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Green Synthesized Nanoparticles from Medicinal Plants for Neuroprotective Applications

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ABSTRACT

Several degenerative disorders, such as MS, PD, Alzheimer's, and stroke-related neuronal degeneration, have few effective treatments. Common issues with traditional neurotherapeutics include low bioavailability, systemic toxicity, and limited blood-brain barrier penetration. Green synthesised nanoparticles derived from medicinal plants have emerged as promising neuroprotective agents due to their enhanced biocompatibility, therapeutic potential, and eco-friendliness. Medicinal plant phytochemicals not only serve as natural reducing and stabilising agents in nanoparticle formation, but they also have neuroprotective, antioxidant, and anti-inflammatory properties. This research covers a wide range of topics, including eco-friendly synthesis methods, phytochemicals, medicinal plants, and recent advances in neuroprotective nanoparticle research. As a safer and more effective way to treat neurodegenerative diseases, phytogenic nanoparticles have the ability to reduce oxidative stress, neuroinflammation, and neuronal damage, as highlighted in the review.

keywords: Green synthesis, medicinal plants, nanoparticles, neuroprotection, neurodegenerative diseases.

INTRODUCTION

Among the world's geriatric populations in particular, neurological diseases are a leading cause of death and disability. In these diseases, the central nervous system progressively degenerates and loses structure and function, leading to severe physical, cognitive, and behavioural impairments. Diseases such as Alzheimer's, Parkinson's, Huntington's, MS, and stroke-related neuronal damage not only impose a significant financial and social burden on healthcare systems, but also significantly diminish the quality of life for millions of individuals. The increasing prevalence of neurological disorders caused by ageing, environmental stress, genetic predisposition, and lifestyle-related variables highlights the urgent need to create safer and more effective treatment options [1].

Traditional approaches to neurotherapy mostly target symptoms rather than aims at complete neuronal regeneration or disease transformation. The limited blood-brain barrier (BBB) penetration, rapid degradation, systemic toxicity, and poor bioavailability of many commercially available drugs make it difficult for them to be delivered to the brain effectively. A highly selective physiological barrier, the blood-brain barrier (BBB) protects neurones in the brain from potentially harmful chemicals while also preventing therapeutic medications from penetrating certain areas of the brain. This means that many neuroprotective drugs have poor

therapeutic efficacy and more unwanted side effects because they do not reach therapeutic concentrations in the CNS. These limitations have stimulated research into innovative drug delivery systems with the potential to improve therapeutic outcomes and targeting efficiency.

The biomedical and pharmaceutical fields are showing great promise in nanotechnology as a potential tool to enhance therapeutic efficacy, targeted delivery, bioavailability, and drug stability. Due to their unique physicochemical properties, such as their nanoscale size, large surface area, enhanced permeability, and improved cellular interaction, nanoparticles are promising prospects for neurological applications. In particular, nanoparticle-based drug delivery systems have demonstrated potential in crossing the blood-brain barrier and delivering therapeutic medications directly to injured brain regions. Numerous nanoparticle kinds, including those of silver, gold, selenium, zinc oxide, and iron oxide, have been investigated for their antioxidant, anti-inflammatory, and neuroprotective capabilities.

Green synthesis, one of various approaches to nanoparticle production, has recently attracted a lot of attention as a viable, cost-effective, and environmentally friendly alternative to conventional physical and chemical synthesis processes. Biological resources like enzymes, microorganisms, medicinal plant extracts, and natural biomolecules are utilised in green synthesis to create nanoparticles without the usage of harmful chemicals. Organic reducing, stabilising, and capping agents utilised in the production of nanoparticles include bioactive phytochemicals derived from medicinal plants, such as polyphenols, flavonoids, alkaloids, terpenoids, proteins, and phenolic compounds. Not only do these phytochemicals make it easier to make nanoparticles, but they also provide added pharmacological properties like antioxidant, anti-inflammatory, antibacterial, and neuroprotective actions [2].

Neuroprotective applications could benefit greatly from green synthesised nanoparticles sourced from medicinal plants due to their enhanced biocompatibility, reduced toxicity, and synergistic therapeutic effects. Evidence suggests that plant-mediated nanoparticles can reduce oxidative stress, inhibit neuroinflammation, prevent neuronal death, and improve neuronal survival in many animal models of neurodegenerative diseases. Furthermore, a novel interdisciplinary strategy for developing safer and more effective therapies for neurological disorders is offered by integrating nanotechnology with phytochemicals derived from medicinal plants.

1.1 Neurodegenerative Disorders and Global Burden

Deterioration of brain cell structure and function over time characterises a group of diseases called neurodegenerative disorders. When it comes to the elderly, several diseases and disorders rank high among the leading causes of death and disability worldwide. Causes such as increased life expectancy, fast urbanisation, environmental stresses, and lifestyle choices are contributing to the rising prevalence of neurological disorders in both developed and developing nations. The physical and mental tolls that neurodegenerative diseases take on patients, their families, and healthcare systems are substantial, but the social and emotional costs are just as high [3].

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There is widespread agreement that Alzheimer's disease, a neurodegenerative disease, is the leading cause of dementia and cognitive decline in the elderly. Its symptoms include neurofibrillary tangles, neuronal death, amyloid-beta plaque accumulation, and progressive memory loss. The degeneration of dopaminergic neurones in the substantia nigra of the brain is associated with Parkinson's disease, another major neurological disorder that produces rigidity, poor motor coordination, tremors, and bradykinesia. The hereditary neurodegenerative disorder Huntington's disease causes increasing mobility dysfunction, mental difficulties, and cognitive loss; it is relatively uncommon, but deadly.

Multiple sclerosis is a chronic inflammatory neurological illness that gradually affects neuronal connection and produces neurological disability. Demyelination and inflammation in the central nervous system are characteristics of this disease. Also, one of the leading causes of permanent neurological impairment worldwide is neuronal damage caused by strokes. Cognitive and motor deficits are common outcomes of brain injury, inflammation, oxidative stress, and neuronal death caused by both ischaemic and hemorrhagic strokes. The urgent requirement for innovative treatment approaches that can protect neurones, reduce oxidative stress, and improve brain-targeted drug delivery systems is highlighted by the combined effects of several neurological disorders [4].

1.2 Limitations of Conventional Neurotherapeutics

Despite a lot of development in neuroscience and pharmacological research, traditional neurotherapeutic methods still have a lot of major flaws that limit their overall clinical effectiveness. One major problem is the low bioavailability of these neuroprotective drugs. They have a short half-life, are quickly broken down in the body, and have limited absorption. This reduces therapeutic efficacy and necessitates higher dosages since only a fraction of the medicine reaches the target area of the brain [5].

There is also the very selective physiological barrier known as the blood-brain barrier (BBB), which blocks most therapeutic medications from reaching the central nervous system. Though it prevents harmful substances from reaching the brain, the blood-brain barrier (BBB) places significant restrictions on the delivery of neuroprotective drugs. Many conventional drugs for neurodegenerative diseases fail to penetrate the blood-brain barrier because of inadequate physicochemical properties.

Systemic toxicity is another major concern with traditional neurotherapeutics. Reaching therapeutic concentrations in the brain requires substantial dosages of the medicine, which may have significant side effects on peripheral systems such as the cardiovascular system, liver, and kidneys. Decreased patient compliance, organ damage, and drug resistance are additional possible outcomes of long-term usage of many neuropathy medications. Furthermore, conventional treatments don't always work very well at concentrating on injured brain areas; instead, the drugs spread out untargetedly across the body. The likelihood of unwanted side effects and the precision of therapy are both diminished by this lack of site-specific dispersion. Due to these limitations, state-of-the-art nanotechnology-based therapeutic systems have been

developed, particularly medicinal plant-based nanoparticles that are "green synthesised," meaning they have been synthesised in a way that minimises toxicity while increasing bioavailability and having specific neuroprotective benefits.

1.3 Background of the Study

One of the most pressing global health concerns is the increasing prevalence, relentless course, and inadequate treatment options for neurodegenerative diseases. Numerous neurological disorders, including Alzheimer's, Parkinson's, Huntington's, MS, and stroke-induced neuronal loss, are characterised by progressive neuronal degeneration. Deterioration in cognition, motor function, memory, and quality of life are all symptoms of these disorders. Environmental stress, an ageing population, lifestyle choices, and genetic susceptibility are some of the factors that have contributed to the worldwide rise in the prevalence of neurological disorders. Aside from the obvious emotional and physical toll these diseases take on those involved, healthcare systems also bear a disproportionate share of the financial burden [6].

Rather than promoting complete neuronal recovery or disease transformation, traditional pharmaceutical approaches to neurodegenerative disease management often merely provide symptomatic alleviation. Inadequate blood-brain barrier (BBB) penetration, rapid degradation, systemic toxicity, inadequate bioavailability, and poor solubility are some of the issues with many neuroprotective drugs. Because the BBB acts as a selective protective barrier, preventing most therapeutic molecules from accessing the brain, the efficacy of conventional treatments is limited. The urgent need for safer, more targeted neuroprotective strategies is further highlighted by the fact that synthetic medicine use may lead to adverse effects and reduced patient compliance with treatment.

Recent years have seen a surge in interest in nanotechnology within the field of neurological research due to its promising applications in the areas of medicine administration, therapeutic efficacy, and targeted treatment of brain diseases. Nanoparticles' unique physicochemical properties—including their small size, high surface area, enhanced stability, and superior blood-brain barrier penetration—make them highly attractive carriers for neuroprotective medications. When compared to more conventional chemical and physical methods, green synthesis is more practical, cost-effective, and environmentally friendly when it comes to making nanoparticles. By utilising biological resources such natural biomolecules, microorganisms, and extracts from medicinal plants, green synthesis is able to decrease and stabilise nanoparticles without the use of harmful chemicals.

Medicinal plants are rich in bioactive phytochemicals that play an essential role in nanoparticle production and stabilisation, including flavonoids, alkaloids, terpenoids, polyphenols, and phenolic acids. The antioxidant, anti-inflammatory, neuroprotective, and anti-apoptotic characteristics of these phytochemicals can enhance the therapeutic efficacy of nanoparticles when combined. Nanoparticles mediated by plants have demonstrated promise in a number of animal models of neurodegenerative diseases, with benefits including reduced oxidative stress, protection of neuronal cells, and improved drug transport to the brain [7].

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Thus, a new and innovative approach that integrates neurology, phytomedicine, and nanotechnology to provide safer and more effective neuroprotective medicines is green synthesised nanoparticles derived from medicinal plants. Standardising nanoparticles, producing them on a large scale, testing their toxicity, and translating them into clinical settings are still a number of challenges, despite the great achievements made in this field. Hence, a comprehensive investigation of medicinal plant-mediated green synthesised nanoparticles and their neuroprotective applications is necessary to understand present advancements, therapeutic processes, constraints, and potential future research prospects in this rapidly expanding domain of nanomedicine.

2. GREEN SYNTHESIS OF NANOPARTICLES USING MEDICINAL PLANTS

A new and sustainable approach has emerged in the domains of nanotechnology and biomedical research: the green synthesis of nanoparticles using medicinal plants. Traditional methods of producing nanoparticles often involve the use of harmful chemicals, expensive machinery, excessive energy usage, and potentially harmful waste products that pose a threat to both human and environmental health. In contrast, green synthesis makes use of natural biological resources like bacteria, enzymes, biomolecules, and medicinal plant extracts to create nanoparticles in a gentle and eco-friendly manner. The advantages of plant-mediated synthesis over other approaches, such as its low cost, rapid synthesis, and enhanced biocompatibility, have led to its rising profile.

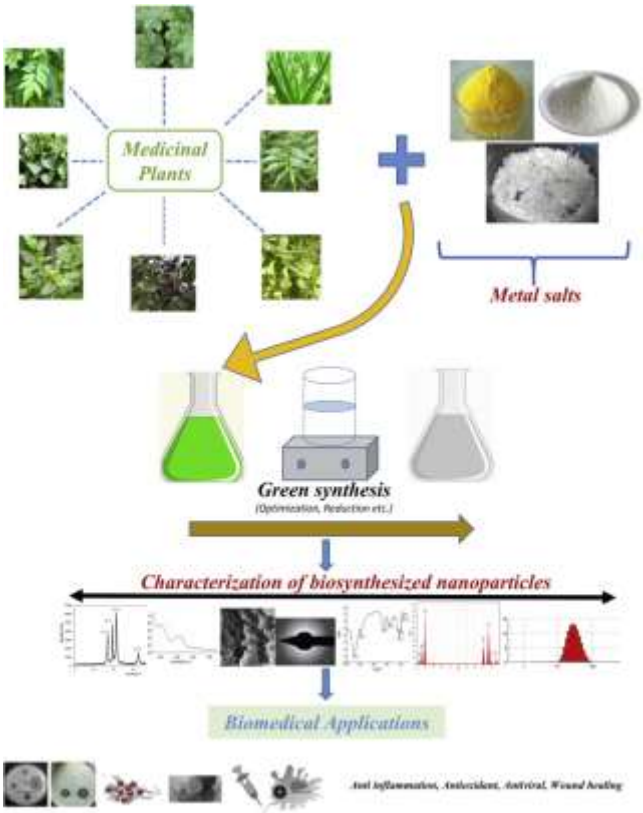

Figure 1: Green Synthesis of Nanoparticles

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Nanoparticle formation relies on a wide variety of bioactive phytochemicals derived from medicinal plants. These include, but are not limited to, polyphenols, flavonoids, alkaloids, terpenoids, proteins, sugars, and phenolic compounds. Traditional synthesis methods sometimes include dangerous chemical reagents; however, these phytochemicals serve as natural reducing, capping, and stabilising agents, thus eliminating the need for them. Stable nanoparticles with tailored physicochemical and biological properties are produced via an interaction between proteins originating from plants and metal precursors. Additionally, nanoparticles that include phytochemical residues on their surfaces may have an improved pharmacological action, which includes antioxidant, anti-inflammatory, antibacterial, and neuroprotective properties [8].

Preparing plant extracts and mixing them with metal salt solutions under precisely controlled conditions (such as pH, reaction duration, and temperature) is the initial step in making green nanoparticles. Phytochemicals in the extract both inhibit the aggregation of metal ions and convert them into nanoparticles during the procedure. Nanoparticles of several metals and elements, including silver, gold, zinc oxide, iron oxide, and selenium, have been successfully synthesised from medicinal plant extracts. Nanoparticles have unique properties that make them well-suited for usage in biomedicine and pharmaceuticals. These properties include small size, large surface area, improved stability, and increased biological activity.

There has been a lot of interest in green synthesised nanoparticles for neuroprotective uses recently because of their abilities to cross the blood-brain barrier, reduce oxidative stress, suppress neuroinflammation, and improve targeted drug delivery to neuronal areas. Combining phytochemicals from medicinal plants with nanotechnology is an exciting new direction in the development of safer and more effective treatment solutions for neurodegenerative diseases. Consequently, research into plant-mediated green synthesis, which integrates phytochemistry, pharmacology, neuroscience, and nanotechnology, has grown into a substantial area of study with promising new medical applications [9].

2.1 Concept of Green Synthesis

The term "green synthesis" describes a sustainable, ecologically friendly, and biologically mediated process for making nanoparticles from things like medicinal plants, bacteria, enzymes, and other biological materials. In contrast to conventional physical and chemical synthesis methods, which often use harmful reducing agents, poisonous solvents, enormous energy consumption, and ecologically destructive by-products, green synthesis makes use of biomolecules that already exist in the environment to create nanoparticles. The easiness, low cost, reduced toxicity, and ecological compatibility of this technology have piqued the curiosity of many in the pharmaceutical and biological research communities.

In biological synthesis methods, nanoparticles are created using reducing and stabilising chemicals mostly found in plant extracts, bacteria, fungus, algae, and biomolecules. One of the most promising approaches is medicinal plant-mediated synthesis, which makes use of plant extracts, which include various bioactive phytochemicals. These compounds have the ability

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to convert metal ions into stable nanoparticles under mild reaction conditions. Throughout the production process, proteins derived from plants serve as capping agents to prevent nanoparticles from aggregating and to enhance their stability. At the same time, they reduce metal salts into nanoscale particles. Because of this, the old methods of nanoparticle synthesis, which sometimes use dangerous chemical stabilisers and reducing agents, are no longer necessary [10].

As concerns about chemical toxicity, energy-intensive manufacturing processes, and environmental contamination have increased, the need of developing sustainable nanoparticles has grown in modern nanotechnology. A sustainable choice, green synthesis reduces energy consumption, makes less hazardous waste, and uses renewable plant resources. Medicinal plant-mediated nanoparticles often exhibit enhanced biocompatibility and heightened biological activity due to the presence of surface-bound phytochemicals. Neuroprotection, targeted drug delivery, antioxidant therapy, and the treatment of neurodegenerative illnesses are just a few of the many biomedical applications that have benefited greatly from the extensive research conducted on green synthesised nanoparticles.

2.2 Role of Phytochemicals in Nanoparticle Formation

The green synthesis of nanoparticles relies heavily on phytochemicals found in medicinal plants, which serve as reducing, stabilising, and capping agents during the creation of the nanoparticles. Plant extracts include a wide variety of bioactive chemicals that can undergo oxidation-reduction processes to form nanoparticles from metal ions. In addition to enhancing the biological activity, stability, and therapeutic potential of nanoparticles, these biomolecules found in nature also make their manufacturing easier. The improved pharmacological characteristics of green synthesised nanomaterials are mostly attributable to the synergistic interaction between nanoparticles and phytochemicals obtained from plants [11].

Major Functions of Phytochemicals in Nanoparticle Formation

- Reduction of metal ions into nanosized particles
- Stabilization and prevention of nanoparticle aggregation
- Enhancement of biological and therapeutic properties

Polyphenols are among the most important phytochemicals involved in nanoparticle synthesis. These compounds possess strong antioxidant properties and donate electrons to metal ions, thereby promoting their reduction into nanoparticles. Polyphenols additionally contribute to nanoparticle stabilization by preventing agglomeration and improving colloidal stability. Similarly, flavonoids play a major role in nanoparticle formation because of their hydroxyl functional groups and reducing capacity. Flavonoids can effectively chelate metal ions and facilitate nanoparticle synthesis while simultaneously imparting antioxidant and anti-inflammatory properties to the synthesized nanoparticles.

Important Phytochemicals Involved

- Polyphenols and flavonoids
- Alkaloids and terpenoids

- Carbs, amino acids, and proteins

Terpenoids and alkaloids also actively contribute to the creation of green nanoparticles. Alkaloids contain nitrogen-containing functional groups that interact with metal ions and support nanoparticle reduction and stabilization processes. Many alkaloids additionally exhibit neuroprotective, antimicrobial, and antioxidant activities that enhance the biomedical significance of phytogenic nanoparticles. Terpenoids, which are widely distributed in medicinal plants, contribute to nanoparticle formation through electron transfer mechanisms and stabilization effects. Their presence can influence nanoparticle morphology, size distribution, and surface characteristics.

In addition to these phytochemicals, plant proteins, amino acids, carbohydrates, and other reducing agents also contribute significantly to nanoparticle synthesis. Proteins may bind to nanoparticle surfaces through functional groups such as amines and carboxyl groups, thereby enhancing nanoparticle stability and preventing aggregation. Natural reducing agents present in plant extracts facilitate rapid and efficient conversion of metal precursors into nanoscale particles under mild reaction conditions.

Advantages of Phytochemical-Mediated Synthesis

- Eco-friendly and sustainable nanoparticle production
- Improved biocompatibility and reduced toxicity
- Enhanced antioxidant and neuroprotective activities

Collectively, these phytochemicals create an efficient biological system for environmentally friendly nanoparticle production while simultaneously enhancing the therapeutic and neuroprotective potential of the synthesized nanomaterials.

3. MEDICINAL PLANTS USED IN GREEN NANOPARTICLE SYNTHESIS

An important component of green nanoparticle manufacturing is the utilisation of medicinal plants, which contain a variety of bioactive phytochemicals that can stabilise and decrease metal ions. A wide variety of compounds, including polyphenols, flavonoids, alkaloids, terpenoids, tannins, proteins, and carbohydrates, are present in plant extracts and act as organic reducing and capping agents. In addition to making it easier to make nanoparticles that are kind to the environment, these phytochemicals also boost the biological and therapeutic properties of the finished products. Chemical synthesis methods are considered to be risky, expensive, environmentally harmful, and incompatible with living organisms as compared to medicinal plant-mediated nanoparticle creation [12].

A number of medicinal plants have been the subject of extensive research into the potential for their nanoparticles to include silver, gold, zinc oxide, selenium, and iron oxide. The size, form, durability, and pharmacological properties of nanoparticles are significantly affected by the type of plant used to make them due to the fact that every plant has a unique phytochemical makeup. Medicinal plant-mediated nanoparticles often exhibit enhanced antioxidant, anti-inflammatory, antibacterial, anticancer, and neuroprotective properties due to the synergistic interaction between nanoparticles and bioactive compounds obtained from plants.

Many plants with a long history of use in herbal medicine have recently demonstrated promising results in the development of neuroprotective nanoparticles. The production of multifunctional nanoparticles for neurological applications is made possible by chemicals present in plants, such as Curcuma longa, Withania somnifera, Ginkgo biloba, Ocimum sanctum, and Azadirachta indica, which have antioxidants and neuroprotective properties. Reducing oxidative stress, avoiding neuroinflammation, protecting neuronal cells, and improving drug delivery to the brain are all areas where these medicinal herbs show potential.

Medicinal Plants' Significance in the Production of Green Nanoparticles [13]

- Offer organic stabilising and lowering agents
- Get rid of hazardous chemical reagents
- Improve the stability and biocompatibility of nanoparticles
- Improve therapeutic and pharmacological activities
- Support eco-friendly and sustainable nanoparticle production

The use of medicinal plants in nanoparticle synthesis has gained substantial attention in modern nanomedicine because it combines the therapeutic benefits of herbal medicine with the advanced properties of nanotechnology [14]. Plant-mediated nanoparticles are increasingly being explored for neuroprotective applications due to their ability to cross the blood–brain barrier, reduce oxidative damage, and improve targeted delivery of therapeutic agents. Consequently, medicinal plants represent a valuable natural resource for the development of innovative and safer nanoparticle-based therapies for neurodegenerative diseases and other neurological disorders [15].

4. RECENT STUDIES ON GREEN SYNTHESIZED NANOPARTICLES FOR NEUROPROTECTIVE APPLICATIONS

The table presents a compilation of recent research on green synthesised nanoparticles and their potential neuroprotective applications. Included are details on the study's focus, methodology, and key findings as well as information about the authors and publication year. Researchers looked at various experimental models to determine the biological and neuroprotective effects of metal nanoparticles made from medicinal plant extracts. Experimental and review-based studies were combined to provide a complete picture of the latest advancements in green nanotechnology for neurological applications.

Nanoparticles of silver and copper produced in an environmentally sustainable way have demonstrated antioxidant, anti-inflammatory, and neuroprotective characteristics, as shown in the table. In animal models of neurodegenerative diseases, green synthesised nanoparticles have been the subject of multiple investigations into their potential to ameliorate oxidative stress, increase neuronal survival, and improve cognitive abilities. Review articles also highlighted phytogenic nanoparticles' biomedical usefulness, environmental friendliness, and therapeutic promise.

Author(s) & Year	Study Focus	Methodology/Approach	Major Findings

Shao et al. (2025) [16]	The neuroprotective potential of copper nanoparticles synthesised using green tea as a mediating agent was studied.	The researchers synthesized copper nanoparticles using green tea extract and performed chemical characterization along with neuroprotective evaluation	The study reported that green synthesized copper nanoparticles exhibited significant antioxidant and neuroprotective activities, indicating their potential application in neurological disorders
Zhang, Li, & Hu (2020)[17]	Examined green synthesized silver nanoparticles for prevention of cognitive deficits in Alzheimer's disease	The authors synthesized silver nanoparticles through a green synthesis approach and evaluated their effects in a sporadic Alzheimer's rat model	The findings demonstrated that the nanoparticles improved recognition and spatial memory deficits, suggesting possible neuroprotective effects against Alzheimer's disease progression
Khorrami et al. (2023) [18]	Assessed the preventive effects of silver nanoparticles produced environmentally on neurones injured by methamphetamine.	The research involved exposing SH-SY5Y human neuroblastoma cells to damage caused by methamphetamine and then treating them with silver nanoparticles that were environmentally synthesised.	The results revealed that the nanoparticles significantly reduced neuronal cell death and oxidative stress, thereby exhibiting protective effects against neurotoxicity
Sena, Ochatt, & Kumar (2023) [19]	Analysed the use of environmentally friendly nanoparticles in studies on medicinal plants	The authors conducted a comprehensive review of eco-friendly nanoparticle synthesis methods and their medicinal applications	According to the review, green synthesised nanoparticles are great for pharmaceutical and biomedical uses since they are more environmentally

			friendly, effective, and biocompatible.
Vijayaram et al. (2023)[20]	Possible uses of environmentally friendly metal nanoparticles	The researchers analyzed recent studies related to synthesis methods, biological activities, and applications of green nanoparticles	The study highlighted that green synthesized metal nanoparticles exhibited significant antioxidant, antimicrobial, anticancer, and neuroprotective properties with promising biomedical applications

The results shown in the table suggest that green synthesised nanoparticles have a great deal of promise for neuroprotective uses. Experimental studies revealed that medicinal plant-mediated nanoparticles could reduce neuronal damage, suppress oxidative stress, and improve memory and cognitive functions in neurological disease models. Silver nanoparticles, in particular, demonstrated protective effects against neurotoxicity and neurodegeneration, suggesting their possible application in disorders such as Alzheimer's disease and drug-induced neuronal injury. The review studies further emphasized that green synthesis provides an environmentally friendly and biocompatible alternative to conventional nanoparticle production methods. The presence of plant-derived phytochemicals on nanoparticle surfaces was found to enhance their therapeutic efficacy and reduce toxicity. Overall, the table suggests that green synthesized nanoparticles represent a promising interdisciplinary approach combining nanotechnology and medicinal plants for the development of advanced neuroprotective therapies. However, additional clinical studies, toxicity assessments, and standardization procedures are still required for successful therapeutic translation.

5. CONCLUSION

A viable and sustainable method for neuroprotective applications in the treatment of neurodegenerative diseases is the use of green synthesised nanoparticles made from medicinal plants. Eco-friendly synthesis, increased biocompatibility, improved blood–brain barrier penetration, decreased toxicity, and tailored therapeutic action are just a few of the many benefits that come with combining nanotechnology with medicinal plant phytochemicals. In several experimental models of neurological illnesses, a variety of plant-mediated nanoparticles, including silver, gold, copper, selenium, and iron oxide nanoparticles, have shown impressive antioxidant, anti-inflammatory, anti-apoptotic, and neuroprotective capabilities. The stability and therapeutic efficiency of these nanoparticles are further improved by the addition of bioactive phytochemicals. Their potential to lower oxidative stress, reduce neuroinflammation, improve neuronal survival, and improve cognitive functioning has been

emphasised by recent investigations. Despite these encouraging results, there are still issues with large-scale production, clinical translation, long-term toxicity assessment, and standardisation of nanoparticles. Thus, to determine the safety, effectiveness, and therapeutic application of green synthesised nanoparticles for the successful treatment of neurodegenerative illnesses, more multidisciplinary research and clinical studies are required.

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