International Journal of Public Health, Pharmacy and Pharmacology, 11(2), 58-71, 2026
Print ISSN: (Print) ISSN 2516-0400
Online ISSN: (Online) ISSN 2516-0419
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Importance of Medicinal Plants in Traditional and Modern Medicine: Implications for Human Health

Telma Aliaj[1], Rozarta Nezaj [1,2], Albana Cuko[3]
[1] Faculty of Medicine, Medical University of Tirana, Albania,
[2]Faculty of Biotechnology and Food, Agricultural University of Tirana, Albania
Otorhinolaryngology Service, "Mother Teresa" University Hospital Center, Tirana, Albania

doi: https://doi.org/10.37745/ijphpp.15/vol11n25871 Published July 13, 2026

Citation: Aliaj T., Nezaj R., Cuko A. (2026) Importance of Medicinal Plants in Traditional and Modern Medicine: Implications for Human Health, International Journal of Public Health, Pharmacy and Pharmacology, 11(2), 58-71

Abstract: *Medicinal plants have long served as a cornerstone of healthcare, providing a rich source of bioactive compounds with diverse pharmacological activities. Growing interest in plant-derived therapeutics, coupled with rapid technological advancements, has transformed medicinal plant research into a multidisciplinary field that integrates traditional knowledge with cutting-edge scientific approaches. This review examines recent progress in the discovery, characterization, and development of bioactive phytochemicals and explores their expanding role in promoting human health. The review highlights the contribution of emerging technologies, including multi-omics platforms (genomics, transcriptomics, proteomics, metabolomics, and spatial omics), artificial intelligence (AI), machine learning, and nanotechnology, to accelerating natural product research and phytopharmaceutical innovation. These approaches have enhanced the identification of novel bioactive compounds, elucidated biosynthetic pathways and molecular mechanisms of action, optimized cultivation and extraction processes, and improved the precision and efficiency of drug discovery. In addition, nanotechnology-based delivery systems have demonstrated considerable potential to enhance the stability, bioavailability, targeted delivery, and therapeutic efficacy of plant-derived compounds, particularly in the treatment of chronic diseases such as cancer, metabolic disorders, cardiovascular diseases, and neurodegenerative conditions. Despite these advances, several challenges continue to limit the translation of medicinal plants into evidence-based therapeutics, including biodiversity loss, variability in phytochemical composition, contamination and adulteration of herbal products, and the need for standardized quality control and harmonized regulatory frameworks. Future progress will depend on multidisciplinary collaboration that integrates traditional medicinal knowledge with advanced analytical technologies, computational tools, and sustainable resource management. Such an approach will facilitate the development of safe, effective, and innovative phytopharmaceuticals while supporting precision medicine and improving global health outcomes.*

Keywords: medicinal plants, phytochemicals, bioactive compounds, artificial intelligence, nanotechnology, drug delivery systems, phytopharmaceuticals, precision medicine, biodiversity

International Journal of Public Health, Pharmacy and Pharmacology, 11(2), 58-71, 2026
Print ISSN: (Print) ISSN 2516-0400
Online ISSN: (Online) ISSN 2516-0419
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

INTRODUCTION

Medicinal plants have served as one of humanity's oldest and most valuable therapeutic resources, providing an extensive repertoire of bioactive compounds that continue to support both traditional healthcare systems and modern pharmaceutical development. Despite remarkable advances in synthetic drug discovery, plant-derived natural products remain indispensable sources of novel therapeutic agents owing to their remarkable chemical diversity, broad spectrum of biological activities, and historical evidence of clinical use. The continued relevance of medicinal plants is reflected in their widespread application for the prevention and treatment of infectious, inflammatory, metabolic, cardiovascular, neurological, and malignant diseases (Bagla 2012).

Global reliance on medicinal plants remains substantial. With the world population projected to exceed 8.2 billion in 2025, approximately 80% of people are estimated to rely, at least partially, on traditional herbal medicine for primary healthcare, particularly in low- and middle-income countries where access to conventional medical services may be limited (Alam et al. 2025; Che et al. 2024). Established medical systems, including Traditional Chinese Medicine, Ayurveda, Unani, and numerous indigenous healing traditions, have accumulated centuries of empirical knowledge regarding medicinal plant use. These systems continue to contribute significantly to healthcare while simultaneously providing valuable leads for contemporary drug discovery and pharmaceutical innovation.

The importance of medicinal plants extends beyond traditional medicine to modern pharmacotherapy. Numerous clinically important drugs have originated from botanical sources, including morphine, codeine, digoxin, quinine, artemisinin, vinblastine, paclitaxel, and reserpine, illustrating the enduring contribution of natural products to the treatment of pain, cardiovascular disorders, infectious diseases, cancer, and neurological conditions (Bagla 2012). The growing commercial value of herbal medicines, together with increasing consumer preference for naturally derived therapeutics, has further stimulated research into plant-based pharmaceuticals and evidence-based phytomedicine.

Recent advances in biotechnology and computational sciences have fundamentally transformed medicinal plant research. High-throughput omics technologies—including genomics, transcriptomics, proteomics, metabolomics, and spatial omics—now enable comprehensive characterization of biosynthetic pathways, metabolite diversity, and molecular mechanisms underlying therapeutic activity. Simultaneously, artificial intelligence and machine learning have accelerated phytochemical identification, prediction of biological activities, optimization of cultivation strategies, and natural product-based drug discovery. In parallel, nanotechnology has emerged as an innovative platform to improve the pharmaceutical performance of herbal medicines by enhancing the stability, bioavailability, controlled release, and targeted delivery of plant-derived bioactive compounds (Allam and Sabra 2024; Saadh et al. 2024).

Despite these advances, several scientific and practical challenges continue to limit the broader clinical application of medicinal plants. Variability in phytochemical composition, insufficient standardization, contamination and adulteration of herbal products, limited pharmacokinetic information, and inconsistent regulatory frameworks remain major barriers to their safe and effective therapeutic use. Furthermore, the increasing global demand for medicinal plants has intensified harvesting pressure on natural populations, threatening biodiversity and placing thousands of medicinal species at risk of overexploitation and extinction (Ghosh et al. 2023; Ma et al. 2005; Marisetti et al. 2025). These concerns highlight the urgent need for sustainable cultivation practices, conservation strategies, quality assurance systems, and internationally harmonized regulatory standards.

Although numerous reviews have addressed individual aspects of medicinal plants, most focus separately on phytochemistry, pharmacology, biotechnology, or conservation. Comprehensive analyses integrating these interconnected disciplines remain limited. An integrated perspective is increasingly important as medicinal plant research evolves toward multidisciplinary approaches that combine traditional knowledge with advanced analytical technologies, computational tools, pharmaceutical engineering, and sustainability principles (Manisha et al. 2025; Saggar et al. 2022). Therefore, this review provides a comprehensive overview of the evolving role of medicinal plants in human health by integrating recent advances in bioactive compound discovery, multi-omics technologies, artificial intelligence, nanotechnology-based drug delivery, quality control, biodiversity conservation, and phytopharmaceutical development. By bridging traditional medicinal knowledge with modern scientific innovation, this review highlights current opportunities, emerging challenges, and future directions that will support the development of safe, effective, sustainable, and evidence-based plant-derived therapeutics.

Medicinal Plants in Modern Healthcare: Global Trends and Economic Perspectives

Medicinal plants remain indispensable components of healthcare systems worldwide, serving as primary therapeutic resources for millions of people while increasingly contributing to modern pharmaceutical research. According to the World Health Organization (WHO), nearly 80% of the global population relies, wholly or partially, on traditional plant-based medicines for primary healthcare, particularly in low- and middle-income countries where access to conventional medical services remains limited. At the same time, industrialized nations have experienced a growing acceptance of herbal medicines as complementary and integrative therapies, reflecting an increasing preference for natural, preventive, and personalized healthcare approaches (Balkrishna et al. 2024).

Several factors have contributed to the renewed global interest in medicinal plants, including concerns regarding the adverse effects associated with synthetic drugs, the emergence of antimicrobial resistance, increasing healthcare expenditures, and growing consumer awareness of wellness and disease prevention. These drivers have stimulated scientific research into plant-derived bioactive compounds while simultaneously expanding the commercial herbal medicine sector.

The global trade of medicinal and aromatic plants (MAPs) has grown substantially over the past decade. International Trade Center (ITC) statistics indicate that between 2010 and 2023, worldwide exports and imports of MAPs nearly doubled, reaching approximately US$4.18 billion and US$4.25 billion, respectively. China and India dominate global production and export activities owing to their exceptional biodiversity, extensive cultivation systems, and long-established traditional medical practices. Conversely, countries such as the United States, Germany, and Japan represent major import markets, supported by sophisticated pharmaceutical, nutraceutical, and cosmetic industries (Anjum 2025; Zamani et al. 2025). Among internationally traded botanical products, commodities classified under Harmonized System (HS) code 121190 account for the largest commercial share, encompassing medicinal plants used in pharmaceutical, cosmetic, perfumery, and agricultural applications.

The COVID-19 pandemic further accelerated consumer demand for herbal products, largely driven by increased interest in immune support, preventive healthcare, and naturally derived therapeutic agents. This trend has encouraged greater investment in medicinal plant research, quality assurance systems, and sustainable production practices. Consequently, international standards such as WHO Good Agricultural and Collection Practices (WHO-GACP) and Good Manufacturing Practices (GMP) have become increasingly important for ensuring product quality, traceability, safety, and regulatory compliance across global supply chains (Djaoudene et al. 2023; Kazemi-Karyani et al. 2025; Paudyal et al. 2022).

Despite the continued expansion of the herbal medicine industry, important challenges remain. Unsustainable harvesting practices, habitat destruction, biodiversity loss, adulteration, contamination, inconsistent quality standards, and fragmented regulatory frameworks continue to compromise both environmental sustainability and public confidence in herbal products. Addressing these issues requires coordinated international efforts that integrate biodiversity conservation, sustainable cultivation, advanced processing technologies, standardized quality control, and evidence-based regulatory policies (Mykhailenko et al. 2025).

The sustained growth of medicinal plant utilization reflects not only their enduring therapeutic significance but also their expanding role in pharmaceutical innovation, functional foods, nutraceutical development, and precision healthcare. As traditional medicinal knowledge increasingly converges with biotechnology, artificial intelligence, omics sciences, and nanotechnology, medicinal plants are poised to become central components of next-generation healthcare systems and sustainable phytopharmaceutical development.

Medicinal plants have played a central role in healthcare throughout human history, serving as the foundation of traditional medical systems and providing invaluable resources for modern drug discovery. Although the widespread adoption of synthetic pharmaceuticals during the eighteenth and nineteenth centuries temporarily reduced reliance on herbal medicine, many traditional remedies were subsequently validated through scientific investigation and became integral to contemporary therapeutics. A landmark example is William Withering's systematic study of

Digitalis purpurea (foxglove), which established its efficacy in treating congestive heart failure and laid the foundations of evidence-based pharmacology (Skou 1986; Withering 2014). Similarly, the isolation of morphine from *Papaver somniferum* in 1806 represented a major breakthrough in pharmaceutical chemistry and initiated the era of bioactive compound purification from medicinal plants (Kapoor 2020; Teuscher and Lindequist 2024). Subsequent advances in organic chemistry, spearheaded by scientists such as Justus von Liebig, facilitated the structural characterization and synthesis of plant-derived compounds, ultimately bridging traditional herbal medicine with modern pharmaceutical science (Neuhaus et al. 2022; Tapia et al. 2024).

The therapeutic value of medicinal plants is largely attributed to their rich diversity of primary and secondary metabolites, including alkaloids, flavonoids, phenolic acids, tannins, terpenoids, glycosides, saponins, steroids, and essential oils. These bioactive compounds serve important ecological functions in plants while exhibiting a wide range of pharmacological properties beneficial to human health (Agidew 2022). Advances in phytochemical analysis have substantially improved the identification and characterization of these compounds, providing new opportunities for the development of innovative phytopharmaceuticals.

Among plant secondary metabolites, phenolic compounds and flavonoids are recognized as major contributors to antioxidant activity through their ability to scavenge reactive oxygen species, reduce oxidative stress, and protect cellular components from oxidative damage. These mechanisms are increasingly associated with the prevention and management of chronic diseases, including cardiovascular disorders, diabetes, neurodegenerative diseases, and cancer (Chociej et al. 2024; Paiva et al. 2024). In parallel, essential oils represent complex mixtures of volatile compounds, predominantly monoterpenes, sesquiterpenes, and oxygenated derivatives, whose composition varies according to plant species, geographical origin, cultivation practices, and environmental conditions (Monib 2024).

Extensive pharmacological research has demonstrated that medicinal plant extracts and essential oils possess broad-spectrum biological activities, including antimicrobial, antiviral, antifungal, anti-inflammatory, antioxidant, antispasmodic, immunomodulatory, and insecticidal properties. Numerous studies have reported significant antibacterial activity against both Gram-positive and Gram-negative pathogens, while several phytochemicals have shown antiviral effects by interfering with viral attachment, replication, and intracellular signaling pathways. Terpenoids, flavonoids, phenolic compounds, and resin acids are among the principal constituents responsible for these therapeutic effects and continue to attract considerable attention as potential alternatives or adjuncts to conventional antimicrobial therapies (Nurzyńska-Wierdak and Walasek-Janusz 2025; Singh et al. 2025).

Beyond pharmaceutical applications, medicinal plants contribute to multiple industrial sectors. Their bioactive constituents are increasingly incorporated into functional foods, nutraceuticals, cosmetics, and natural preservatives owing to their antioxidant and antimicrobial properties. Essential oils are widely used as flavoring agents, fragrances, and environmentally friendly

bioactive ingredients, while plant-derived metabolites have also demonstrated potential as botanical pesticides for sustainable agricultural production (Chaughule and Barve 2024; Patel and Patel 2024).

The growing scientific understanding of medicinal plant phytochemistry has strengthened the integration of traditional knowledge with evidence-based medicine. Continued advances in analytical chemistry, molecular biology, and pharmacology are accelerating the discovery of novel plant-derived therapeutics while providing scientific validation for traditional medicinal practices. Collectively, medicinal plants remain an indispensable source of structurally diverse bioactive compounds with significant potential to support future drug discovery, personalized medicine, and sustainable healthcare (Singh et al. 2025).

Aim and Scope of the Review

This review provides an integrated overview of recent advances in medicinal plant research, highlighting how emerging technologies are transforming the discovery and development of plant-derived therapeutics. It focuses on the application of multi-omics approaches, artificial intelligence, and nanotechnology to improve the identification of bioactive compounds, elucidate biosynthetic pathways, and enhance drug delivery and therapeutic efficacy. In addition, the review discusses key challenges related to quality control, standardization, regulatory frameworks, and biodiversity conservation. By bridging traditional medicinal knowledge with modern technological innovations, this review offers current perspectives and future directions for the sustainable development of safe, effective, and evidence-based phytopharmaceuticals to improve human health.

RESULTS AND DISCUSSIONS

Historical Use of Medicinal Plants Across Traditional Medical Systems

Medicinal plants have formed the foundation of traditional healthcare systems for thousands of years and continue to influence modern medicine through their diverse bioactive compounds and therapeutic applications. Ancient medical traditions such as Ayurveda, Unani, and Traditional Chinese Medicine (TCM) developed sophisticated frameworks for disease prevention and treatment based on extensive empirical knowledge of medicinal plants. These systems not only shaped healthcare practices within their respective cultures but also provided the basis for numerous modern pharmaceuticals and continue to inspire contemporary drug discovery and phytopharmaceutical research.

Ayurveda medical system

Originating in India more than 3,000 years ago, Ayurveda is one of the oldest holistic medical systems, emphasizing the maintenance of health through balanced nutrition, lifestyle, and herbal medicine. Treatment is individualized according to a person's constitutional type (*Prakriti*), reflecting an early concept of personalized medicine (Kizhakkeveettil et al. 2024). More than 7,000 medicinal plants are described in Ayurvedic literature, including *Withania somnifera*

(ashwagandha), *Curcuma longa* (turmeric), *Bacopa monnieri* (brahmi), *Centella asiatica* (gotu kola), *Azadirachta indica* (neem), and *Asparagus racemosus* (shatavari), which contain pharmacologically active compounds such as withanolides, curcuminoids, bacosides, and triterpenoids (Anand et al. 2022; Kamath 2025). Numerous experimental and clinical studies have confirmed their antioxidant, anti-inflammatory, immunomodulatory, neuroprotective, hepatoprotective, and antimicrobial activities, supporting many traditional therapeutic applications (Dhole and Yedey 2024; Kamath 2025). Modern analytical techniques, including high-performance liquid chromatography, mass spectrometry, genomics, and metabolomics, have further facilitated the standardization and scientific validation of Ayurvedic medicines, while artificial intelligence and pharmacogenomic approaches are increasingly supporting the identification of bioactive compounds and personalized herbal therapies (Chaudhari and Tayade 2024; Mukherjee et al. 2022; Patil et al. 2025; Soni and Soni 2025).

Unani system of medicine

The Unani system of medicine originated from the medical traditions of ancient Greece and was subsequently refined by Persian and Arab scholars before becoming firmly established throughout South Asia. Based on the humoral theory, Unani medicine aims to restore the balance of bodily temperaments through individualized dietary interventions, lifestyle modifications, and medicinal plants (Ahmad et al. 2024). Over centuries, its pharmacopeia expanded through the incorporation of numerous botanical species from the Middle East, Central Asia, and the Indian subcontinent. Medicinal plants remain central to Unani therapeutics owing to their anti-inflammatory, digestive, antimicrobial, and restorative properties, while the holistic philosophy of balancing physiological functions continues to influence complementary healthcare practices (Basu et al. 2023; Lepcha et al. 2023).

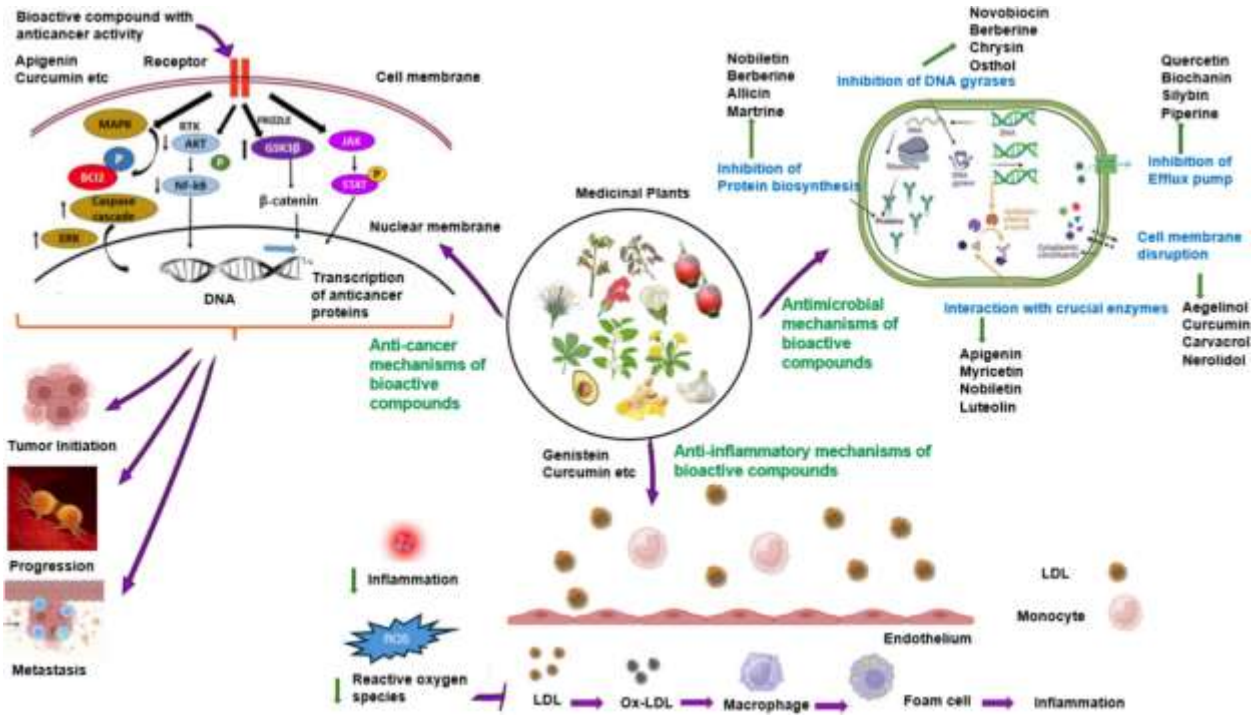
Traditional Chinese Medicine

Traditional Chinese Medicine (TCM) represents one of the world's oldest continuously practiced medical systems and is founded on the principles of Yin–Yang balance and the harmonious flow of *Qi*. Classical texts, including the *Shennong Ben Cao Jing* and later herbal compendia, documented hundreds of medicinal plants and established the theoretical basis for herbal therapy (Anderson 1997; Lord 2021; Lust 2014). For centuries, TCM served as the primary healthcare system in China and continues to play a major role in disease prevention and treatment (Inchauspe 2025). Modern TCM integrates traditional herbal formulations with standardized manufacturing processes, quality control, and evidence-based research while preserving its philosophical foundations (Elendu 2024). In addition to herbal medicine, TCM incorporates acupuncture, moxibustion, cupping, and therapeutic massage as complementary interventions that aim to restore physiological balance (Luo et al. 2025; Wang et al. 2023a). Similar concepts of maintaining bodily equilibrium have also been recognized in historical Western medicine, illustrating the universal importance of balance in traditional healing systems (Jaeger 2012; Daly and Brater 2000; Dong 2023; Ungerer 2025; Matos et al. 2021).

Collectively, these traditional medical systems demonstrate the enduring importance of medicinal plants as sources of therapeutic agents and provide an invaluable foundation for contemporary phytochemical research, pharmaceutical development, and evidence-based integrative medicine.

Health-Promoting Properties of Medicinal Plants

Medicinal plants are rich sources of secondary metabolites that play essential roles in plant defense and adaptation while providing numerous health benefits for humans. These bioactive compounds—including alkaloids, flavonoids, phenolic compounds, terpenoids, tannins, and sulfur-containing metabolites—have attracted considerable attention because of their antioxidant, antimicrobial, anti-inflammatory, anticancer, and immunomodulatory properties. Their structural diversity and multiple biological targets make them valuable candidates for drug discovery and the development of novel phytopharmaceuticals.



(Adapted from Latif, R., et al. 2026)

Fig.1. Health benefits of medicinal plants

Antimicrobial Activity of Plant Secondary Metabolites

Plant-derived secondary metabolites exhibit antimicrobial activity through multiple complementary mechanisms, reducing the likelihood of resistance development compared with conventional antibiotics. Their selective toxicity toward microbial cells results from differences in membrane composition, metabolic pathways, and enzyme targets between microorganisms and host cells. Growing antimicrobial resistance has renewed interest in these natural compounds as

alternative or adjunct antimicrobial agents capable of enhancing the efficacy of existing antibiotics (Khare et al. 2021; Choudhury 2022).

One of the principal mechanisms involves disruption of bacterial cell membranes. Lipophilic alkaloids such as **berberine** and **sanguinarine** interact with phospholipid bilayers, increasing membrane permeability, dissipating membrane potential, and ultimately causing bacterial cell death (Yan et al. 2021; Laines-Hidalgo et al. 2022). Berberine has demonstrated potent activity against methicillin-resistant *Staphylococcus aureus* (MRSA), whereas sanguinarine is particularly effective against Gram-positive bacteria through membrane destabilization (Yildirim et al. 2025; Zhu et al. 2025).

Plant flavonoids also interfere with essential bacterial enzymes involved in DNA replication and energy metabolism. Compounds such as **quercetin** and **kaempferol** inhibit DNA gyrase, topoisomerases, and other metabolic enzymes, thereby suppressing bacterial growth while enhancing the activity of conventional antibiotics through inhibition of β-lactamase enzymes (Taleghani et al. 2024).

Another important mechanism is the inhibition of bacterial efflux pumps, which are major contributors to multidrug resistance. Alkaloids including **reserpine** and **piperine** inhibit ATP-dependent transport systems responsible for antibiotic extrusion, restoring bacterial susceptibility and improving the effectiveness of existing antimicrobial therapies.

Unlike many conventional antibiotics that target a single cellular pathway, phytochemicals often exert multitarget effects. Compounds such as **curcumin**, **allicin**, **berberine**, terpenes from **tea tree oil**, phenolics from **oregano**, tannins from **green tea**, and alkaloids from **neem** simultaneously affect membrane integrity, biofilm formation, protein synthesis, cellular respiration, and nucleic acid metabolism. This multifaceted mode of action makes plant-derived compounds promising candidates for combating multidrug-resistant (MDR) pathogens and reducing the emergence of antimicrobial resistance (El-Saadony et al. 2025).

The broad-spectrum antimicrobial properties of medicinal plants, together with their synergistic interactions with conventional antibiotics, highlight their growing importance as a source of innovative therapeutic agents for addressing the global challenge of infectious diseases and antimicrobial resistance.

CONCLUSIONS

Medicinal plants remain an indispensable source of structurally diverse bioactive compounds that have supported human health for centuries and continue to drive pharmaceutical innovation. Traditional medical systems such as Ayurveda, Unani, and Traditional Chinese Medicine have established the therapeutic value of medicinal plants, while modern scientific research has

validated many of their pharmacological properties and expanded their applications in disease prevention and treatment.

Advances in phytochemistry, multi-omics technologies, artificial intelligence, and nanotechnology have transformed medicinal plant research by accelerating the discovery of bioactive compounds, elucidating their molecular mechanisms, and improving their delivery, bioavailability, and therapeutic efficacy. These interdisciplinary approaches are bridging traditional knowledge with evidence-based medicine, creating new opportunities for the development of safe, effective, and targeted phytopharmaceuticals.

Despite these advances, several challenges remain, including variability in phytochemical composition, quality control, adulteration, biodiversity loss, unsustainable harvesting, and the lack of harmonized regulatory frameworks. Addressing these limitations will require standardized cultivation and manufacturing practices, comprehensive quality assurance, sustainable resource management, and robust clinical validation of plant-derived therapies.

Future research should emphasize multidisciplinary collaborations integrating biotechnology, computational sciences, pharmacology, and conservation biology to accelerate the translation of medicinal plants into clinically effective therapeutics. Such an integrated approach will not only enhance the discovery of novel bioactive compounds but also promote sustainable utilization of botanical resources, supporting precision medicine and contributing to improved global health outcomes.

REFERENCES

Agidew, M. G. (2022). Phytochemical analysis of some selected traditional medicinal plants in Ethiopia. *Bulletin of the National Research Centre*, *46*(1), 87. https://doi.org/10.1186/s42269-022-00757-1 *(assigned DOI)*

Ahmad, A., Naqvi, S. B. K., & Sultana, N. (2024). Exploring the roots: The historical journey and evolution of the Unani system of medicine. *Journal of Emerging Technologies and Innovative Research, 11*(6). https://www.jetir.org DOI: **Not available (web journal without DOI indexing)**

Alam SI, Bari ML, Saeed SS, Siraj MT (2025) Data-driven and computational statistical analysis of the impact of GDP, population, and land area on renewable energy capacity across countries. J Therm Energy Syst 10(2):35–47

Allam, E. A., & Sabra, M. S. (2024). Plant-based therapies for urolithiasis: A systematic review of clinical and preclinical studies. *International Urology and Nephrology, 56*(12), 3687–3718. https://doi.org/10.1007/s11255-024-03821-0 *(assigned DOI)*

Anand U, Tudu CK, Nandy S, Sunita K, Tripathi V, Loake GJ, Dey A, Proc´ko ´w J (2022) Ethnodermatological use of medicinal plants in India: from ayurvedic formulations to clinical perspectives—a review. J Ethnopharmacol 284:114744

Anderson FJ (1997) An illustrated history of the herbals. iUniverse, Bloomington
Anjum R (2025) Neuroprotective role of traditional Chinese plant extracts on Parkinson disease; a comprehensive preclinical review. Pharmacol Res-Mod Chin Med. https://doi.org/10.1016/j.prmcm.2025.100573
Babu SN, Noor A (2023) Medicinal plants in the Indian traditional medicine and current practices. In: Bioprospecting of tropical medicinal plants, pp 253 286
Bagla VP (2012) Isolation and characterization of compounds from Podocarpus henkelii (Podocarpaceae) with activity against bacterial, fungal and viral pathogens University of Pretoria]Basu R, Dasgupta S,
Balkrishna A, Sharma N, Srivastava D, Kukreti A, Srivastava S, Arya V (2024) Exploring the safety, efficacy, and bioactivity of herbal medicines: bridging traditional wis dom and modern science in healthcare. Future Integr Med 3(1):35–49
Briskin DP (2000) Medicinal plants and phytomedicines. Linking plant biochemistry and physiology to human health. Plant Physiol 124(2):507–514
Chaudhari S, Tayade P (2024) The impact of integrating arti ficial intelligence in Ayurveda: a new era of traditional medicine
Chociej P, Foss K, Jabłon ´ska M, Ustarbowska M, Sawicki T (2024) The profile and content of polyphenolic com pounds and antioxidant and anti-glycation properties of root extracts of selected medicinal herbs. Plant Foods Hum Nutr 79(2):468–473
Choudhury A (2022) Potential role of bioactive phytochemi cals in combination therapies against antimicrobial activity. J Pharmacopunct 25(2):79
Daly WJ, Brater DC (2000) Medieval contributions to the search for truth in clinical medicine. Perspect Biol Med 43 (4):530–540
Dhole SP, Yedey S (2024) Ayurveda-Dosha assessment: a computational survey of the human body's constitution. In: Recent advances in science, engineering & technol ogy. CRC Press, pp 215–226
Dong S (2023) The development of modern Chinese medicine in a comparative perspective of the history of Chinese and western medicine. BCP Educ Psychol 10:107–117
Elendu C (2024) The evolution of ancient healing practices: from shamanism to Hippocratic medicine: a review. Medicine 103(28):e39005
El-Saadony MT, Saad AM, Mohammed DM, Korma SA, Alshahrani MY, Ahmed AE, Ibrahim EH, Salem HM, Alkafaas SS, Saif AM (2025) Medicinal plants: bioactive compounds, biological activities, combating multidrug resistant microorganisms, and human health benefits-a comprehensive review. Front Immunol 16:1491777
Ghosh S, Bishal A, Ghosh SK, Jana K, Gayen B, Sahu S, Debnath B (2023) Herbal medicines: a potent approach to human diseases, their chief compounds, formulations, present status, and future aspects. Int J Membr Sci Technol 10:442–464
Inchauspe AA (2025) The concept of Tao and of Yin/Yang: a study on origins and dynamics of the five movements. Adv Anthropol 15(3):73–117
Jaeger S (2012) A geomedical approach to Chinese medicine: the origin of the Yin-Yang symbol. In: Recent advances in theories and practice of Chinese medicine, pp 29–44

Kamath V (2025) Assessing classification approaches for cat egorizing Ayurvedic herbs. Multimedia Tools Appl 84 (9):6711–6735

Kapoor L (2020) Opium poppy: botany, chemistry, and phar macology. CRC Press, Boca Raton

Khare T, Anand U, Dey A, Assaraf YG, Chen Z-S, Liu Z, Kumar V (2021) Exploring phytochemicals for combating antibiotic resistance in microbial pathogens. Front Phar macol 12:720726

Kizhakkeveettil A, Parla J, Patwardhan K, Sharma A, Sharma S (2024) History, present and prospect of Ayurveda. In: History, present and prospect of world traditional medi cine. World Scientific, pp 1–72

Laines-Hidalgo JI, Mun˜oz-Sa´nchez JA, Loza-Mu¨ller L, Va´z quez-Flota F (2022) An update of the sanguinarine and benzophenanthridine alkaloids' biosynthesis and their applications. Molecules 27(4):1378

Latif, R., Nawaz, T. Medicinal plants and human health: a comprehensive review of bioactive compounds, therapeutic effects, and applications. Phytochem Rev 25, 2299–2342 (2026). https://doi.org/10.1007/s11101-025-10194-7

Lepcha I, Patra B, Saha D (2023) Medicinal plants in Ayurveda and Unani systems including Siddha in the Indian sce nario. Shashwat Publication, Bilaspur

Lord R (2021) Clinical herbalism-E-book: clinical herbalism E-book. Elsevier Health Sciences, Amsterdam

Luo L, Zhou J, Liu X, Chen Y, Du X, Gao L, Sun Y, Wang S (2025) Development of modern Chinese medicine guided by molecular compatibility theory. J Adv Res 73:713–728

Lust J (2014) The herb book: the most complete catalog of herbs ever published. Courier Corporation, Grants Pass

Ma JK, Chikwamba R, Sparrow P, Fischer R, Mahoney R, Twyman RM (2005) Plant-derived pharmaceuticals–the road forward. Trends Plant Sci 10(12):580–585

Manisha DRB, Begam AM, Chahal KS, Ashok MA (2025) Medicinal plants and traditional uses and modern appli cations. J Neonatal Surg 14(3):162–175

Marisetti AL, Sharma A, Tiwari A, Tiwari V, Karwasra R, Mittal V, Bhatia S, Al-Harrasi A, Khodaie L (2025) Drug discovery, commercial applications, regulations, safety and toxicity of latexes. In: Introduction to plant-based latex. Jenny Stanford Publishing, pp 361–445

Matos LC, Machado JP, Monteiro FJ, Greten HJ (2021) Understanding traditional Chinese medicine therapeutics: an overview of the basics and clinical applications. Healthcare. https://doi.org/10.3390/healthcare9030257

Mukherjee S, Bera S, Banerjee S, Mitra A, Mukherjee PK (2022) Ayurveda—translational approaches towards val idation as sustainable healthcare practices. In: Evidence based validation of herbal medicine. Elsevier, pp 463–485

Neuhaus W, Reininger-Gutmann B, Rinner B, Plasenzotti R, Wilflingseder D, De Kock J, Vanhaecke T, Rogiers V, Jı´rova´ D, Kejlova´ K (2022) The rise of three Rs centres and platforms in Europe. Altern Lab Anim 50(2):90–120

Nurzyn´ska-Wierdak R, Walasek-Janusz M (2025) Chemical composition, biological activity, and potential uses of oregano (Origanum vulgare L.) and oregano essential oil. Pharmaceuticals 18(2):267

Paiva LS, Motta MH, Baptista JAB (2024) Nutraceutical value of eleven aromatic medicinal plants and azorean Camellia sinensis: comparison of antioxidant properties and phe nolic and flavonoid contents. Processes 12(7):1375

Patel K, Patel DK (2024) Biological importance of Phel lodendrine in traditional and modern medicines: an update on therapeutic potential in medicine. Curr Drug Res Rev 16(2):209–218

Patil A, Singh N, Patwekar M, Patwekar F, Patil A, Gupta JK, Elumalai S, Priya NS (2025) AI-driven insights into the microbiota: figuring out the mysterious world of the gut. Intell Pharm 3(1):46–52

Paudyal V, Sun S, Hussain R, Abutaleb MH, Hedima EW (2022) Complementary and alternative medicines use in COVID-19: a global perspective on practice, policy and research. Res Social Adm Pharm 18(3):2524–2528

Saadh MJ, Mustafa MA, Kumar S, Gupta P, Pramanik A, Rizaev JA, Shareef HK, Alubiady MHS, Al-Abdeen SHZ, Shakier HG (2024) Advancing therapeutic efficacy: nanovesicular delivery systems for medicinal plant-based therapeutics. Naunyn Schmiedebergs Arch Pharmacol 397 (10):7229–7254

Saggar S, Mir PA, Kumar N, Chawla A, Uppal J, Kaur A (2022) Traditional and herbal medicines: opportunities and challenges. Pharmacogn Res. https://doi.org/10.5530/ pres.14.2.15

Singh LS (2024) Developing nanocarrier-based formulations of antidiabetic drugs derived from medicinal plants: a sys temic review. Pharmacol Res-Nat Prod 2:100004

Soni N, Soni G (2025) Synergy between Prakriti and medicinal plants in Ayurveda. Prakriti: interdisciplinary perspectives on ayurvedic constitutions, p 77

Taleghani A, Eghbali S, Moghimi R, Mokaber-Esfahani M (2024) Crataegus pentagyna Willd. fruits, leaves and roots: phytochemicals, antioxidant and antimicrobial potentials. BMC Complement Med Ther 24(1):126

Tapia ECO, Albitres J, Caldero´n PCC, Mendoza GMA, Jime´ nez HRP, Giro´n ECA (2024) Health and medical informatics research: identifying international collabora tion patterns at the country and institution level. Iberoam J Sci Meas Commun 4(3):1–16

Teuscher E, Lindequist U (2024) Natural poisons and venoms: plant toxins: alkaloids and lectins. Walter de Gruyter GmbH & Co KG, Berlin

Ungerer JT (2025) Grow, gather, heal: mullein-the gentle giant of herbal medicine: a deep dive into mullein, exploring it's history, traditional and modern day uses and studies, recipes, remedies and growing. John T. Ungerer, Rushden

Wang X, He B (2024) Endothelial dysfunction: molecular mechanisms and clinical implications. MedComm 5(8): e651

Withering W (2014) An account of the foxglove, and some of its medical uses. Cambridge University Press, Cambridge

Yang R, Wang R, Xu A, Zhang J, Ma J (2024) Mitigating neurodegenerative diseases: the protective influence of baicalin and baicalein through neuroinflammation regu lation. Front Pharmacol 15:1425731

Yildirim M, Cimentepe M, Dogan K, Necip A, Amangeldinova M (2025) Next-generation antibacterial cryogels: Ber berine-infused smart membranes with molecular docking guided targeting of MRSA and MDR E. coli. Biophys Chem. https://doi.org/10.1016/j.bpc.2025.107481

Zhu X, Zhao P, Jiang L, Qi Y (2025) Sanguinarine-induced proteomic changes in methicillin-resistant Staphylococcus aureus. Xenobiotica. https://doi.org/10.1080/00498254. 2025.2530998