al.</i> (2019)
4.	<i>Azadirachta indica</i>	Nimbolide, nimbione, nimbidin, nimbin, β -sistosterol, limonoids, 6-desacetylnimbinene, quercetin, methyl eugenol, oleanolic acid, ursolic acid	Anti-inflammatory, antiviral, hepatoprotective, anticancerous, antidiabetic, antitumor	Immunomodulatory, diabetes, blood purifier, cardioprotective, cancer	Alzohairy, (2016); Rahmani <i>et al.</i> (2018); Kumar (2020)
5.	<i>Cinnamomum verum</i>	Tenufolin, pavenannin C1, cinnamaldehyde, eugenol, linalool, β -caryophyllene	Antidiabetic, antiviral, anti-fungal, immunomodulatory, antihypertensive, antitumor, antioxidant	SARS-CoV-2, pneumonia, immunity booster, cold, fever, obesity, viral disease, diabetes, tumor, blood pressure	Shen <i>et al.</i> (2012); Prasanth <i>et al.</i> (2021); Yakhchali <i>et al.</i> (2021)
6.	<i>Clerodendroum serratum</i>	Stigmasterol, saponins, querearic acid, terpenoids, D-mannitol, serratagenic acid, ursolic acid, oleanolic acid, sitosterol, scutellarein, -lupeol, arabinose, baicalein, ferulic acid	Carminative, anti-inflammatory, expectorant, anthelmintic, antispasmodic, sudorific and digestive actions	Breathlessness, cough, asthma, fever, wound, swelling	Singh <i>et al.</i> (2012)
7.	<i>Curcuma longa</i>	Curcumin, polyphenols	Antiviral, immunity booster, anti-inflammatory, chemopreventive, neuroprotective	Chikungunya, zika, AIDS, hepatitis B, hepatitis C, dengue, COVID	Wen <i>et al.</i> (2007); Mehla <i>et al.</i> (2010); Omosa <i>et al.</i> (2017)
8.	<i>Cymbopogon citratus</i>	Alkaloids, terpenoids, flavanoids, phenols, saponins, tannins, anthraquinones, ateroids, phlobotannins, cardiac glycosides	Anti-inflammatory, anti-microbial, antiobesity, antioxidant, antihypertensive effects	Obesity, inflammations, arthritis, stress reliever	Olorunnisola <i>et al.</i> (2014); Ranade and Thiagarajan, (2015)
9.	<i>Glycyrrhiza glabra</i>	Glycyrrhizin, glycyrrhizic acid, triterpenoid, saponins, phenol, flavonoids, coumarins	Antiviral, anti-inflammatory, analgesic	Sore throat, influenza, herpes, hepatitis, SARS viruses, bronchitis	Chen <i>et al.</i> (2004); Parvaiz <i>et al.</i> , (2014)
10.	<i>Jatropha curcas</i>	Jatrophine, apigenin, vitexin, isovitexin	Antiviral, anticancerous	Malarial fever, cough, cold, arthritis, gout, jaundice, HIV, oral infections, rheumatic muscle aches	Sriprang <i>et al.</i> (2010); Islam <i>et al.</i> (2011)
11.	<i>Ocimum basilicum</i>	Monoterpenoids (carvone, cineole, linalool, myrcene, fenchone, geraniol, thujone), triterpenoids (ursolic acid), sesquiterpenoids (farnesol, caryophyllene), flavonoids (apigenin)	Antiviral, antioxidant, anti-inflammatory, antipyretic, antidiabetes, cardioprotective	SARS-CoV-2, malaria, cold, fever, flu, anorexia, diabetes	Chiang <i>et al.</i> (2005); Shahrajabian <i>et al.</i> (2020)
12.	<i>Ocimum sanctum</i>	Vicenin, 4-O-glucoside 2-O-p-hydroxybenzoate, isorientin, urosolic acid, apigenin	Antiviral, antimicrobial, antispasmodic, antidiabetic, immunomodulatory, adipogenic, cardioprotective, vitalizer, increases physical endurance	Cold, cough, fever, bronchitis, influenza, asthma, diarrhea, pain, vaccinia, infectious bursal disease	Prakash and Gupta (2005); Mohan <i>et al.</i> (2011); Shree <i>et al.</i> (2020), Srivastva <i>et al.</i> (2020)
13.	<i>Phyllanthus emblica</i>	Phyllaemblicin G7, phyllemblic acid, ellagic acid, gallic acid, flavonoids, ascorbic acid	Antiviral, anti-inflammatory, immunity booster, rejuvenating, anti-aging, antioxidant	COVID, cold, cough, diabetes, heart disorders, asthma, digestion problems	Wu <i>et al.</i> (2020); Abobaker <i>et al.</i> (2020)

14.	<i>Picrorhiza kurroa</i>	Kutkin iridoid glucosides (picroside I, II, III, IV, kutkoside, pikuroside, d-mannitol, kutkiol, kutki sterol), flavonoids (apocynin, vanillic acid)	Antimicrobial, hepatoprotective, antioxidant, antibacterial, antimutagenic, anticancer capabilities	Malaria, fever, common cold, sore throat, cough, dyspepsia, chronic diarrhoea, liver, respiratory tract disorders	Sultan <i>et al.</i> (2016); Kumari <i>et al.</i> (2021)
15.	<i>Swertia chirata</i>	Chiratin, swerchirin, swertiamarin, sweroside, amarogentin, mangiferin, amaroswerin	Antimicrobial (virus, fungus and bacteria), antioxidant, anti-inflammatory, anti-diabetic, anticancerous	Fever, cough, diabetes, bronchial asthma, loss of appetite, heart and liver tonic, cancer, AIDS, regulate bowl movement	Chen <i>et al.</i> (2011); Aleem and Kabir (2018)
16.	<i>Syzygium aromaticum</i>	Hidroxicinamic acids, hidroxihipenylpropens, hidroxi benzoic acids, flavonoidseugenol, tellimagrandin-II	Antiviral, antimicrobial, antifungal, antiseptic, antimutagenic, antioxidant	SARS-CoV-2 ebola, influenza virus, viral diseases, diabetes, inflammations, heart diseases, cancer, tumor	Mittal <i>et al.</i> (2014)
17.	<i>Terminalia chebula</i>	Arjunetin, maslinic acid, bellericoside and daucosterol, triterpenoids, phytosterols, phenolic compounds, glycosides, tannins, pyrogallol, ethyl gallate, luteolin, vitamin C	Antiviral and antibacterial	SARS-CoV-2, asthma, chronic diarrhea, dysentery, sore throat, cough, cancer, urinary disorders	Choudary <i>et al.</i> (2021); Ghosh <i>et al.</i> (2022)
18.	<i>Tinospora cordifolia</i>	Berberine, diterpenoid, tinosporin, tinocordiside, syringin, octacosanol	Immunomodulatory, anti-diabetic, antioxidant, antihepatotoxic and cytotoxic effects, antistress, Anti-inflammatory	Malaria, viral diseases, SARS-CoV-2, diabetes, cancer	Choudhary <i>et al.</i> (2013); Shree <i>et al.</i> (2020)
19.	<i>Withania somnifera</i>	Withanolides, withanoside V, withaferin A, withanone	Anti influenza, antiviral, cardio protectant, immunomodulator, antistress, aphrodisiac	SARS-CoV-2, SARS-CoV, respiratory diseases, asthma, diabetes, bronchitis, human papillomavirus, chikungunya, neuraminidase type I, hemagglutinin type I, hepatitis C virus, herpes simplex	Singh <i>et al.</i> (2010); Tripathi <i>et al.</i> (2020); Kashyap <i>et al.</i> (2020); Balkrishna <i>et al.</i> (2021); Dhawan <i>et al.</i> (2021)
20.	<i>Zingiber officinale</i>	Gingerol, gingerenone A, geraniol, zingeron, zingiberene, shogaol, zingiberenol	Antiviral, antidiabetic, antioxidant, antibacterial, anti-inflammatory, anticancer, antihyperalgesic, gastroprotective, neuroprotective	Maintain body temperature, cold, cough, nausea, headache, inflammations, arthritis, body discomfort, cancer, brain deformities, diabetes	Mao <i>et al.</i> (2019); Shahrajabian <i>et al.</i> (2019); Ahkam <i>et al.</i> (2020)

4. Conclusion

CORONA, the cause of deadliest pandemic of twenty-first century has claimed millions of lives. Although, the intensity this pandemic was reduced due to adequate immunization and healthy eating habits among the population. However, this is not the end of the virus as it has potential to become lethal again due to mutation and increased climatic adaptation. India has really shown ability to effectively tackle this virus. Ayurvedic remedies, botanicals and a nutrient-dense diet have played important roles in this instance. Plant metabolites aided in the development of disease resistance and boosting immunity. In the future, the enormous potential of the aforementioned medicinal

plants and herbs in lowering the rate of fatality can be investigated. Plants that are widely accessible, such as neem, tulsi, harar, jatropa and many others are high in nutrients and secondary metabolites which aid in the prevention of infection of COVID-19. The powerful functional compounds present in medicinal plants can prevent disease development before it begins. The intake of medicinal plants and its Bi-products as a part of diet or supplements in our daily lives can reduce the reliance upon the chemical drugs to combat COVID-19 infection and its related effects.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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