

Neuroprotective phytochemicals of Lamiaceae: a holistic approach

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Abstract: Neurodegenerative disorders (NDDs) are progressive conditions characterized by irreversible neuronal loss, primarily driven by oxidative stress, neuroinflammation, mitochondrial dysfunction and protein aggregation. With increasing life expectancy, the global burden of these disorders continues to rise, while current therapeutic options remain largely symptomatic and ineffective in halting disease progression. In this context, medicinal plants, particularly members of the Lamiaceae family, have gained attention due to their diverse bioactive compounds and multi-target mechanisms of action. Rich in phenolics and volatile oils, these plants exhibit significant neuroprotective potential through antioxidant, anti-inflammatory, anti-amyloidogenic and neurotransmitter-modulating activities. Additionally, their influence on mitochondrial stability and the gut-brain axis further strengthens their therapeutic relevance. This review focuses on the potential of Lamiaceae species for developing safer lead compounds and more effective strategies in the management of neurodegenerative disorders.

Keywords: Lamiaceae, mint family, neurological disorder, novel therapeutics, pharmacology

Introduction

Nerve cells are among the longest cells in the human body and are highly specialized in structure and function (Purves et al., 2001). While their primary role is to transmit electrical and chemical signals across the body, they are also actively involved in metabolism, intracellular transport, maintenance of homeostasis and various secretory functions (Purves et al., 2001). A large proportion of neurons are formed during early development and childhood, after which their numbers gradually decline with age, a process referred to as neurodegeneration (Lamprey et al., 2022). Although this is a natural and progressive phenomenon, age remains the most significant contributing factor to neurodegenerative disorders (NDDs). However, an individual's genetic makeup and environmental conditions can further accelerate neuronal loss, increasing the risk of early-stage neurodegeneration. The early and rapid loss of neuronal integrity eventually leads to debilitating conditions such as Alzheimer's, Parkinson's and Huntington's diseases (Lim et al., 2025). At the same time, the increasing global ageing population has contributed to a steady rise in the prevalence of these disorders, creating a growing burden on healthcare systems and affecting overall quality of life (Xi et al., 2025). In the present scenario, there is still no permanent cure for NDDs and most of the available treatments are largely symptomatic, offering limited relief without effectively slowing or reversing disease progression. This has led to a continued search for new treatment strategies, safer alternatives and more effective therapeutic approaches. In this backdrop, medicinal plants stand out due to their diverse chemical composition and unique molecular mechanisms. Plants belonging to the Lamiaceae family, in particular, have gained attention for their neuroprotective potential. The wide range of bioactive compounds present in these plants contributes significantly to their therapeutic value. They function as potent antioxidants, anti-inflammatory agents and inhibitors of protein aggregation (Pineda-Ramírez et al., 2020). Their ability to combat oxidative stress, reduce neuronal apoptosis caused by inflammation, modulate cell-specific signaling pathways to activate neurotrophic factors and support gut microbiota, thereby improving the gut-brain axis, makes them a viable option when exploring better alternatives for managing neurodegenerative disorders.

Methodology

The present study is based on an extensive survey of published literature related to the family Lamiaceae. Scientific databases, including Google Scholar, Scopus, PubMed and Web of Science, were consulted to retrieve peer-reviewed research articles, review papers, ethnobotanical surveys and pharmacological studies. Keywords including "Lamiaceae", "neurodegenerative disorders", "neuroprotective bioactives", "secondary metabolites", "oxidative stress", "anti-inflammatory activity", "mint family" and "neurochemical properties" were used to review relevant publications. Additionally, regional floras, books and reports documenting traditional knowledge and distribution patterns were examined. Only studies containing verifiable scientific or ethnomedicinal data were considered. Information obtained was critically analyzed and systematically organized under thematic sections to ensure clarity and coherence (Kumar, 2025; Sahu et al., 2026).

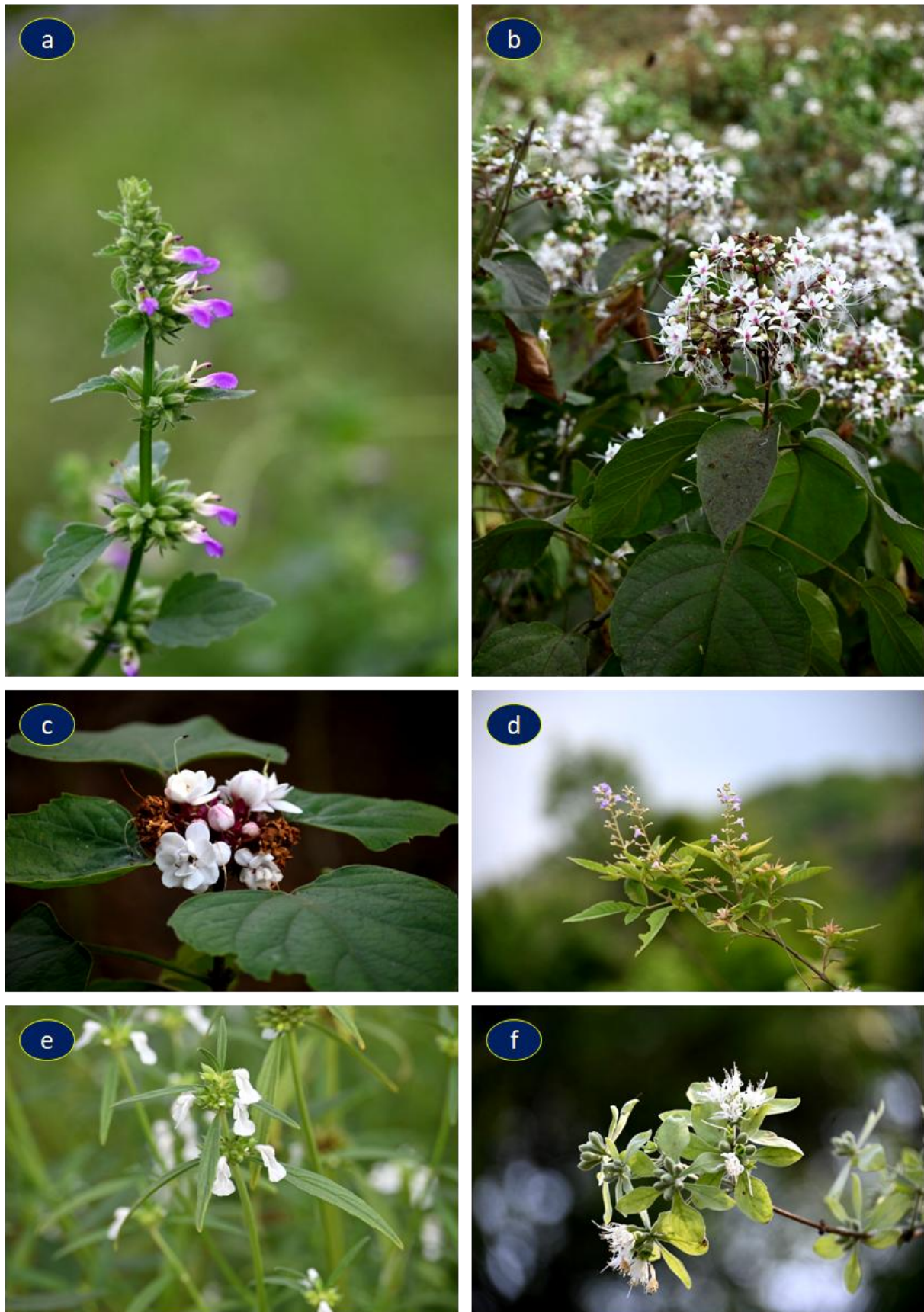


Plate 1: Members of family Lamiaceae; (a) *Anisomeles indica*, (b) *Clerodendrum infortunatum*, (c) *Clerodendrum chinense*, (d) *Vitex negundo*, (e) *Leucas aspera* and (f) *Symphorema involucreatum*

Neuroprotective activity

Plants of the mint family possess a well-established reputation in regulating the nervous system. Their bioactive profile, rich in volatile oils and phenolic compounds, has neuroprotective, sedative and antioxidant effects. They have long been recognized as “nervines,” supporting and calming the neural circuit (Table 1). For instance, rosemary (*Salvia rosmarinus*) and sage (*Salvia officinalis*) are traditionally associated with improved memory, focus and overall cognitive performance (Lopresti, 2017; Uritu et al., 2018). Species such as skullcap (*Scutellaria lateriflora*) and holy basil (*Ocimum sanctum*) further demonstrate restorative and stress-resilience properties (Yeong and Chin, 2021). Lavender (*Lavandula angustifolia*) is widely used to reduce anxiety, while lemon balm (*Melissa officinalis*) promotes sleep and relieves nervous tension (Mathews et al., 2024; Manzoor et al., 2025). Fast forward to today’s biomedical research and their relevance in neurodegenerative disorders lies in their multi-target actions. The presence of a broad spectrum of bioactive compounds reviewed in Table 1 contributes to their strong antioxidant capacity, which helps neutralize reactive oxygen species (ROS), protecting neurons from oxidative damage, while anti-inflammatory effects suppress microglial activation and cytokine release. Several compounds also inhibit protein aggregation, interfering with β -amyloid and α -synuclein accumulation (Nazzaro et al., 2025). Additionally, they enhance cognitive function, modulate neurotransmitter systems, particularly via cholinesterase inhibition and support mitochondrial stability, thereby reducing neuronal apoptosis. Their emerging role in modulating the gut-brain axis further adds to their therapeutic significance. Collectively, these properties position Lamiaceae plants (Plate 1) as promising candidates for developing strategies aimed at managing and potentially slowing the progression of neurodegenerative disorders.

Table 1: Neuroprotective bioactive potential of selected Lamiaceae species

Plant species	Common name	Key compounds	Biological action	Source(s)
<i>Anisomeles indica</i> (L.) Kuntze (Plate 1a)	Indian catmint	Ovatodiolide	Attenuates microglial-mediated neuroinflammation	Hu et al., (2022)
<i>Clerodendrum chinense</i> (Osbeck) Mabb. (Plate 1c)	Chinese glory bower	Verbascoside	Induces apoptosis and necrosis; enhances ROS generation	Chittasupho et al., (2023); Chittasupho et al., (2025)
<i>Clerodendrum infortunatum</i> L. (Plate 1b)	Hill glory bower	Stigmasterol, Octadecadienoic acid, Quercetin, Hispidulin-7-O-glucuronide, Reserpine	Anti-inflammatory, antidepressant, inhibits multistage carcinogenesis and alleviates neuropathic pain	Hossain et al., (2025)
<i>Gmelina arborea</i> Roxb. ex Sm.	White teak	Premnazole	Anti-inflammatory activity	Anjaneyulu et al., (1972)
		Tyrosol, 3,4,5-trimethoxyphenol	Mitigates neuronal oxidative stress	Sharma et al., (2001); Arora and Tamrakar, (2017)
<i>Lavandula angustifolia</i> subsp. <i>angustifolia</i>	English lavender	Linalool, Linalyl acetate	Neuroprotective and antioxidant activity (\downarrow ROS, \uparrow cell viability)	Chen et al., (2023)

(Flower)				
<i>Leucas aspera</i> (Willd.) Link (Plate 1e)	White dead nettle	Oleanolic acid	Inhibits microglial activation and NLRP3 inflammasome signaling	Prajapati et al., (2010); Sapkota and Choi, (2021)
<i>Leucas cephalotes</i> (Roth) Spreng.	Head leucas	β -sitosterol, Stigmasterol	Anti-inflammatory activity	Patel et al., (2015)
<i>Melissa officinalis</i> L.	Lemon balm	Polyphenols, Flavonoids	Antioxidant and anti-inflammatory properties	Piccirillo et al., (2025)
<i>Mentha x piperita</i> L. (Leaf)	Peppermint	Monoterpenes (menthol-type)	Mild antioxidant activity; non-toxic with limited neuroprotection	Chen et al., (2023)
<i>Ocimum tenuiflorum</i> L.	Holy basil	Eugenol	Anti-amyloidogenic, antioxidant, mitochondrial protection, cognitive enhancement	Vasincu et al., (2025)
<i>Origanum vulgare</i> L.	Oregano	Terpeneols	Neuritogenic (increase neurite outgrowth), antioxidant	Chen et al., (2023)
		Carvacrol, Thymol	Dual cholinesterase inhibition (AChE & BuChE); neuroprotective	
<i>Orthosiphon stamineus</i> Benth.	Java tea	Rosmarinic acid	Reduces oxidative stress, apoptosis and inflammation	Li et al., (2021)
<i>Perilla frutescens</i> (L.) Britton	Perilla	Polysaccharides (PEPF)	Neuroprotective; antioxidant (reduce ROS, \uparrow SOD, \downarrow lipid peroxidation)	Byun et al., (2018)
			Anti-apoptotic (\downarrow Bax, cytochrome c, caspases; \uparrow Bcl-2, PARP)	
<i>Pogostemoncablin</i> (Blanco) Benth.	Patchouli	Pachypodol, Patchouli alcohol	Antioxidant, anti-inflammatory and antidepressant activities	Wu et al., (2025)
<i>Prunella vulgaris</i> L.	Self-heal / Heal-all	Vulgarisin-type diterpenoids	Suppresses apoptosis; improves mitochondrial function (\downarrow cytochrome c release, \downarrow ROS, stabilizes membrane potential)	Ma et al., (2022)
<i>Salvia officinalis</i> L.	Garden sage	Monoterpenes, Polyphenols	Selective BuChE inhibition; antioxidant	Chen et al., (2023)
<i>Salvia rosmarinus</i> Spenn.	Rosemary	1,8-Cineole	Antioxidant; moderate cytotoxicity at higher doses	
		Mixed terpenes	Non-toxic; weak neuroprotective	

			activity	
<i>Sideritis scardica</i> Griseb.	Greek mountain tea	Terpenoids, Flavonoids, Phenolic acids, Phenylethanoid glycosides	Antioxidant and neuroprotective	Segneanu et al., (2024)
		Iridoids	Neuroprotective, anti- inflammatory and hepatoprotective	
		Amino acids (Lysine, Serine)	Neuroprotective and cytoprotective	Segneanu et al., (2024)
<i>Vitex negundo</i> L. (Plate 1d)	Chinese chaste tree	Vitexin, Isovitexin	Anti-inflammatory; protects dopaminergic neurons and reduces neurotoxicity	Phate and Patil, (2026)

Research gaps

Despite extensive use in traditional medicine and promising pharmacological evidence, the clinical validation of Lamiaceae-derived phytochemicals in neurodegenerative disorders remains limited. There is a lack of standardized studies focusing on bioavailability, dose optimization, long-term safety and precise molecular mechanisms in human models.

Future aspects

Future research should focus on isolating and characterizing key bioactive compounds from Lamiaceae species, followed by well-designed clinical trials to validate their efficacy in NDDs. Integrating phytochemistry with molecular biology and systems pharmacology can help uncover multi-target mechanisms and synergistic effects. Additionally, exploring their role in modulating the gut-brain axis and developing novel delivery systems (e.g., nano formulations) may enhance their therapeutic potential, paving the way for safer, plant-based interventions in neurodegenerative disease management.

Conclusion

The nervine, anxiolytic, cognitive-enhancing and neuroprotective properties of Lamiaceae members hold direct and growing relevance in the context of treating neurodegenerative disorders (NDDs). The conditions of these disorders are characterized by progressive neuronal loss, driven by complex and overlapping mechanisms such as oxidative stress, chronic neuroinflammation, mitochondrial dysfunction, protein misfolding and impaired neurotransmission. Bioactive compounds from Lamiaceae species are specifically valuable because they target multiple aspects of this pathology simultaneously, compared to conventional single-target drugs. This can significantly contribute to the current symptomatic treatment procedures, giving them an integrated and holistic approach.

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