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Natural Products *and* Herbal Strategies *in* COVID-19 *and* Mental Health Management

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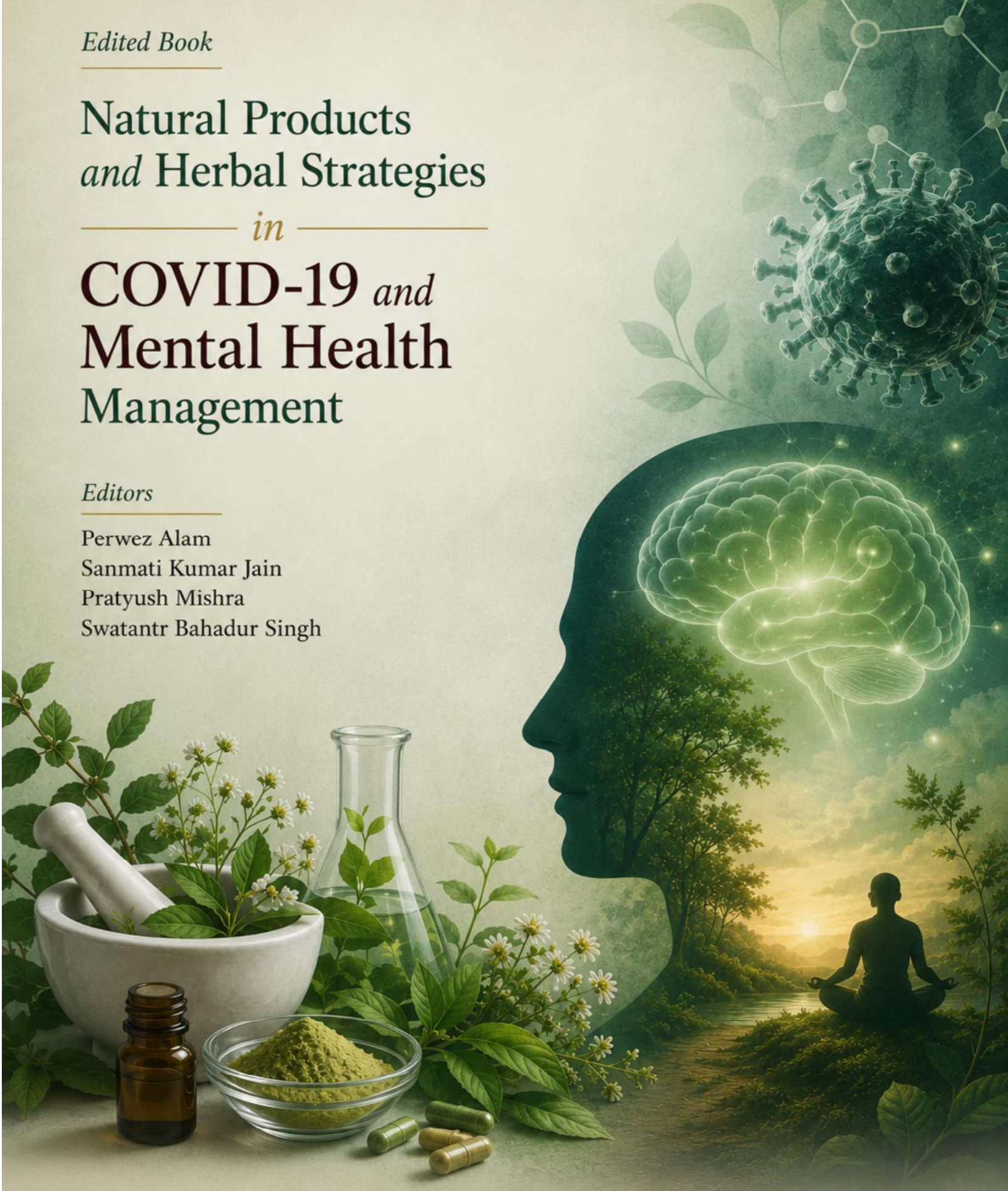
Perwez Alam
Sanmati Kumar Jain
Pratyush Mishra
Swatantr Bahadur Singh



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Natural Products and Herbal Strategies in Covid- 19 and Mental Health Management

Editors

Perwez Alam
Department of Pharmacognosy
College of Pharmacy, PO Box 2457,
King Saud University, Riyadh, 11451,
Saudi Arabia

Sanmati Kumar Jain
Professor, Department of Pharmaceutical Chemistry,
Guru Ghasidas Vishwavidyalaya, Bilaspur (CG), India

Pratyush Mishra
Assistant Professor, Department of Pharmacology & Therapeutics,
MKCG Medical College & Hospital, Berhampur, Odisha, India

Swatantr Bahadur Singh
Assistant Professor, Department of Pharmacognosy
School of Pharmaceutical sciences faculty of pharmacy IFTM University Moradabad Uttar Pradesh, India

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Chapter 8: Role of Nutraceutical Herbs Phyllanthus emblica and Allium sativum in Immunity Enhancement and Mental Health Support During COVID-19

Mhaveer Singh[*1], Bhavana Singh[2], Ankita Vijay Thul[3], Johny Lakra[4], Vikash Kumar Mehta[5]

[1]*Associate Professor, School of Pharmaceutical Sciences, Faculty of Pharmacy, IFTM University Moradabad, Uttar Pradesh, India*
[2]*Assistant Professor, School of Pharmacy, Sharda University, Knowledge Park II & III, Greater Noida – 201310, Uttar Pradesh, India*
[3]*Assistant Professor, School of Pharmacy, G. H. Raisoni Skill Tech University, Nagpur, Maharashtra, India*
[4]*Research Scholar (Pharmaceutics), Department of Pharmacy, MM College of Pharmacy Maharishi Markandeshwar (Deemed to be University), Mullana–Ambala, Haryana, India*
[5]*Assistant Professor, Department of Pharmacy, Mahadeva Lal Schroff College of Pharmacy Aurangabad, Bihar, India*

Abstract

The coronavirus disease 2019 (COVID-19) pandemic has created unprecedented challenges to global healthcare systems by affecting not only respiratory health but also immune, neurological, and psychological functions. Increasing evidence indicates that SARS-CoV-2 infection induces immune dysregulation, cytokine storm, oxidative stress, neuroinflammation, anxiety, depression, and cognitive impairment in affected individuals. In this context, nutraceutical herbs possessing immunomodulatory, antiviral, antioxidant, and neuroprotective properties have gained considerable scientific attention as supportive therapeutic agents. *Phyllanthus emblica* (Amla) and *Allium sativum* (Garlic) are two traditionally valued medicinal plants widely utilized in Ayurveda and complementary medicine for enhancing immunity and promoting overall health. *Phyllanthus emblica* is rich in vitamin C, emblicanins, gallic acid, ellagic acid, flavonoids, and tannins, which contribute to its strong antioxidant, anti-inflammatory, and immunostimulatory activities. Similarly, *Allium sativum* contains biologically active sulfur compounds such as allicin, alliin, and ajoene that exhibit potent antiviral, antimicrobial, cardioprotective, and immunomodulatory effects. Experimental and computational studies suggest that phytochemicals from these herbs may interfere with SARS-CoV-2 entry and replication pathways, reduce inflammatory cytokines, and protect tissues against oxidative injury. Furthermore, both herbs demonstrate neuroprotective potential through modulation of neurotransmitter systems, reduction of neuroinflammation, and attenuation of stress-induced neuronal damage. This chapter comprehensively discusses the phytochemical composition, traditional medicinal importance, immunomodulatory mechanisms, antiviral potential, and mental health-supportive roles of *Phyllanthus emblica* and *Allium sativum* during COVID-19. The chapter also highlights their therapeutic applications in nutraceutical formulations, dietary supplements, and integrative healthcare strategies. Additionally, challenges related to standardization, dosage optimization, safety, and clinical validation are critically examined. The available evidence suggests that these nutraceutical herbs may serve as valuable adjunctive agents for improving immune resilience and mental well-being during and after COVID-19 infection. However, further clinical and translational studies are necessary to establish their efficacy and safety in evidence-based therapeutic practice.

Keywords

COVID-19; SARS-CoV-2; *Phyllanthus emblica*; *Allium sativum*; Amla; Garlic; Nutraceuticals; Immunomodulation; Neuroprotection; Mental health; Cytokine storm; Oxidative stress; Antiviral herbs; Herbal medicine; Phytochemicals

**Corresponding Author: Mhaveer Singh, Associate Professor, School of Pharmaceutical Sciences, Faculty of Pharmacy, IFTM University Moradabad, Uttar Pradesh, India*

1. Introduction

The emergence of coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), resulted in one of the most devastating global public health crises in modern history. The outbreak was first identified in Wuhan, China, in late 2019 and rapidly spread worldwide due to the highly transmissible nature of the virus (Zhu et al., 2020). The World Health Organization (WHO) officially declared COVID-19 a pandemic in March 2020, and since then millions of individuals have been infected globally, leading to substantial morbidity, mortality, social disruption, and economic instability (World Health Organization [WHO], 2023). Although SARS-CoV-2 primarily affects the respiratory system, increasing evidence demonstrates that COVID-19 is a multisystemic disease involving cardiovascular, neurological, gastrointestinal, renal, and immunological complications (Gupta et al., 2020). The large-scale burden on healthcare systems and the persistence of post-COVID complications have intensified the search for safe and effective supportive therapeutic approaches.

SARS-CoV-2 enters host cells mainly through interaction between the viral spike glycoprotein and angiotensin-converting enzyme 2 (ACE2) receptors present on epithelial and endothelial cells (Hoffmann et al., 2020). Following viral entry and replication, infected individuals may develop dysregulated immune responses characterized by excessive release of inflammatory mediators and cytokines. In severe COVID-19 cases, uncontrolled production of pro-inflammatory cytokines such as interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and interleukin-1β (IL-1β) leads to a phenomenon known as "cytokine storm" (Mehta et al., 2020). This hyperinflammatory response contributes to acute respiratory distress syndrome (ARDS), tissue injury, endothelial dysfunction, oxidative stress, coagulation abnormalities, and multiorgan failure (Fajgenbaum & June, 2020). Studies have shown that oxidative stress and immune imbalance play major roles in worsening disease severity and promoting long-term pathological consequences (Cecchini & Cecchini, 2020). Therefore, therapeutic strategies capable of regulating immune responses and reducing oxidative damage are considered highly valuable in COVID-19 management.

Apart from respiratory manifestations, COVID-19 is strongly associated with neurological and neuropsychiatric complications. Clinical studies have reported symptoms including headache, dizziness, anosmia, ageusia, confusion, encephalopathy, stroke, seizures, cognitive dysfunction, depression, anxiety, and sleep disturbances among infected individuals (Ellul et al., 2020; Mao et al., 2020). Emerging evidence suggests that SARS-CoV-2 may affect the central nervous system either directly through neuroinvasion or indirectly via systemic inflammation, cytokine-mediated neuronal injury, and blood–brain barrier disruption (Song et al., 2021). Persistent neuroinflammation and immune activation may contribute to "brain fog," impaired memory, reduced concentration, and psychiatric disturbances observed in post-COVID syndrome (Premraj et al., 2022). Furthermore, social isolation, fear of infection, financial insecurity, and prolonged stress during the pandemic have significantly increased the prevalence of anxiety and depressive disorders worldwide (Troyer et al., 2020). These findings indicate that comprehensive COVID-19 management should not only target viral replication but also address immune dysfunction and mental health complications.

In recent years, nutraceutical herbs and traditional medicinal plants have gained considerable attention as supportive interventions during the COVID-19 pandemic. Nutraceuticals are bioactive natural products

that provide health benefits beyond basic nutrition and may contribute to disease prevention and immune enhancement. Medicinal herbs rich in antioxidants, polyphenols, flavonoids, vitamins, sulfur compounds, and immunomodulatory phytochemicals are increasingly being explored for their antiviral and neuroprotective activities (Jahan et al., 2021). Herbal medicines may help strengthen innate and adaptive immunity, reduce inflammatory cytokines, improve antioxidant defenses, and protect against stress-related neurological complications (Paraiso et al., 2020). Additionally, several phytochemicals have shown promising inhibitory effects against SARS-CoV-2 targets such as ACE2 receptors, main protease (Mpro), and viral replication enzymes in molecular docking and experimental studies (Kharwar et al., 2020). Consequently, nutraceutical herbs have emerged as important complementary approaches for improving resilience against viral infections and supporting post-COVID recovery.

Among various medicinal plants, *Phyllanthus emblica* (Amla) and *Allium sativum* (Garlic) have attracted significant scientific interest because of their extensive pharmacological properties and long history of traditional use. *Phyllanthus emblica* is widely utilized in Ayurveda as a rejuvenating herb and is recognized for its exceptionally high vitamin C content, antioxidant potential, and immunomodulatory activity. The fruit contains important phytochemicals such as emblicanins, gallic acid, ellagic acid, flavonoids, and tannins that exhibit anti-inflammatory, antiviral, and neuroprotective effects. Similarly, *Allium sativum* is one of the most extensively studied medicinal herbs due to the presence of bioactive sulfur compounds including allicin, alliin, ajoene, and diallyl sulfides, which possess antimicrobial, antiviral, antioxidant, cardioprotective, and immune-enhancing properties (Rahman, 2007). Garlic has also demonstrated beneficial effects on inflammatory regulation, oxidative stress reduction, and mental health support. Both herbs possess strong nutraceutical value and are commonly consumed as dietary supplements, functional foods, and traditional remedies. Their multitarget therapeutic properties make them promising candidates for supportive management of COVID-19-related immune and neurological complications.

2. Botanical Profile and Traditional Medicinal Importance

Medicinal plants have played a central role in traditional healthcare systems for centuries and continue to provide valuable therapeutic agents for the prevention and management of infectious and inflammatory diseases. Among nutraceutical herbs, *Phyllanthus emblica* (Amla) and *Allium sativum* (Garlic) are widely recognized for their immunomodulatory, antioxidant, antimicrobial, and neuroprotective properties. Both plants are extensively utilized in Ayurveda, Traditional Chinese Medicine, and folk medicine for promoting vitality, resistance against infections, and overall well-being (Baliga & Dsouza, 2011; Bayan et al., 2014). Their rich phytochemical composition and broad pharmacological activities have generated considerable interest for supportive applications during the COVID-19 pandemic.

2.1 *Phyllanthus emblica* (Amla)

Phyllanthus emblica L., commonly known as Amla or Indian gooseberry, belongs to the family Phyllanthaceae. It is a medium-sized deciduous tree widely distributed throughout tropical and subtropical regions of India, Southeast Asia, and China. The fruit of Amla is spherical, greenish-yellow, and highly valued for its exceptional nutritional and medicinal properties. In Ayurveda, Amla is

considered a “Rasayana” herb, meaning a rejuvenating agent capable of promoting longevity, immunity, cognitive health, and tissue regeneration (Krishnaveni & Mirunalini, 2010).

Traditionally, Amla has been used for the treatment of respiratory disorders, digestive disturbances, fever, inflammation, liver dysfunction, diabetes, and cardiovascular diseases. Ayurvedic formulations such as Triphala and Chyawanprash extensively incorporate Amla due to its adaptogenic and immunoprotective effects (Scartezzini & Speroni, 2000). The fruit is particularly rich in vitamin C, tannins, polyphenols, flavonoids, gallic acid, and emblicanins, which collectively contribute to its potent antioxidant activity. Studies have demonstrated that Amla exhibits antiviral, antimicrobial, anti-inflammatory, hepatoprotective, and neuroprotective activities through modulation of oxidative stress and inflammatory pathways (Dasaroju & Gottumukkala, 2014).

Recent scientific investigations have highlighted the potential role of Amla in enhancing innate and adaptive immune responses. Its antioxidant phytochemicals help reduce reactive oxygen species (ROS), suppress inflammatory mediators, and improve cellular defense mechanisms. Such properties may be beneficial in reducing immune dysregulation and oxidative stress associated with SARS-CoV-2 infection (Variya et al., 2016). Moreover, Amla has demonstrated beneficial effects on cognitive performance and neuronal protection through inhibition of lipid peroxidation and enhancement of endogenous antioxidant enzymes.

2.2 *Allium sativum* (Garlic)

Allium sativum L., commonly known as garlic, belongs to the family Amaryllidaceae and is one of the oldest cultivated medicinal plants in human history. Garlic is extensively grown worldwide and has been traditionally used for culinary, medicinal, and spiritual purposes. The bulb of garlic contains numerous sulfur-containing compounds responsible for its characteristic aroma and therapeutic effects (Bayan et al., 2014).

Historically, garlic has been employed for the treatment of respiratory infections, hypertension, digestive disorders, parasitic diseases, and cardiovascular abnormalities. Traditional medical systems have recommended garlic for enhancing resistance against infections and improving circulatory health. Ancient Egyptian, Greek, Chinese, and Ayurvedic texts describe garlic as a powerful natural remedy possessing antimicrobial and rejuvenating properties (Rivlin, 2001).

The pharmacological activities of garlic are primarily attributed to organosulfur compounds such as allicin, alliin, ajoene, diallyl sulfide, and diallyl disulfide. These compounds exhibit broad-spectrum antimicrobial, antiviral, antioxidant, anti-inflammatory, and cardioprotective properties (Borlinghaus et al., 2014). Allicin, produced enzymatically when garlic cloves are crushed, has demonstrated inhibitory effects against bacteria, fungi, and viruses through interference with microbial enzymes and oxidative pathways.

In the context of COVID-19, garlic has gained considerable attention due to its immunomodulatory and antiviral activities. Experimental studies suggest that garlic-derived compounds may interfere with viral entry and replication while also reducing inflammatory cytokines involved in cytokine storm syndrome

(Donma & Donma, 2020). Garlic also exhibits antioxidant properties capable of protecting tissues against oxidative injury induced by excessive immune activation. Furthermore, several studies indicate that garlic may contribute to mental well-being by reducing neuroinflammation, improving cerebral circulation, and modulating neurotransmitter balance.

2.3 Comparative Ethnomedicinal and Pharmacological Relevance

Both *Phyllanthus emblica* and *Allium sativum* possess extensive ethnopharmacological importance and are commonly consumed as nutraceuticals and functional foods. While Amla is especially valued for its antioxidant richness and rejuvenating properties, garlic is predominantly recognized for its antimicrobial and cardiovascular benefits. Nevertheless, both herbs share common pharmacological actions including immunomodulatory, anti-inflammatory, antiviral, antioxidant, and neuroprotective effects.

Their traditional use during infectious outbreaks and respiratory illnesses provides a strong basis for scientific evaluation against COVID-19-related complications. Additionally, the multitarget therapeutic actions of their phytochemicals make them suitable candidates for integrative healthcare approaches aimed at improving immunity and psychological resilience during pandemics.

Table 1. Comparative Botanical and Traditional Medicinal Profile of *Phyllanthus emblica* and *Allium sativum*

Parameter	***Phyllanthus emblica* (Amla)**	***Allium sativum* (Garlic)**
Family	Phyllanthaceae	Amaryllidaceae
Common Names	Amla, Indian Gooseberry	Garlic
Plant Part Used	Fruit	Bulb
Traditional System	Ayurveda, Siddha, Unani	Ayurveda, Traditional Chinese Medicine, Folk medicine
Major Traditional Uses	Rejuvenation, immunity enhancement, digestion, respiratory support	Antimicrobial, cardiovascular support, respiratory infections
Major Bioactive Compounds	Vitamin C, emblicanins, gallic acid, ellagic acid	Allicin, alliin, ajoene, diallyl sulfides
Antioxidant Activity	Very high due to polyphenols and tannins	Strong antioxidant sulfur compounds
Immunomodulatory Effects	Enhances immune defense and antioxidant enzymes	Regulates cytokines and immune activation
Neuroprotective Potential	Reduces oxidative neuronal damage	Improves circulation and reduces neuroinflammation
Relevance in COVID-19	Oxidative stress reduction and immune support	Antiviral and anti-inflammatory activity

3. Phytochemical Composition of *Phyllanthus emblica* and *Allium sativum*

The therapeutic potential of medicinal herbs largely depends on their phytochemical composition and biological activities. *Phyllanthus emblica* and *Allium sativum* contain diverse classes of bioactive constituents including polyphenols, flavonoids, tannins, sulfur-containing compounds, alkaloids, vitamins, and essential oils. These phytochemicals exhibit significant antioxidant, antiviral, anti-inflammatory, immunomodulatory, and neuroprotective properties that may help counteract SARS-CoV-2-induced immune dysfunction and neurological complications (Akhtar et al., 2011; Banerjee & Maulik, 2002). Scientific investigations have demonstrated that many of these compounds regulate oxidative stress pathways, inflammatory mediators, and cellular signaling systems associated with viral infections and neurodegeneration.

3.1 Major Phytochemicals of *Phyllanthus emblica*

The fruit of *Phyllanthus emblica* is recognized as one of the richest natural sources of vitamin C and hydrolysable tannins. Its pharmacological activities are primarily attributed to emblicanins, gallic acid, ellagic acid, quercetin, kaempferol, and various polyphenolic compounds (Gaire & Subedi, 2014). These compounds contribute to strong antioxidant activity capable of scavenging free radicals and protecting biological systems against oxidative damage.

Among the major constituents, emblicanin A and emblicanin B are highly potent antioxidant tannins that enhance endogenous antioxidant defense systems. These compounds increase the activity of catalase, superoxide dismutase, and glutathione peroxidase, thereby reducing oxidative stress-induced cellular injury (Suryanarayana et al., 2007). Since oxidative stress is a critical factor in COVID-19-associated inflammation and tissue damage, emblicanins may help mitigate pathological complications associated with SARS-CoV-2 infection.

Gallic acid and ellagic acid are important phenolic acids present in Amla that exhibit antiviral, anti-inflammatory, antimicrobial, and neuroprotective properties. Experimental studies indicate that gallic acid suppresses inflammatory cytokines such as IL-6 and TNF-α and inhibits lipid peroxidation pathways involved in neuroinflammation (Yang et al., 2014). Quercetin, another important flavonoid in Amla, has attracted considerable attention due to its potential antiviral activity against SARS-CoV-2. Molecular docking studies suggest that quercetin may interact with viral proteases and ACE2 receptors, thereby interfering with viral entry and replication mechanisms (Abian et al., 2020).

Amla also contains flavonoids, pectin, amino acids, and minerals that collectively contribute to immunostimulatory and adaptogenic effects. The synergistic interaction among these phytochemicals enhances the overall therapeutic potential of the plant in infectious and inflammatory disorders.

3.2 Major Phytochemicals of *Allium sativum*

The medicinal value of garlic is primarily attributed to sulfur-containing bioactive compounds generated during enzymatic conversion processes. Intact garlic bulbs contain alliin, a sulfur amino acid derivative, which is converted into allicin by the enzyme alliinase when garlic is crushed or chopped (Amagase,

2006). Allicin is highly unstable but exhibits potent antimicrobial, antiviral, antioxidant, and anti-inflammatory properties.

Allicin has been widely investigated for its antiviral effects against influenza viruses, herpes simplex virus, rhinovirus, and coronaviruses. It acts by inhibiting viral replication enzymes, interfering with thiol-containing proteins, and modulating immune responses (Rouf et al., 2020). Computational studies have suggested that allicin and related organosulfur compounds may bind to SARS-CoV-2 main protease (Mpro) and ACE2 receptors, thereby potentially reducing viral infectivity (Thuy et al., 2020).

Garlic also contains ajoene, diallyl sulfide, diallyl disulfide, diallyl trisulfide, and S-allyl cysteine, which contribute to antioxidant and cardioprotective activities. These compounds reduce reactive oxygen species generation and suppress inflammatory mediators such as NF-κB and cyclooxygenase pathways (Arreola et al., 2015). Because severe COVID-19 is characterized by excessive inflammatory responses and oxidative injury, garlic phytochemicals may help attenuate cytokine-mediated tissue damage.

In addition to antiviral and immunomodulatory activities, garlic-derived compounds possess neuroprotective potential. S-allyl cysteine has been shown to improve neuronal survival, inhibit oxidative neuronal damage, and reduce neuroinflammation in experimental models (Chauhan, 2006). Such properties may be beneficial in preventing cognitive impairment and neurological complications associated with post-COVID syndrome.

3.3 Pharmacological Significance of Phytochemicals in COVID-19 and Mental Health

The phytochemicals present in *Phyllanthus emblica* and *Allium sativum* exert multitarget biological effects relevant to COVID-19 management. Polyphenols and flavonoids act as powerful antioxidants capable of neutralizing reactive oxygen species generated during viral infections. Organosulfur compounds and tannins regulate inflammatory signaling pathways and suppress cytokine overproduction associated with severe COVID-19 (Mrityunjaya et al., 2020).

Several phytochemicals from these plants also influence neurochemical pathways involved in mood regulation and cognitive function. Antioxidant compounds help preserve neuronal integrity, enhance mitochondrial function, and reduce neuroinflammation linked to anxiety, depression, and cognitive dysfunction. Furthermore, immunomodulatory effects of these herbs may indirectly improve mental well-being by reducing systemic inflammation and stress-related immune disturbances.

The synergistic action of multiple phytochemicals makes these herbs promising nutraceutical candidates for integrative approaches targeting immune resilience, viral inhibition, and neurological protection during and after COVID-19 infection.

Table 2. Major Phytochemicals of *Phyllanthus emblica* and *Allium sativum* and Their Pharmacological Activities

Plant	Major Phytochemicals	Chemical Class	Major Pharmacological	Relevance to COVID-19

			Activities	
Phyllanthus emblica	Emblicanin A & B	Hydrolysable tannins	Antioxidant, anti-aging	Reduces oxidative stress and tissue injury
Phyllanthus emblica	Gallic acid	Phenolic acid	Anti-inflammatory, antiviral	Suppresses cytokines and inflammation
Phyllanthus emblica	Ellagic acid	Polyphenol	Antioxidant, neuroprotective	Protects neurons and immune cells
Phyllanthus emblica	Quercetin	Flavonoid	Antiviral, immunomodulatory	Potential SARS-CoV-2 protease inhibition
Allium sativum	Allicin	Organosulfur compound	Antiviral, antimicrobial	May inhibit viral replication
Allium sativum	Ajoene	Sulfur compound	Anti-inflammatory, antioxidant	Reduces inflammatory signaling
Allium sativum	Diallyl sulfides	Sulfur compounds	Cardioprotective, antioxidant	Protects against oxidative injury
Allium sativum	S-allyl cysteine	Water-soluble sulfur compound	Neuroprotective, anti-inflammatory	Reduces neuroinflammation
Both herbs	Flavonoids & polyphenols	Polyphenolic compounds	Antioxidant, immunomodulatory	Enhances immune defense and neuronal protection

4. Immunomodulatory Mechanisms of *Phyllanthus emblica* and *Allium sativum* in COVID-19

The pathogenesis of COVID-19 is closely associated with immune dysregulation, hyperinflammation, oxidative stress, and cytokine storm syndrome. Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) infection triggers abnormal activation of innate and adaptive immune responses, resulting in excessive production of inflammatory mediators that contribute to pulmonary injury, endothelial dysfunction, multiorgan damage, and neurological complications (Del Valle et al., 2020). Consequently, therapeutic strategies capable of modulating immune responses without causing immunosuppression are of significant clinical importance. Nutraceutical herbs such as *Phyllanthus emblica* and *Allium sativum* possess potent immunomodulatory phytochemicals that may help restore immune balance and reduce inflammatory damage during COVID-19.

4.1 Immune Dysregulation and Cytokine Storm in COVID-19

SARS-CoV-2 infection activates host immune cells including macrophages, neutrophils, dendritic cells, and T lymphocytes through recognition of viral antigens by pattern recognition receptors (PRRs). Activation of these pathways stimulates the release of pro-inflammatory cytokines such as IL-6, IL-1β,

TNF-α, interferon-γ, and chemokines, which collectively contribute to cytokine storm syndrome (Tang et al., 2020). Excessive cytokine production causes vascular permeability, oxidative stress, thrombosis, and tissue injury in severe COVID-19 patients.

Persistent inflammation also disrupts blood–brain barrier integrity and promotes neuroinflammation, which is associated with cognitive dysfunction, anxiety, depression, and post-COVID neurological sequelae (Heneka et al., 2020). Oxidative stress generated during hyperinflammatory responses further aggravates mitochondrial dysfunction and neuronal injury. Therefore, herbs possessing anti-inflammatory, antioxidant, and immunoregulatory activities may provide supportive therapeutic benefits.

4.2 Immunomodulatory Actions of *Phyllanthus emblica*

Phyllanthus emblica exerts significant immunomodulatory effects through its polyphenols, tannins, flavonoids, and vitamin C-rich phytochemical profile. Experimental studies have shown that Amla enhances both humoral and cell-mediated immune responses while simultaneously regulating inflammatory pathways (Ngamukote et al., 2011). The antioxidant properties of emblicanins and gallic acid help neutralize reactive oxygen species generated during viral infections, thereby reducing oxidative damage to immune cells.

Vitamin C present in Amla plays a crucial role in supporting leukocyte function, phagocytosis, interferon production, and antibody responses. It also contributes to regeneration of endogenous antioxidants such as glutathione and vitamin E, which protect immune cells from oxidative injury (Carr & Maggini, 2017). Since severe COVID-19 is associated with depletion of antioxidant defenses, Amla supplementation may help maintain immune homeostasis and reduce inflammatory complications.

Amla polyphenols also inhibit activation of nuclear factor-kappa B (NF-κB), a major transcription factor responsible for cytokine production and inflammatory signaling (Variya et al., 2016). Suppression of NF-κB pathways may reduce levels of IL-6 and TNF-α implicated in cytokine storm syndrome. Furthermore, studies suggest that Amla improves macrophage and natural killer cell activity, thereby enhancing innate antiviral defenses.

In addition to immunological benefits, antioxidant phytochemicals in Amla protect neuronal tissues against oxidative stress-induced neurodegeneration. Such effects may contribute to improved cognitive resilience and reduced neuroinflammation during post-COVID recovery.

4.3 Immunomodulatory Actions of *Allium sativum*

Garlic possesses broad-spectrum immunomodulatory activity primarily mediated by sulfur-containing compounds including allicin, ajoene, diallyl sulfides, and S-allyl cysteine. These compounds regulate cytokine production, immune cell activation, and inflammatory signaling pathways (Arreola et al., 2015). Garlic has been reported to stimulate macrophage phagocytosis, lymphocyte proliferation, and natural killer cell function, thereby strengthening host defense mechanisms against microbial infections.

Allicin exhibits potent anti-inflammatory activity through inhibition of NF-κB signaling and suppression of pro-inflammatory cytokines such as IL-1β, IL-6, and TNF-α (Rahman, 2020). Garlic-derived compounds also reduce oxidative stress by increasing antioxidant enzyme activity and limiting lipid peroxidation. These properties are particularly relevant in COVID-19 because oxidative injury and uncontrolled inflammation are major contributors to disease severity.

Experimental studies suggest that garlic compounds may regulate T-helper cell balance and improve adaptive immune responses. Garlic supplementation has also been associated with reduced frequency and severity of respiratory infections due to enhancement of immune surveillance mechanisms (Percival, 2016). Additionally, aged garlic extract has demonstrated anti-inflammatory and neuroprotective activities capable of attenuating neuroimmune dysfunction and stress-related neuronal injury.

Several computational studies have indicated that organosulfur compounds from garlic may interact with SARS-CoV-2 proteases and ACE2 receptors, suggesting possible antiviral effects alongside immune modulation (Mohammed et al., 2021). Such multitarget actions make garlic a promising adjunctive nutraceutical during viral infections.

4.4 Synergistic Immunological and Neuroprotective Effects

The combined use of *Phyllanthus emblica* and *Allium sativum* may provide synergistic therapeutic benefits because both herbs target multiple inflammatory and oxidative pathways simultaneously. While Amla primarily enhances antioxidant defenses and immune resilience through polyphenols and vitamin C, garlic contributes strong anti-inflammatory and antimicrobial actions through sulfur compounds.

Their combined phytochemicals may help regulate cytokine release, improve antioxidant status, reduce oxidative neuronal injury, and support immune homeostasis during COVID-19. Moreover, the neuroprotective effects of these herbs may reduce stress-induced neuroinflammation and support mental well-being in post-COVID patients experiencing anxiety, fatigue, and cognitive impairment.

Table 3. Immunomodulatory Mechanisms of *Phyllanthus emblica* and *Allium sativum* Relevant to COVID-19

Herb	Major Active Compounds	Immunological Actions	Anti-inflammatory Effects	Neuroprotective Relevance
Phyllanthus emblica	Vitamin C, emblicanins, gallic acid	Enhances leukocyte activity and innate immunity	Suppresses NF-κB and cytokine production	Reduces oxidative neuronal injury
Phyllanthus emblica	Polyphenols and flavonoids	Improves antioxidant defense mechanisms	Reduces ROS-mediated inflammation	Protects neurons from oxidative stress
Allium sativum	Allicin	Stimulates	Inhibits IL-6,	Reduces

		macrophages and NK cells	TNF-α, and NF-κB	neuroinflammation
Allium sativum	Ajoene and diallyl sulfides	Enhances adaptive immune responses	Limits oxidative stress and lipid peroxidation	Supports neuronal survival
Combined effect	Polyphenols + sulfur compounds	Immune balancing and antiviral support	Cytokine storm attenuation	Cognitive and mental health support

5. Antiviral Potential of *Phyllanthus emblica* and *Allium sativum* Against SARS-CoV-2

The rapid spread of SARS-CoV-2 and the emergence of viral variants have intensified the search for natural antiviral agents capable of targeting different stages of the viral life cycle. Medicinal plants rich in polyphenols, flavonoids, sulfur compounds, and tannins have demonstrated promising antiviral activities against several respiratory viruses, including coronaviruses (Mani et al., 2020). Among nutraceutical herbs, *Phyllanthus emblica* and *Allium sativum* have gained significant scientific attention because of their ability to interfere with viral entry, replication, inflammatory signaling, and oxidative stress pathways. Their multitarget phytochemicals may therefore serve as supportive therapeutic agents in COVID-19 management.

5.1 SARS-CoV-2 Structure and Therapeutic Targets

SARS-CoV-2 is an enveloped positive-sense single-stranded RNA virus belonging to the family Coronaviridae. The viral genome encodes structural proteins including spike (S), membrane (M), envelope (E), and nucleocapsid (N) proteins, along with non-structural proteins involved in viral replication (V'kovski et al., 2021). The spike glycoprotein mediates viral attachment to angiotensin-converting enzyme 2 (ACE2) receptors on host cells, followed by membrane fusion facilitated by transmembrane serine protease 2 (TMPRSS2) (Hoffmann et al., 2020).

Several viral components are considered important therapeutic targets, including the main protease (Mpro/3CLpro), papain-like protease (PLpro), RNA-dependent RNA polymerase (RdRp), and spike protein. Inhibition of these proteins may suppress viral replication and reduce infectivity (Anand et al., 2003). Natural phytochemicals capable of interacting with these targets are therefore being actively investigated as complementary antiviral agents.

5.2 Antiviral Activities of *Phyllanthus emblica*

The antiviral activity of *Phyllanthus emblica* is mainly attributed to its high concentration of polyphenols, flavonoids, tannins, and vitamin C. Studies have demonstrated that these phytochemicals possess inhibitory effects against influenza virus, hepatitis virus, herpes simplex virus, and other RNA viruses (Saini et al., 2022). The antioxidant and immunomodulatory actions of Amla further contribute to antiviral defense by strengthening host immunity and reducing oxidative stress-induced tissue injury.

Quercetin, one of the major flavonoids present in Amla, has shown promising activity against SARS-CoV-2 in computational and experimental studies. Molecular docking analyses suggest that quercetin can bind to viral main protease and spike protein, thereby interfering with viral entry and replication (Agrawal et al., 2020). Quercetin also acts as a zinc ionophore, facilitating intracellular zinc transport, which may inhibit RNA-dependent RNA polymerase activity required for viral replication.

Gallic acid and ellagic acid present in Amla exhibit anti-inflammatory and antiviral effects through modulation of oxidative stress pathways and inhibition of viral enzyme activity. Tannins from Amla may also disrupt viral envelope integrity and inhibit attachment of viruses to host cells. Additionally, vitamin C contributes to antiviral immunity by promoting interferon synthesis, leukocyte function, and antioxidant defense mechanisms (Hemilä & Chalker, 2013).

Experimental evidence indicates that Amla extracts may reduce inflammatory cytokines and oxidative injury associated with severe COVID-19. Such combined antiviral and immunomodulatory properties make *Phyllanthus emblica* a promising nutraceutical herb for supportive therapy during viral infections.

5.3 Antiviral Activities of *Allium sativum*

Garlic has been extensively investigated for its broad-spectrum antimicrobial and antiviral properties. Organosulfur compounds such as allicin, alliin, ajoene, and diallyl sulfides are primarily responsible for its antiviral activity (Rouf et al., 2020). These compounds exert antiviral effects by interfering with viral entry, inhibiting viral replication enzymes, modulating immune responses, and reducing oxidative stress.

Allicin is considered the principal antiviral constituent of garlic. It reacts with thiol-containing proteins and enzymes essential for viral survival and replication. Studies have reported that garlic extracts exhibit inhibitory effects against influenza virus, rhinovirus, herpes simplex virus, cytomegalovirus, and infectious bronchitis virus (Mehrbod et al., 2009). During the COVID-19 pandemic, computational studies suggested that allicin and related sulfur compounds may bind to SARS-CoV-2 main protease and ACE2 receptors, thereby reducing viral infectivity (Pandey et al., 2021).

Ajoene and diallyl sulfides also demonstrate anti-inflammatory and antioxidant activities capable of limiting cytokine storm-associated tissue damage. Garlic compounds may inhibit NF-κB activation and reduce production of IL-6 and TNF-α, which are major mediators of COVID-19 severity (Donma & Donma, 2020). Additionally, garlic enhances natural killer cell activity and macrophage responses, thereby strengthening innate antiviral immunity.

Garlic-derived phytochemicals have also shown protective effects against endothelial dysfunction and thrombosis, complications commonly observed in severe COVID-19 patients. Such multitarget therapeutic actions highlight the potential utility of garlic as an adjunctive herbal intervention during SARS-CoV-2 infection.

5.4 Synergistic Antiviral and Protective Effects

The combined use of *Phyllanthus emblica* and *Allium sativum* may provide synergistic antiviral benefits because their phytochemicals target multiple viral and host pathways simultaneously. Polyphenols from Amla enhance antioxidant defenses and immune resilience, whereas sulfur compounds from garlic directly interfere with viral proteins and inflammatory pathways.

Both herbs may collectively reduce viral replication, suppress hyperinflammation, protect against oxidative tissue injury, and improve immune competence. Furthermore, their neuroprotective and cardioprotective properties may help reduce long-term complications associated with post-COVID syndrome.

Table 4. Antiviral Mechanisms of *Phyllanthus emblica* and *Allium sativum* Against SARS-CoV-2

Herb	Major Phytochemicals	Proposed Antiviral Targets	Mechanisms of Action	Additional Protective Effects
Phyllanthus emblica	Quercetin	Spike protein, Mpro	Inhibits viral entry and protease activity	Antioxidant and anti-inflammatory
Phyllanthus emblica	Gallic acid, tannins	Viral envelope and enzymes	Reduces viral attachment and oxidative stress	Immune enhancement
Phyllanthus emblica	Vitamin C	Host immune system	Enhances interferon production and leukocyte function	Reduces oxidative injury
Allium sativum	Allicin	Mpro, ACE2 receptor	Inhibits viral replication enzymes	Anti-inflammatory activity
Allium sativum	Ajoene and diallyl sulfides	NF-κB and inflammatory pathways	Suppresses cytokine storm and oxidative stress	Endothelial protection
Combined herbs	Polyphenols + sulfur compounds	Multiple viral and host targets	Synergistic antiviral and immunomodulatory effects	Neuroprotective support

6. Neuroprotective and Mental Health Supportive Effects of *Phyllanthus emblica* and *Allium sativum*

The COVID-19 pandemic has significantly affected neurological and psychological health worldwide. Beyond respiratory complications, SARS-CoV-2 infection is associated with neuroinflammation, oxidative stress, cognitive dysfunction, anxiety, depression, fatigue, insomnia, and post-traumatic stress disorders (Taquet et al., 2021). Persistent neurological symptoms collectively described as “long COVID”

or “post-COVID syndrome” have emerged as major public health concerns. Increasing evidence suggests that medicinal plants possessing antioxidant, anti-inflammatory, adaptogenic, and neuroprotective properties may help alleviate these complications (Siddiqui et al., 2022). Among nutraceutical herbs, *Phyllanthus emblica* and *Allium sativum* demonstrate significant potential in supporting cognitive health and psychological well-being during and after COVID-19 infection.

6.1 Neurological and Psychological Impact of COVID-19

SARS-CoV-2 affects the nervous system through multiple mechanisms including direct neuroinvasion, cytokine-mediated neuroinflammation, endothelial dysfunction, hypoxia, and oxidative stress (Boldrini et al., 2021). Viral infection and systemic inflammation disrupt blood–brain barrier integrity, activate microglial cells, and induce excessive production of inflammatory cytokines such as IL-6 and TNF-α within neural tissues. These processes contribute to neuronal damage and neurotransmitter imbalance associated with anxiety, depression, and cognitive impairment.

Clinical studies have reported neurological manifestations such as headache, dizziness, anosmia, encephalopathy, stroke, memory impairment, confusion, sleep disturbances, and mood disorders in COVID-19 patients (Mao et al., 2020). Post-COVID cognitive dysfunction or “brain fog” is characterized by poor concentration, mental fatigue, reduced executive function, and impaired memory (Becker et al., 2021). Chronic inflammation and oxidative stress are considered major contributors to these neurological complications.

Furthermore, pandemic-related stressors including social isolation, fear of infection, financial insecurity, and grief have substantially increased the prevalence of depression and anxiety disorders worldwide (Vindegaard & Benros, 2020). Therefore, nutraceutical herbs capable of reducing neuroinflammation and improving stress resilience may provide supportive benefits in mental health management.

6.2 Neuroprotective Effects of *Phyllanthus emblica*

Phyllanthus emblica possesses strong neuroprotective activity due to its abundance of vitamin C, flavonoids, tannins, and polyphenolic antioxidants. Oxidative stress is one of the major mechanisms underlying neurodegeneration and cognitive dysfunction during viral infections. Antioxidants present in Amla neutralize reactive oxygen species and protect neuronal cells from oxidative injury (Bhattacharya et al., 2000).

Experimental studies have demonstrated that Amla extracts improve memory, learning ability, and cognitive performance through enhancement of cholinergic neurotransmission and antioxidant enzyme activity. Polyphenols such as gallic acid and ellagic acid reduce lipid peroxidation and inhibit neuroinflammatory pathways associated with neuronal degeneration (Sabu & Kuttan, 2002). Additionally, Amla has shown adaptogenic and anti-stress properties capable of improving resilience against psychological stress and fatigue.

Vitamin C present in Amla also plays an important role in neurotransmitter synthesis, neuronal maturation, and regulation of hypothalamic–pituitary–adrenal (HPA) axis responses. Adequate

antioxidant support may therefore help reduce neuroinflammation and cognitive dysfunction observed in post-COVID patients.

Studies further suggest that Amla may improve cerebral blood flow and mitochondrial function, thereby supporting neuronal survival during inflammatory conditions. Such multitarget neuroprotective effects indicate its therapeutic relevance in managing long COVID-related cognitive complications.

6.3 Neuroprotective Effects of *Allium sativum*

Garlic exhibits broad neuroprotective activity through its sulfur-containing compounds including allicin, S-allyl cysteine, ajoene, and diallyl sulfides. These compounds possess antioxidant, anti-inflammatory, antiapoptotic, and neuromodulatory properties that may help protect the brain from oxidative and inflammatory injury (Chauhan, 2006).

S-allyl cysteine has demonstrated beneficial effects in experimental models of neurodegeneration by reducing oxidative stress, suppressing inflammatory cytokines, and improving neuronal survival. Garlic compounds inhibit activation of microglia and NF-κB pathways, thereby limiting neuroinflammation and neuronal apoptosis (Ray et al., 2011). Since neuroinflammation plays a crucial role in post-COVID cognitive impairment, these mechanisms are particularly significant.

Garlic has also shown antidepressant and anxiolytic potential through modulation of serotonin, dopamine, and gamma-aminobutyric acid (GABA) neurotransmitter systems. Experimental studies indicate that garlic extracts reduce stress-induced behavioral changes and improve memory and learning functions (Mikaili et al., 2013). Additionally, antioxidant sulfur compounds improve cerebral circulation and mitochondrial function, thereby supporting neuronal energy metabolism.

The anti-inflammatory actions of garlic may also reduce systemic cytokine-mediated neural injury associated with severe COVID-19. Such combined antioxidant and neuromodulatory properties make garlic a promising nutraceutical herb for mental health support during recovery from viral infections.

6.4 Synergistic Mental Health Supportive Potential

The combined use of *Phyllanthus emblica* and *Allium sativum* may provide synergistic benefits in supporting mental and neurological health during COVID-19 recovery. Amla contributes strong antioxidant and adaptogenic actions, whereas garlic provides anti-inflammatory and neuromodulatory effects.

Together, these herbs may help reduce oxidative neuronal damage, suppress neuroinflammation, improve neurotransmitter balance, and enhance stress resilience. Their combined phytochemicals may therefore support cognitive recovery, emotional stability, and overall mental well-being in individuals experiencing post-COVID neurological complications.