

THE CHEMISTRY INSIDE SPICES & HERBS: RESEARCH AND DEVELOPMENT

VOLUME 5



Editors:
Pankaj Kumar Chaurasia
Shashi Lata Bharati

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The Chemistry Inside Spices & Herbs: Research and Development

(Volume 5)

Edited by

Pankaj Kumar Chaurasia

*Chemical, Biological and Environmental Laboratory,
P.G. Department of Chemistry,
Langat Singh College, Babasaheb
Bhimrao Ambedkar Bihar
University, Muzaffarpur,
Bihar, India*

&

Shashi Lata Bharati

*Department of Chemistry,
North Eastern Regional Institute
of Science and Technology (NERIST),
Nirjuli, Arunachal Pradesh
India*

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FOREWORD

The book titled “**The Chemistry Inside Spices and Herbs: Research and Development (Volume 5)**” is a unique collection of knowledge and information on detailed phytochemistry, emerging extraction techniques, and pharmacological advantages of different medicinally renowned plants. The involvement of different researchers, scientists, and professors as experts in developing the unique content of this book makes it more informative and valuable. Its first chapter extensively deals with the various emerging technologies in the field of the extraction of different phytochemicals from spices and herbs. Comprehensive phytochemical and pharmacological literature on the medicinally significant plants like *Catharanthus spp.*, *Podophyllum spp.*, *Mappia spp.*, *Annona spp.*, *Bryophyllum pinnatum*, *Azadirachta indica*, and *Andrographis paniculata* (Burm. f.) Wall. ex Nees, and *Euphorbia* spp. shows the excellent utility of the book in the field of biochemistry, phytochemistry, and medicine.

I hope this book will be an excellent source for the researchers, scientists, academicians, and students working or studying in the field of Ayurveda, biochemistry, naturopathy, and medicinal phytochemistry.

Shailendra Kumar Sinha
Professor and Head
P.G. Department of Chemistry
L.S. College, Muzaffarpur, India

PREFACE

This book, **volume 5** of the book series “**The Chemistry Inside Spices and Herbs: Research and Development**,” presents an extensive discussion on the various phytochemical extraction techniques, and comprehensive literature on the phytochemistry and medicinal advantages of various pharmacologically significant herbs/plants like *Catharanthus*, *Podophyllum hexandrum*, *Mappia*, *Annona*, *Bryophyllum pinnatum*, *Azadirachta indica* L., *Andrographis paniculata*, and *Euphorbia*. This volume is composed of a total of nine chapters written by experts in their field and is an excellent source of literature on the aforementioned medicinal plants’ phytochemical and pharmacological attributes.

Chapter 1, Written by Bamidele *et al.*, delves into the principles and applications of different extraction methods, supported by case studies of spices and herbs. Emphasis is placed on their potential for scalability, improved bioavailability, and creation of high-value products for the nutraceutical, pharmaceutical, and food industries. Future advancements require a multidisciplinary approach to refine these techniques to enable sustainable and efficient phytochemical recovery tailored to industrial applications.

Chapter 2, Written by Sarkar *et al.*, deals with the detailed chemistry and pharmacological roles of *Catharanthus*, commonly known as Madagascar periwinkle. The promising pharmacological profile of *Catharanthus* highlights the necessity for ongoing exploration into its phytochemical constituents and their therapeutic applications, which could pave the way for the development of new treatments for a variety of diseases, thereby reinforcing the plant’s significance in both traditional and modern medicine.

Chapter 3, Written by Patel *et al.*, presents a comprehensive assessment of chemistry and pharmaceutical roles of *Podophyllum*. *Podophyllum hexandrum* L., a perennial herb native to the Himalayan region, has garnered significant attention due to its remarkable medicinal properties. This plant, known as the "divine drug," possesses a rich repertoire of secondary metabolites with potent pharmacological activities. Through a detailed analysis of the phytochemistry and pharmacology of *Podophyllum*, this chapter provides critical insights into the potential of this remarkable medicinal plant while advocating for sustainable approaches to its utilization and the development of safer derivatives for clinical use.

Chapter 4, Written by Ameen *et al.*, presents a descriptive overview of the phytochemistry and pharmacology of *Mappia*. This chapter also explores the barriers and opportunities to exploit *Mappia*'s pharmacological potential fully, highlighting the need for more studies to isolate new molecules and understand their mechanisms of action.

Chapter 5, Written by Kumar *et al.*, examines the phytochemical and pharmacological profiles of *Annona*, with particular reference to the broad spectrum of bioactive compounds that are found within this genus and their pharmacological properties. This chapter has endeavoured to bring together Western trends in scientific research and indigenous wisdom and culled from it the benefits of *Annona* as a medicinal plant.

Chapter 6, Written by Rajak *et al.*, presents an insight into phytochemistry and medicinal properties of *Bryophyllum pinnatum*. The phytochemistry and pharmacology of *Bryophyllum pinnatum* highlight its potential as a versatile medicinal agent. Further research is warranted to explore its therapeutic applications in many other health-related issues.

Chapter 7, written by Sharma and Kumar, describes the chemistry and medicinal applications of *Azadirachta indica* L, commonly known as 'Neem'. Due to its promising traditional medicinal applications, it is also known as "Village dispensary".

Chapter 8, Written by Agarwalla *et al.*, is envisioned to provide an extensive study of diverse phytochemicals present in *Andrographis paniculata* and their pertinent pharmacological actions to support its ethno-medicinal uses with an opportunity for development in the future. *Andrographis paniculata* (Burm. F.) Wall. Ex Nees, usually known as Kalmegh or Green chiretta, is a distinguished herbal plant belonging to the taxonomic family Acanthaceae with a worldwide distribution.

Chapter 9, Written by Thakur *et al.*, presents a thorough investigation of the phytochemistry of *Euphorbia* and seeks to review the wide array of bioactive compounds available from different species. The chapter also discusses historical uses of *Euphorbia* as herbal medicine. The integration of traditional knowledge with modern pharmacological research highlights the importance of *Euphorbia* as a valuable source of therapeutic agents. This comprehensive review aims to provide valuable information on the chemical profile of *Euphorbia* sp. and of its potential therapeutic uses.

Pankaj Kumar Chaurasia

P.G. Department of Chemistry, L.S. College,
B. R. Ambedkar Bihar University,
Muzaffarpur-842001, Bihar,
India

&

Shashi Lata Bharati

Department of Chemistry, North Eastern
Regional Institute of Science and
Technology (NERIST), Nirjuli-791109,
Itanagar, Arunachal Pradesh,
India

List of Contributors

Arati Chourasiya	Department of Pharmacy, Indira Gandhi National Tribal, University, Amarkantak, Madhya Pradesh, India
Anamita Sen	School of Agriculture Sciences and Forestry, Sardar Bhagwan Singh University, Balawala, Dehradun, Uttarakhand, India
Abhishek Kumar	Institute of Pharmaceutical Research, GLA University, Mathura, Uttar Pradesh, India
Ankur Srivastava	Institute of Pharmacy, Dr. Ram Manohar Lohia Avadh University, Ayodhya, Uttar Pradesh, India
Abhramanu Ganguly	Department of Animal Science, Kazi Nazrul University, Asansol, West Bengal, India
Ajay Thakur	Department of Chemistry, University Institute of Sciences, Chandigarh University, Gharuan, Mohali, Punjab, India
Cristóbal N. Aguilar	Bioprocesses and Bioproducts Research Group, Food Research Department, School of Chemistry, Universidad Autónoma de Coahuila, Saltillo, Coahuila, Mexico
Dibyendu Shil	Department of Pharmaceutical Chemistry, Mata Gujri College of Pharmacy, Mata Gujri University, Kishanganj, Bihar, India
Durgawati Patel	Bhagyoday Tirth Pharmacy College, Sagar, Madhya Pradesh, India
Dilip Kumar Chaurasiya	Faculty of Agricultural Sciences, GLA University, Mathura, Uttar Pradesh, India
Deepti Dwivedi	Institute of Pharmacy, Dr. Shakuntala Misra National Rehabilitation University, Lucknow, Uttar Pradesh, India
Devendra Kumar	College of Biotechnology, Uttar Pradesh Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya, Mathura, Uttar Pradesh, India
Arati Chourasiya	Department of Pharmacy, Indira Gandhi National Tribal, University, Amarkantak, Madhya Pradesh, India
Farooq Ahmad	Department of Botany, University of Agriculture, Faisalabad, Pakistan
Jashabir Chakraborty	Department of Pharmaceutical Chemistry, Mata Gujri College of Pharmacy, Mata Gujri University, Kishanganj, Bihar, India
Kamalesh Sen	Department of Environmental Science, Syamsundar College, Shyamsundar, Burdwan, West Bengal, India
Muyideen O. Bamidele	Bioprocesses and Bioproducts Research Group, Food Research Department, School of Chemistry, Universidad Autónoma de Coahuila, Saltillo, Coahuila, Mexico
María L. Flores-López	Centro de Investigación e Innovación Científica y Tecnológica, Universidad Autónoma de Coahuila, Saltillo, Coahuila, Mexico
Mónica L. Chavez-González	Bioprocesses and Bioproducts Research Group, Food Research Department, School of Chemistry, Universidad Autónoma de Coahuila, Saltillo, Coahuila, Mexico
Muhammad Shahbaz	Department of Botany, University of Agriculture, Faisalabad, Pakistan

Muhammad Sajid Aqeel Ahmad	Department of Botany, University of Agriculture, Faisalabad, Pakistan
Mahima	Institute of Pharmacy, Dr. Shakuntala Misra National Rehabilitation University, Lucknow, Uttar Pradesh, India
Monika Verma	Department of Chemistry, University Institute of Sciences, Chandigarh University, Gharuan, Mohali, Punjab, India
Nimrah Ameen	School of Agriculture & Biology, Shanghai Jiao Tong University, Shanghai, China
Olga B. Álvarez Pérez	Research and Technical Development Department, GreenCorp Biorganiks de Mexico S.A de C.V., Saltillo, Mexico
Prem Rajak	Department of Animal Science, Kazi Nazrul University, Asansol, West Bengal, India
Pimily Langthasa	Department of Zoology, Gargaon College, Gargaon, Simaluguri, Assam, India
Pakiza Begum	Department of Chemistry, Gargaon College, Gargaon, Simaluguri, Assam, India
Ruchi Bharti	Department of Chemistry, University Institute of Sciences, Chandigarh University, Gharuan, Mohali, Punjab, India
Renu Sharma	Department of Chemistry, University Institute of Sciences, Chandigarh University, Gharuan, Mohali, Punjab, India
Sibaji Sarkar	Department of Pharmaceutical Chemistry, Mata Gujri College of Pharmacy, Mata Gujri University, Kishanganj, Bihar, India
Saumendu Deb Roy	Department of Pharmaceutical Chemistry, Mata Gujri College of Pharmacy, Mata Gujri University, Kishanganj, Bihar, India
Sushanta Kumar Das	Department of Pharmaceutical Chemistry, Mata Gujri College of Pharmacy, Mata Gujri University, Kishanganj, Bihar, India
Shubham Tripathi	School of Pharmacy and Research Centre, Sanskriti University, Chhata, Mathura, Uttar Pradesh, India
Satadal Adhikary	Post Graduate Department of Zoology, A.B.N. Seal College, Cooch Behar, West Bengal, India
Suchandra Bhattacharya	Department of Chemistry, A.B.N. Seal College, Cooch Behar, West Bengal, India
Sukhendu Dey	Department of Environmental Science, The University of Burdwan, Burdwan, West Bengal, India
Sandeepa Agarwalla	Department of Botany, Gargaon College, Gargaon, Simaluguri, Assam, India
Tarun Sharma	Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya (CSK HPKV), Palampur, Himachal Pradesh, India
Uma Sharma	College of Biotechnology, Uttar Pradesh Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya, Mathura, Uttar Pradesh, India

CHAPTER 1

Emerging Techniques for Phytochemical Extraction from Spices and Herbs

Muyideen O. Bamidele¹, José Sandoval-Cortes¹, Olga B. Álvarez Pérez²,
Mónica L. Chavez-González¹, María L. Flores-López³ and Cristóbal N. Aguilar^{1,*}

¹ *Bioprocesses and Bioproducts Research Group, Food Research Department, School of Chemistry, Universidad Autónoma de Coahuila, Saltillo, Coahuila, Mexico*

² *Research and Technical Development Department, GreenCorp Biorganiks de Mexico S.A de C.V., Saltillo, Mexico*

³ *Centro de Investigación e Innovación Científica y Tecnológica, Universidad Autónoma de Coahuila, Saltillo, Coahuila, Mexico*

Abstract: The growing recognition of the health and culinary benefits of spices and herbs, driven by their rich phytochemical profiles, has accelerated research on advanced extraction techniques. These bioactive compounds, including polyphenols, flavonoids, alkaloids, terpenes, and essential oils, exhibit diverse therapeutic properties such as antioxidant, anti-inflammatory, antibacterial, and anticancer activities. However, traditional extraction methods often fall short and are characterized by prolonged processing times, low yields, and reliance on toxic solvents, which compromise both product integrity and environmental safety. To address these limitations, innovative “green” extraction methods have emerged as transformative alternatives. Techniques such as supercritical fluid extraction, ultrasound-assisted extraction, microwave-assisted extraction, and enzyme-assisted extraction optimize the yield and bioactivity while reducing the environmental impact. Furthermore, advanced strategies, such as pulsed electric field extraction and pressurized liquid extraction, paired with eco-friendly solvents, such as deep eutectic solvents and ionic liquids, have shown significant promise in enhancing efficiency and sustainability. This chapter delves into the principles and applications of these methods, supported by case studies of spices and herbs. Emphasis is placed on their potential for scalability, improved bioavailability, and creation of high-value products for the nutraceutical, pharmaceutical, and food industries. Future advancements require a multidisciplinary approach to refine these techniques to enable sustainable and efficient phytochemical recovery tailored to industrial applications.

* **Corresponding author Cristóbal N. Aguilar:** Bioprocesses and Bioproducts Research Group, Food Research Department, School of Chemistry, Universidad Autónoma de Coahuila, Saltillo, Coahuila, Mexico; E-mail: cristobal.aguilar@uadec.edu.mx

Keywords: Supercritical fluid, ultrasound-assisted extraction, microwave-assisted extraction, enzyme-assisted extraction.

INTRODUCTION TO MODERN PHYTOCHEMICAL EXTRACTION

Phytochemicals, which are bioactive compounds derived from plants, are transforming the nutraceutical, pharmaceutical, and functional food industries [1]. Owing to their antioxidant, anti-inflammatory, and antimicrobial properties, compounds such as polyphenols, alkaloids, and flavonoids from spices and herbs are pivotal for combating chronic diseases and promoting well-being [2]. However, their efficient extraction and stability remain bottlenecks owing to the susceptibility of phytochemical matrices to degradation under conventional methods reliant on toxic solvents and prolonged processing [3]. These limitations highlight the urgent need for next-generation extraction techniques [4, 5]. Emerging green technologies, such as ultrasound-assisted extraction (UAE), supercritical fluid extraction (SFE), and microwave-assisted extraction (MAE), have revolutionized phytochemical recovery through eco-friendly, precision-driven approaches [6, 7]. By leveraging sustainable solvents such as deep eutectic solvents (DES) and ionic liquids (ILs) and employing innovations in nanotechnology and artificial intelligence for process optimization, these methods achieve superior yields, enhanced bioactivity retention, and a reduced environmental footprint [8, 9]. Moreover, the integration of high-throughput omics technologies facilitates the discovery and characterization of novel phytochemicals, thereby expanding their applicability to global health and environmental sustainability [10]. As we transition towards a circular bioeconomy, these advancements position phytochemicals as a cornerstone of sustainable development, addressing critical global challenges such as resource efficiency and health equity [11].

Overview of Traditional Extraction Methods

Historically, phytochemical extraction has relied on conventional techniques such as maceration, Soxhlet extraction, hydrodistillation, and solvent extraction [12]. Although these methods have laid the groundwork for isolating bioactive compounds, their efficacy is increasingly being questioned in the context of modern applications that require precision and sustainability [13]. Conventional approaches often compromise the structural integrity of thermolabile and volatile phytochemicals due to exposure to prolonged heat and harsh solvents, leading to reduced yields, diminished bioactivity, and significant environmental footprints [14]. Additionally, these methods suffer from inefficiencies, such as high solvent consumption, time-intensive processing, and limited scalability, which are incompatible with the growing demand for green and cost-effective solutions [15].

As industries pivot towards sustainable practices, these traditional techniques are being replaced by innovative methodologies that prioritize eco-efficiency, enhanced selectivity, and the preservation of phytochemical integrity [16]. By critically examining these limitations, the scientific community is poised to reimagine extraction paradigms, paving the way for transformative advancements in phytochemical recovery and application [17].

• ***Limited Efficiency***

Traditional extraction methods, such as Soxhlet extraction and hydrodistillation, have long been used to isolate bioactive compounds [18, 19]. However, their limitations are becoming increasingly apparent in the face of modern demands for efficiency, sustainability, and quality [20]. Prolonged exposure to high temperatures and harsh solvents often compromises the stability of heat-sensitive and volatile phytochemicals, leading to degradation, evaporation, or irreversible structural changes that diminish their bioactivities [21]. Beyond these thermal and chemical stresses, the inefficiency of conventional techniques in navigating complex plant matrices restricts the recovery of diverse and structurally intricate compounds, often leaving valuable secondary metabolites unexploited [22]. Moreover, these methods are resource-intensive and consume large volumes of organic solvents and energy, raising concerns regarding their environmental impact and scalability [23].

• ***Lack of Selectivity***

The inherent non-specificity of conventional extraction techniques, such as maceration and Soxhlet extraction, frequently leads to the co-extraction of undesirable compounds, including pigments, lipids, and polysaccharides [24, 25]. This unintended recovery not only dilutes the concentration of the target bioactive compounds but also introduces significant challenges in downstream processing [26]. The presence of excess lipids or polysaccharides can interfere with compound isolation and bioassay accuracy, necessitating labour-intensive and resource-intensive purification steps [6]. These additional processes increase operational costs, extend processing times, and elevate the risk of target compound degradation, ultimately compromising efficiency and product quality [27].

• ***Environmental Concerns***

The widespread reliance on traditional organic solvents, such as benzene, toluene, and methanol, has raised critical concerns regarding their environmental and health implications [28, 29]. These solvents contribute to environmental degradation by releasing volatile organic compounds (VOCs), which exacerbate

Phytochemistry and Pharmacology of *Catharanthus*: Research and Development

Sibaji Sarkar^{1,*}, Saumendu Deb Roy¹, Dibyendu Shil¹, Jashabir Chakraborty¹ and Sushanta Kumar Das¹

¹ Department of Pharmaceutical Chemistry, Mata Gujri College of Pharmacy, Mata Gujri University, Kishanganj, Bihar, India

Abstract: *Catharanthus*, commonly known as Madagascar periwinkle, is renowned for its extensive phytochemical and pharmacological properties. The plant is an abundant source of alkaloids such as vincristine and vinblastine, which are pivotal in cancer chemotherapy due to their potent antineoplastic activities. In addition to these alkaloids, *Catharanthus* contains a variety of bioactive compounds, including flavonoids, tannins, saponins, and phenolic acids, which contribute to its wide-ranging therapeutic potential. Phytochemical studies have demonstrated that these compounds exhibit significant antioxidant, antimicrobial, anti-inflammatory, antidiabetic, and cardioprotective properties. Traditionally, *Catharanthus* has been used in folk medicine to treat an array of ailments, including diabetes, hypertension, malaria, and bacterial infections. Modern pharmacological research supports these traditional uses, revealing that *Catharanthus* extracts can effectively modulate blood glucose levels, reduce blood pressure, exhibit potent antimicrobial activity, and provide cardiovascular benefits. The integration of *Catharanthus* into contemporary medical practices underscores its potential as a source of novel therapeutic agents. However, further research is essential to fully elucidate the mechanisms of action of its bioactive compounds and to develop standardised, clinically viable extracts. The promising pharmacological profile of *Catharanthus* highlights the necessity for ongoing exploration into its phytochemical constituents and their therapeutic applications, which could pave the way for the development of new treatments for a variety of diseases, thereby reinforcing the plant's significance in both traditional and modern medicine.

Keywords: Alkaloids, anticancer agents, antidiabetic properties, antioxidant, apoptotic pathway, bioactive phytochemical, cardioprotective effect, *Catharanthus roseus*, cytotoxic compounds, ethnopharmacology, flavonoid, herbal therapeutics.

* Corresponding author Sibaji Sarkar: Department of Pharmaceutical Chemistry, Mata Gujri College of Pharmacy, Mata Gujri University, Kishanganj, Bihar, India; E-mail: sibajisarkar004@gmail.com

INTRODUCTION

Catharanthus roseus, or Madagascar periwinkle, is a plant with great scientific, medicinal, and cultural value. Members of its family, Apocynaceae, are known to be prolific in the production of bioactive compounds. *Catharanthus roseus* is classified taxonomically as part of the kingdom Plantae, phylum Tracheophyta, class Magnoliopsida, order Gentianales, family Apocynaceae, genus *Catharanthus*, and species *C. roseus*. This taxonomic framework places *Catharanthus roseus* in a class of plants universally recognized for their medicinal properties, especially in traditional and modern pharmacology [1, 2].

Morphologically, *Catharanthus roseus* is an evergreen, perennial herb or low shrub. It is often between 30 and 100 cm tall (Photo 1). The plant has a branching, woody stem and oblong, shiny leaves that are arranged oppositely. The flowers have five-lobed corollas and an extensive range of pink, white, and red, often with a very dark central zone. The fruits are made up of two cylindrical follicles containing hundreds of small, ovate, black seeds. The morphology of the plant also aligns well with most environmental conditions that mitigate the effects of harsh conditions, thereby contributing significantly to its widespread existence [3, 4].



Photo (1). Morphology of *Catharanthus roseus* – flower, leaf, stem, and root.

Catharanthus roseus - The native country of *Catharanthus roseus* is Madagascar. This plant thrives well in the humid tropical and subtropical climatic regions of the coastal regions of the island. On forest clearings, rocky surfaces, and on coasts, this plant grows spontaneously. Its advantages include ease of drainage and plentiful solar irradiation. However, its primary habitat remains Madagascar while *C. roseus* has been widely naturalized in many parts of the world, including Southeast Asia, India, Africa, and South America due to its adaptability and medicinal value [5, 6].

The worldwide distribution of *Catharanthus roseus* has been mainly facilitated through its medicinal uses that make it a plant cultivated in different parts of the world [7]. It is nowadays an element of ordinary gardens and parks, and collections of botanical gardens in many areas of tropical and subtropical regions. Ease of cultivation with aesthetic and pharmaceutical value makes this plant preferable for both private and commercial farming. It is normally produced from seeds or cuttings and does not tolerate much care, performing well with full sun exposure and consistent moisture levels in well-drained soils [8]. *Catharanthus roseus* has been traditionally used by people of different cultures for their folk medicine. For thousands of years in Madagascar, the plant has been used to treat various diseases like diabetes, malaria, and skin infections [9]. In India, the plant has been widely used in Ayurvedic medicine to treat various diseases such as diabetes, high blood pressure, and cancer. This traditional Chinese medicine also acknowledges the treatment capability of *C. roseus*, especially to utilize its diuretic and anti-inflammatory action. The application of the plant in numerous forms as part of traditional medicine emphasizes its cultural value across so many nations worldwide [10].

Catharanthus roseus's historical importance in modern medicine dates back to the mid-20th century, when the isolation of alkaloids vincristine and vinblastine in the plant saw a revolution in cancer treatment since they were successful in treating childhood leukaemia and Hodgkin's lymphoma. It marked the turning point in a field of cancer therapy since a huge number of phytochemical plant-based compounds could be realized to be useful in the development of life-saving drugs [11]. In addition to the success story of vincristine and vinblastine, the pharmacological properties of *C. roseus* compelled further investigation and led to other bioactive compounds that might be therapeutic agents. The contributions of this plant to modern medicine are but one example of the importance of ethnobotanical knowledge and the imperative of continued exploration in traditional medicinal plants for new drugs [12]. *Catharanthus roseus* is botanically and medicinally of importance with high value through a long history and wide global distribution. The taxonomic classification presents it as belonging to a family of plants, often known for producing diverse bioactive compounds.

CHAPTER 3

Phytochemistry and Pharmacology of *Podophyllum*: A Comprehensive Assessment

Durgawati Patel¹, Dilip Kumar Chaurasiya², Arati Chourasiya^{3,*} and Anamita Sen⁴

¹ Bhagyoday Tirth Pharmacy College, Sagar, Madhya Pradesh, India

² Faculty of Agricultural Sciences, GLA University, Mathura, Uttar Pradesh, India

³ Department of Pharmacy, Indira Gandhi National Tribal, University, Amarkantak, Madhya Pradesh, India

⁴ School of Agriculture Sciences and Forestry, Sardar Bhagwan Singh University, Balawala, Dehradun, Uttarakhand, India

Abstract: *Podophyllum hexandrum*, a perennial herb native to the Himalayan region, has garnered significant attention due to its remarkable medicinal properties. This plant, known as the “divine drug,” possesses a rich repertoire of secondary metabolites with potent pharmacological activities, including antifungal, antioxidant, antibacterial, anticancer, antiviral, and insecticidal properties. The primary bioactive constituent of *Podophyllum* is podophyllotoxin, an aryltetralin lignan found in the roots and rhizomes of the plant. Podophyllotoxin has exhibited promising cytotoxic and antitumor effects, making it a valuable compound in the treatment of certain cancers. Moreover, *Podophyllum* and its components have anti-inflammatory, metal chelation, free radical scavenging, apoptosis inhibition, DNA repair pathways, and gastrointestinal, hemopoietic, and testicular protection.

Despite its remarkable therapeutic potential, the direct clinical application of *Podophyllum* is hindered by its inherent toxicity and the production of adverse effects. Consequently, significant efforts have been directed toward the development of safe and effective analogs of podophyllotoxin that possess superior pharmacological properties. In conclusion, *Podophyllum hexandrum* is a valuable medicinal plant with a rich phytochemical profile and diverse pharmacological activities, while advocating for sustainable approaches to its utilization and the development of safer derivatives for clinical use. Through a detailed analysis of the phytochemistry and pharmacology of *Podophyllum*, this chapter provides critical insights into the potential of this remarkable medicinal plant while advocating for sustainable approaches to its utilization and the development of safer derivatives for clinical use.

* Corresponding author Arati Chourasiya: Department of Pharmacy, Indira Gandhi National Tribal University, Amarkantak, Madhya Pradesh, India; E-mail: pchemarati@gmail.com

Keywords: Anticancer, antioxidant, medicinal plant, *Podophyllum hexandrum*, phytochemistry, pharmacology, podophyllotoxin.

INTRODUCTION TO *PODOPHYLLUM*

Plant-derived compounds account for approximately 25% of the most commonly used substances in modern medicine. In the northwestern Himalayas, *Podophyllum hexandrum* [L.] Royle is a significant medicinal plant known for producing podophyllotoxin, a powerful anti-cancer compound. The term *Podophyllum* is derived from two ancient Greek words: *podos* (meaning “foot”) and *phyllon* (meaning “leaf”), referring to the leaf's shape, which resemble a duck's foot. Currently, three species of *Podophyllum* are commonly used, most of which belong to the genus *Podophyllum*: *Podophyllum hexandrum*, *Podophyllum peltatum*, and *Podophyllum sikkimensis*. Among these, *Podophyllum hexandrum* contains significantly higher levels of podophyllotoxin compared to the other species, making it particularly valuable for medicinal applications [1]. Several valuable plants economically important that have potential medicinal uses are found in the North Western Himalayas. An increase in the utilisation of medicinal plants in preference to synthetic materials has caused a high rate of exploitation of plant species. These facilities improve the standards of living of needy societies as they provide a measure of income besides the medical one [2]. *Podophyllum hexandrum* Royle is a very useful plant belonging to the family Berberidaceae. Although generally recognized by its theoretical name of Himalayan Mayapple, *Podophyllum* is a genus of plants, which translates into English as ‘foot-shaped leaf’, because the form of the leaf looks like a duck's foot. Six species of this genus namely *P. peltatum*, *P. hexandrum*, and *P. sikkimensis*. However, *P. hexandrum* and *P. peltatum* are the most commercially important [3].

The rhizome, foliage, fruits, and roots of the plant possess culinary, medicinal, ornamental, and fiber applications. The following are all used in Chinese and Ayurvedic medication for curing different illnesses, including Hodgkin's lymphoma, monocytoid leukemia, bacterial and viral diseases, venereal plants, paralysis of limbs, rheumatoid arthritis, and pyogenic infections of cutaneous tissues. Moreover, studies have confirmed that treatment using *P. hexandrum* could be effective in the management of radiation-induced cell and tissue damage. Some of the physiologically active metabolites available in *P. Hexandrum* have cytotoxic, antifungal, anti-inflammatory, antioxidant, and radioprotective effects [4]. According to Ayurveda, Unani, and Tibetan pharmacy, *P. hexandrum* has been used to cure many diseases. Podophyllotoxin and its related semisynthetic derivatives, Etoposide, Teniposide, and Etoposide phosphate are all derived from rhizomes and roots. These compounds are used for the treatment of non-lymphocytic leukemia, non-Hodgkin's lymphomas, and testicular carcinomas.

Moreover, etoposide has shown its efficacy in the treatment of AIDS associated Kaposi's sarcoma and lung cancer. Moreover, the isolated plant *P. hexandrum* exhibits a high level of antioxidant property because of its ability to neutralise free radicals [5]. While this plant exhibits great medicinal use, the populations of the subterranean portions of *P. hexandrum* have diminished due to overexploitation. There are conservation problems with the species at the moment. The species is rare and threatened in India and worldwide, according to the IUCN Red List. Due to horticulture extraction for its aromatic rhizomes and roots, the plant has suffered dramatic population declines and is currently a species native only to certain alpine zones.

Earlier, it was known as Aindri, which is described as a divine material of *P. hexandrum*. Podophyllotoxin belongs to the group of natural plant secondary metabolites, and the major source is the root of *P. hexandrum* and allied species. This is due to its anticancer, antineoplastic and anti-HIV activity, which puts it to have great pharmacological and therapeutic importance. One thing needs to be clarified that the *P. hexandrum*, obtained in India, is much better than the *P. peltatum* of American origin. This is because the desiccated roots contain a higher concentration of *P. hexandrum* in the Indian plant [4%] than in that of the *P. peltatum* [0.25%]. As mentioned earlier, this plant contains podophyllotoxin and is also described as a natural lignin. More importantly, this lignin shows cell toxicity. For its antiviral activity, podophyllotoxin is known to feature in many pharmacopoeias and is used as an antiviral reagent. It is used in the treatment of condyloma acuminatum, which is a viral disease caused by the human papilloma virus or any other virus.

This is a foundation on which steady production methods need to be set up, depending on the current conservation problems with the goal of supplying reliable, abundance of superior quality *P. hexandrum*. To ensure the availability of this important medicinal plant at future dates and to define effective modes of protection, an investigation of genetic variability and population dissemination of this plant is needed.

Like other orchid species, *P. hexandrum* is covered by the CITES rules on commercial utilization that prohibit the export of specimens of wild origin from India. Measures taken in the conservation crisis have considered both ex situ and in situ practices, in vitro multiplication techniques, and seed germination technologies to mitigate the pressure arising from the harvesting of seeds from natural habitats. The National Medicinal Plant Board of India has developed actions to save threatened medicinal plants, such as *P. hexandrum*, through organized plantation.

CHAPTER 4

Phytochemistry and Pharmacology of *Mappia*: Research and Development

Nimrah Ameen^{1,*}, Muhammad Shahbaz², Farooq Ahmad², Muhammad Sajid Aqeel Ahmad² and Tarun Sharma³

¹ School of Agriculture & Biology, Shanghai Jiao Tong University, Shanghai, China

² Department of Botany, University of Agriculture, Faisalabad, Pakistan

³ Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya (CSK HPKV), Palampur, Himachal Pradesh, India

Abstract: *Mappia*, a genus in the *Icacinaceae* family, has attracted widespread interest due to its potent bioactive chemical compounds and pharmacological properties. The most important species, *Mappia foetida*, also known as *Nothapodytes foetida*, is known for its high concentration of camptothecin, a monoterpene indole alkaloid with anticancer effects. Camptothecin and its derivatives, such as topotecan and irinotecan, are commonly used in chemotherapy to treat ovarian, colorectal, and lung malignancies. Phytochemical studies on *Mappia* species have shown various secondary metabolites, including alkaloids, flavonoids, terpenoids, and phenolic chemicals. These chemicals show various pharmacological actions, including anti-inflammatory, antibacterial, antioxidant, and anticancer properties. *Mappia*'s pharmacological potential lies in its ability to regulate critical biological processes such as apoptosis, cell cycle arrest, and DNA topoisomerase inhibition. Its pharmacological interest continues to be the focus of research for innovative therapeutic agents, and ongoing research explores its full potential in drug development and complementary medicine. Research has also shown that *Mappia* extracts have the potential as therapeutic agents for various diseases, including cancer, microbial infections, and inflammatory disorders. This chapter also explores the barriers and opportunities to fully exploit *Mappia*'s pharmacological potential, highlighting the need for further studies to isolate new molecules and understand their mechanisms of action.

Keywords: Camptothecin, *Mappia*, Phytochemistry, Pharmacology.

INTRODUCTION

The genus *Mappia* Jacquin was established by Mears in 1852. This genus is related to the Neotropical species *Lereticia Vellozo*, which has several different

* Corresponding author Nimrah Ameen: School of Agriculture & Biology, Shanghai Jiao Tong University, Shanghai, China; E-mail: nimrahameen22@gmail.com

treatments. Many authors have combined these genera, while others have retained both. *Neolaretia Baehni* is a new genus for the Asian genus *Mappia*. The palynological data support *Laretia* and *Mappia* as distinct organisms. Based on the phylogenetic analysis, *Mappia* and *Laretia* are not closely related, being sister to *Mapia* of the Asian genus *Nothapodytes*. However, many genera have not been included in molecular phylogenetic studies, leaving the relationships between members of the *Mappia* complex and other glacial genera such as *Lavigeria*, *Pleurisanthes*, *Iodes Blume*, and *Phytocrene* [1]. Therapeutic plants are gaining appeal in developing nations due to their safety, dependability, and few side effects. Traditional medicine is utilized initially and foremost for basic health care, and it supports 80% of the world's population. Biodiscovery of novel pharmaceuticals from plant sources has higher commercial value [2]. Free radicals, which cause oxidative damage to proteins, lipids, and DNA, play a significant role in illnesses including cancer, diabetes, and aging. Plants, particularly those rich in antioxidants, produce secondary metabolites such as alkaloids, flavonoids, tannins, cardiac glycosides, sterols, and amino acids [3].

Natural antioxidants can lessen the risk of cancer as well as other disorders. *Nothapodytes nimmoniana* is a large, poisonous tree that can cause cancer. *Nothapodytes foetida*. Wight includes significant quantities of the powerful chemicals camptothecin (CPT) and 9-methoxycamptothecin, which have been linked to cancer [4]. Camptothecin inhibits nuclear DNA topoisomerase and has been demonstrated to block Tat-mediated activation of the human immunodeficiency virus type 1 (HIV-1) LTR, making it a prospective target for HIV-1 therapy. However, camptothecin is not utilized therapeutically because its cytotoxicity effects are the most effective cancer therapy on the planet [4].

Camptothecin and its derivatives suppress the development of human cancer cells *in vitro* and cause total regression of breast cancers. This resulted in the creation of water-soluble camptothecin substitutes, such as irinotecan (CPT-11) and topotecan, which have attracted attention in recent years and have been licensed for cancer therapy [5]. The extraction and recovery of fruits is an important step in the study of chemicals originating from many plants. Most extraction techniques are time and labor-intensive, necessitating extensive handling, heavy metals, and heat. Bioactive chemicals have been extracted from plant materials using various techniques, including stir extraction, Soxhlet extraction, and ultrasonic extraction. Microwave extraction has been used to extract essential oils, polysaccharides, fragrances, and phytochemicals from numerous plant sources. However, no study has been conducted on the utilization of alternative extraction techniques for the extraction of CPT and 9-Me-CPT from the dry plant material *N. foetida* to shorten the extraction time and raise the extraction percentage [6].

BOTANICAL DESCRIPTION

Mappia mexicana and *M. longipes* are distinct species in appearance and distribution. Mexican mappa grows in the woods and forests of northern Mexico. Its leaves are short and oval, with the background darkened, and all the flowers are crazy. *Mappia longipes* has oval or oval leaves, small stems (about 3 cm long), and mature flowers. It grows up to 1300 meters in the cloud forest of Chiapas (southeast Mexico), as shown in Fig. (1). In addition, its distribution area is more general and is found in the dry forests of *Cuba*, *Jamaica*, and *Puerto Rico* [7]. Previous evolutionary studies using plastid molecular markers (*ndhF*), and morphological data have been carried out in *Mappia* and related groups [8]. According to the results, *Mappia* supports the terrestrial form (*M. longipes*, *M. mexicana*, and *M. multiflora*) sister to *M. racemosa* from the West Indies. However, these relationships have not been established in molecular and morphological studies due to limited data and insufficient evidence.



Fig. (1). Botanical description.

Phylogenetic Markers

In recent years, digitizing environmental history collections has made it possible to integrate these materials into international archives and produce high-resolution global environmental data [9]. The integration of this data provided valuable insight into the global distribution of biodiversity and the role of ecological variation in species. Niche maintenance is defined as the number of ecological characteristics maintained over time [10]. Most species exhibit adaptive variation at the local population level, such as the swamp orchid. Different temperature environments can act to impede gene flow, leading to reproductive isolation and reduced connectivity between populations. There were two distinct species in the West Indies with similar physical characteristics and comparisons [11].

CHAPTER 5

Phytochemical and Pharmacological Profiling of *Annona* Species

Abhishek Kumar^{1,*}, Deepti Dwivedi², Ankur Srivastava³, Mahima² and Shubham Tripathi⁴

¹ Institute of Pharmaceutical Research, GLA University, Mathura, Uttar Pradesh, India

² Institute of Pharmacy, Dr. Shakuntala Misra National Rehabilitation University, Lucknow, Uttar Pradesh, India

³ Institute of Pharmacy, Dr. Ram Manohar Lohia Avadh University, Ayodhya, Uttar Pradesh, India

⁴ School of Pharmacy and Research Centre, Sanskriti University, Chhata, Mathura, Uttar Pradesh, India

Abstract: *Annona* is the common name for a number of species of flowering plants, and they are known to provide some of the nutrients needed in the diet. This chapter examines the phytochemical and pharmacological profiles of *Annona*, with particular reference to the broad spectrum of bioactive compounds found within this genus and their pharmacological properties. *Annona* contains phytochemical compounds, such as acetogenins, alkaloids, flavonoids, and essential oils, all of which explain its medicinal use. This chapter discusses the extraction techniques, chemical profiling of the plant, and pharmacodynamics in relation to anticancer, antimicrobial, anti-inflammatory, and antidiabetic activities. Furthermore, it has provided information on the clinical uses, risks involved, and prospects for further investigation of plants belonging to the *Annona* family. This chapter has endeavored to bring together Western trends in scientific research and indigenous wisdom and culled the benefits of *Annona* as a medicinal plant.

Keywords: Acetogenins, anticancer activity, antimicrobial properties, anti-inflammatory effects.

INTRODUCTION

The genus *Annona* in the *Annonaceae* family comprises several flowering plants that are common in the tropics and subtropics. The plants in this genus are not only valued for their ornamental beauty but also as a good source of nutrition and medicine. *Annona* species in this family are naturally distributed in the New

* Corresponding author **Abhishek Kumar:** Institute of Pharmaceutical Research, GLA University, Mathura, Uttar Pradesh, India; E-mail: abhiworld1997@gmail.com

World, particularly in the Americas, Africa, and parts of Asia, and have been traditionally used for food and medicine [1]. This large genus contains many species that are ethnomedicinally and economically important; some of them are *Annona muricata*, known as soursop, *Annona squamosa*, sugar apple, cherimoya, and *Annona cherimola*. Originally, members of the *Annona* genus were used for their fruits, leaves, seeds, and bark, some of which were used in various medicinal products. Besides their medical benefits, people from indigenous backgrounds have incorporated these plants into their practices. This is based on the empirical data acquired from the folk use of these plants as cures for various ailments, accumulated over centuries, and their therapeutic efficiency, as determined by their phytochemical constituents. These results suggest that some species contain biologically active compounds with therapeutic applications that have been affirmed in traditional pharmacopoeias and are currently receiving scientific support [2].

OVERVIEW OF SPECIES

Annona muricata (Soursop), also known as soursop or graviola, is among the most popular species of this genus. It is used in various parts of the tropical Americas, where it is primarily grown in Central and South America and islands of the Caribbean. Often, its fruit is described as being large and spiky with green skin and a soft, pulpy, juicy interior with a taste somewhat similar to that of strawberry and pineapple with a trace of citrus. The unripe and ripe fruit pulp, leaves, and seeds of *A. muricata* are traditionally used for their therapeutic effects [3]. Soursop has been used in South American folk medicine for many ailments for several years. For instance, by simply boiling them in water, infusions are used to cure fever, asthma, and diarrhea. These infusions are used to cure ailments associated with the respiratory tract, digestive system, and inflammatory diseases. Moreover, the present study found that the leaves and bark of *Annona muricata* can be used to prepare ointments for the treatment of wounds and skin infections. Because of its high content of vitamin C, antioxidants, and dietary fiber, the fruit is consumed for its nutritional value. It is also used in the treatment of insomnia and anxiety. Bacupin has been used in the treatment of different forms of cancer, and in recent years, the name *Annona muricata* L. has received much attention globally because of its therapeutic uses in alternative medicine [3].

• *Annona squamosa* (Sugar Apple):

Another member of the *Annona* family, the sugar apple is originally from the tropical regions of the Americas, but it is now also grown in Asian, African, and Pacific regions. This fruit is easily identified by its bumpy, green skin that surrounds it and spills out a taste that is both sweet and custard-like, with a white

color. Similar to many species of this genus, the fruit is valued for its food utility and is rich in vitamins, fiber, and minerals [4]. The medicinal value of *Annona squamosa* is common in South Asian and African countries. Sugar apple leaves are used in India for treating various ailments such as wounds, ulcers, and infections. They are usually fresh, pounded, or soaked in water to yield related active constituents. Besides, the seeds of the fruit have a historical record of being used as an anthelmintic agent to cure parasitic ailments, particularly intestinal worms. The fruit is also said to have digestive health benefits, and has a cooling effect. It works in easing indigestion, heartburn, and constipation. In West Africa, it has been identified as an antimalarial; sugar apple leaves and bark are incorporated into various medicinal mixtures [5].

• ***Annona cherimola* (Cherimoya):**

Cherimoya, also known as custard apple, was originally found in the Andes of South America. Cherimoya is a large, heart-shaped fruit with edible skin that is green in color and has a creamy white, delicate texture on the inside. Pound cake is popular for its taste and is described as pineapple-y, banana-y, and strawberry-like in some cases. Originally, people ate cherimoya pulp only fresh, and it can still be used in the preparation of juices, shakes, and sweet dishes [6]. Cherimoya seeds, which contain toxic elements, are usually separated before the fruit is eaten. Besides eating, the Ark of Taste *Annona cherimola* has also been used in traditional medicine for the treatment of various conditions. In Peru, this tree is mostly used for preparing herbal teas and decoctions made from the leaves and bark to cure fevers, coughs, and respiratory disorders. The fruit is also used to treat stomach complaints, skin diseases, and general debility, and as a tonic for the weak [7].

Uses In Different Countries

• ***South America***

In South America, particularly in countries such as Brazil, Colombia, and Peru, diverse species of *Annona* are of great medicinal use to local communities. The leaves, bark, and roots of *Annona muricata* have been used in traditional medicine to treat fever, cough, and digestive system disorders. The fruit of *Annona cherimola* has an edible part used mainly for its sweetening and energizing properties, while the seed part of the plant is used cautiously to eliminate parasites because of its anthelmintic nature [8].

Root extracts of *Annona* species have also been used by South American herbalists for parasitic disorders. The multiple topical applications of *Annona* preparations are for the treatment of skin infections and wound healing. Some of

A Comprehensive Insight into the Phytochemistry and Medicinal Properties of *Bryophyllum pinnatum*

Prem Rajak^{1,*}, Abhratanu Ganguly¹, Satadal Adhikary², Suchandra Bhattacharya³, Sukhendu Dey⁴ and Kamalesh Sen⁵

¹ Department of Animal Science, Kazi Nazrul University, Asansol, West Bengal, India

² Post Graduate Department of Zoology, A.B.N. Seal College, Cooch Behar, West Bengal, India

³ Department of Chemistry, A.B.N. Seal College, Cooch Behar, West Bengal, India

⁴ Department of Environmental Science, The University of Burdwan, Burdwan, West Bengal, India

⁵ Department of Environmental Science, Syamsundar College, Shyamsundar, Burdwan, West Bengal, India

Abstract: *Bryophyllum*, a genus of succulent plants, has been employed as traditional medicine for centuries. Phytochemical analysis has demonstrated a diverse spectrum of bioactive compounds, including flavonoids, alkaloids, glycosides, and bufadienolides. These compounds contribute to various pharmacological properties. The widely studied *B. pinnatum* exhibits anti-inflammatory, antioxidant, and antimicrobial activities, making it a potential treatment alternative for various health issues. The anti-diabetic properties of *B. pinnatum* have been demonstrated through enhanced insulin sensitivity and glucose uptake. The plant also has beneficial effects on cardiovascular health, with vasodilatory and antihypertensive properties. Furthermore, *B. pinnatum* has been found to possess anti-cancer properties, inducing apoptosis and inhibiting tumor growth. Its neuroprotective effects have also been reported, with potential applications in neurodegenerative diseases. Additionally, the anti-ulcerogenic and wound-healing properties of *B. pinnatum* have been documented. Overall, the phytochemistry and pharmacology of *B. pinnatum* highlight its potential as a versatile medicinal agent. Further research is warranted to fully explore its therapeutic applications in many other health-related issues.

Keywords: Anti-inflammatory, *Bryophyllum*, Cardiovascular health, Neuroprotection.

* Corresponding author Prem Rajak: Department of Animal Science, Kazi Nazrul University, Asansol, West Bengal, India; E-mail: prem.rjk@gmail.com

INTRODUCTION

Bryophyllum, also known as Kalanchoe, belongs to the family Crassulaceae and is a genus of succulent plants that are native to tropical and subtropical regions of Africa, Asia, and Europe, comprising approximately 125 species, characterized by their fleshy leaves, stems, and roots. The fleshy character of the plant parts enables them to store water and survive in arid environments. They have notable medicinal values [1]. Some species of this plant can grow up to 10 cm in length and produce numerous plantlets along the edges of their leaves. *B. pinnatum*, also known as the Air Plant, is native to Madagascar and southern Africa. However, it can also be found in other parts of the world, including India, Nepal, Myanmar, Australia, Brazil, and China. *B. daigremontianum*, also known as the Mother of Millions, is another notable species native to Madagascar, with leaves that produce numerous small plantlets that can detach and grow into new plants. This unique reproductive feature of the plant makes it a popular ornamental plant, but also a highly invasive species in many parts of the world. Another notable species is *B. delagoense*, which is also known as the Chandelier plant. This plant species is native to South Africa and has leaves that are shaped like a chandelier and produce numerous small plantlets. Another species is *B. tubiflorum*, which is native to Madagascar. This plant species has leaves that are shaped like tubes and produces numerous small plantlets. Different species of *Bryophyllum* have adapted to their environments in unique ways. For instance, they have developed CAM photosynthesis, which enables them to open their stomata at night and avoid water loss by conserving the water content in the succulent parts of the plant [2]. Moreover, various species of *Bryophyllum* have specialized roots that enable them to absorb water and nutrients from the soil. These plants have also been used in traditional medicine for various purposes, including treating wounds, fever, and respiratory problems, and have been cultivated as ornamental plants due to their unique shapes and colors. In addition, various species of *Bryophyllum* have been used as a food source in some parts of the world, with the leaves and stems being edible and rich in nutrients. Despite their many uses and adaptations, plants of *Bryophyllum* are also highly invasive in many parts of the world, outcompeting native species for resources and habitat, and causing significant ecological and economic damage.

Extracts of various parts of *B. pinnatum* have several medicinal properties. For instance, the leaf extract of *B. pinnatum* has been found to exhibit gastric ulcer healing properties [3]. This gastroprotective activity of *B. pinnatum* has been attributed to the biological activity of flavonoids found in the species. Moreover, the phenolic compounds of the plant extract have been found to enhance GSH content and lower lipid peroxidation. In another investigation, the leaf extract of *B. pinnatum* has been reported to exert anti-inflammatory and chemoprotective

effects in the rodent model of colitis. Flavonoids such as quercetin-3-O-rhamnopyranoside, kaempferol 3-O- α -L-arabinopyranosyl-(1-2)- α -L-rhamnopyranoside, and quercetin 3-O- α -L-arabinopyranosyl-(\rightarrow 2)- α -L-rhamnopyranoside, were reported to have immunomodulatory potential [4]. More specifically, the bioactive compounds found in the plant extract of *B. pinnatum* downregulate the gene expression of *kappa* B p65 nuclear factor and Toll-like receptor. This outcome is mainly responsible for the reduction in inflammatory and oxidative stress mediators, in addition to a decline in chemokines. This action of bioactive compounds in *B. pinnatum* enables them to exert anti-inflammatory effects [4]. Ethanolic extract of *B. pinnatum* has also been reported to provide relief from diarrhea by improving the antioxidant status of the body [5]. Notably, the aqueous extract of *B. pinnatum* has been demonstrated to exert dose-dependent anxiolytic and psychoactive effects on model animals [6]. The plant species have also been reported to have anti-cancer medicinal properties. For instance, in a study, chloroform extract of *B. pinnatum* has been reported to suppress the expression of anti-apoptotic molecules Bcl-2 and improve the expression of pro-apoptotic protein Bax. Moreover, the plant extract was also demonstrated to enhance the induction of caspase-3 and PARP-1 cleavage. These results suggest the leaves of *B. pinnata* have anti-HPV and anticancer medicinal properties [7].

Therefore, various plant parts of *B. pinnatum* have a number of medicinal properties, and these therapeutic potentials are mainly attributed to the different phenolic compounds found in the plant. Therefore, the present chapter aims to present the phytochemistry of *Bryophyllum* and the therapeutic potential of the plant against various health ailments. In addition, the chapter also aims to delve into the putative molecular mechanism through which the bioactive compounds in the plant exert their medicinal functions.

PHYTOCHEMISTRY

The phytochemistry of *Bryophyllum* is characterized by the presence of a diverse range of bioactive compounds, including flavonoids, phenolic acids, triterpenoids, and bufadienolides, which are responsible for the medicinal and pharmacological properties of the herb. The leaves and stems of *B. pinnatum* contain flavonoids like quercetin, kaempferol, and isorhapontigenin, which have been shown to possess antioxidant, anti-inflammatory, and antimicrobial activities [8 - 10]. Phenolic acids, such as caffeic acid, ferulic acid, and sinapic acid, are also present in *B. pinnatum* species and have been reported to have antioxidant and anti-inflammatory effects [11, 12]. The terpenoid fraction of *B. pinnatum* includes compounds like lupeol, α -amyrin, and β -sitosterol, which have been shown to possess anti-inflammatory, antimicrobial, and antiproliferative activities.

CHAPTER 7

Phytochemistry and Pharmacology of *Azadirachta indica* L.: Research and Development

Uma Sharma^{1,*} and Devendra Kumar¹

¹ College of Biotechnology, Uttar Pradesh Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya, Mathura, Uttar Pradesh, India

Abstract: *Azadirachta indica* L. belongs to the family Meliaceae and is a commonly growing, evergreen tree that is widely distributed throughout India. It is commonly known as Neem. In India, the traditional medical system uses all of its sections to treat a variety of illnesses, giving it the nickname “village dispensary.” According to traditional medical literature, it has a long history of therapeutic use. In Indian medical systems, all parts of *Azadirachta indica* L. have been utilized. Numerous therapeutic applications of *Azadirachta indica* L. have made it significant in today's worldwide setting. Many illnesses, including dermatitis, eczema, acne, bacterial and fungal infections, and other skin ailments, can be treated with neem. Inflammation, infections, fever, skin conditions, and dental disorders have been treated with neem tree parts, including the seeds, fruits, twigs, leaves, blossoms, roots, and bark. Various beneficial bioactive compounds have been isolated from different plant parts, including quercetin, salannin, nimbolinin, nimbin, nimbidin, nimbidol, and azadirachtin. Various extracts of the *Azadirachta indica* L. tree have antiviral, antibacterial, antifungal, and hypoglycemic properties, among others. Both chemical and particle pollution from the atmosphere are expected to be reduced by the tree.

Keywords: *Azadirachta indica* L., Bioactive compounds, Medicinal plant, Meliaceae, Neem.

INTRODUCTION

For many people around the world, medicinal plants continue to be an important part of healthcare systems, particularly in underdeveloped nations where they have long been utilized. The therapeutic and economic benefits of these plants are becoming increasingly recognized in both developed and developing countries. They are still developing new medications for humanity. Medicinal plant treatment is founded on experimental findings that date back hundreds to

* Corresponding author Uma Sharma: College of Biotechnology, Uttar Pradesh Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya, Mathura, Uttar Pradesh, India; E-mail: umasharma1988mtr@gmail.com

thousands of years, and some of the beneficial qualities attributed to plants have been shown to be erroneous [1].

Certain chemical compounds found in plants have therapeutic potential because they have a specific physiological effect on humans. Alkaloids, flavonoids, phenolic compounds, and tannins are the most significant of these bioactive plant components. Traditional treatments are being sought after as an alternative medicine by numerous scientists and organizations. An estimated 25% of all prescribed medications currently in use are believed to be derived from plants [2]. Plants have produced almost 7,000 distinct compounds that are used today, including analgesics, antibiotics, laxatives, anticancer drugs, contraceptives, diuretics, and decongestants [3].

The Indian Subcontinent gave rise to the alternative medical system known as Ayurveda, which is now practiced worldwide. The term “Nimba” in Sanskrit refers to “good health,” which eventually evolved into “Neem.” The tree is also known as “Sarvaroganivarini,” which translates to “cure all ailments.” Neem is referred to in Ayurveda as “Arishtha,” which means “reliever of sickness.” In India, the tree's medical qualities have led to its continued designation as a “divine tree” or “village pharmacy” [4, 5]. The herbal plants used in Ayurveda are the source of many contemporary medications that have no known adverse effects. It is estimated that over 70% of pharmaceuticals originate from Mother Nature, and more than 80% of people rely on plant-based health products [6 - 8].

One of the best and most important tree species in India is Neem (*Azadirachta indica* L.), which belongs to the family Meliaceae. It is one of the most significant and adaptable trees on the Indian subcontinent, growing on a variety of soil types, including those with pH levels as high as 10. Since the Vedic era, Indian farmers have cultivated it for its numerous applications, and it is now deeply ingrained in Indian culture. It grows well in all agroclimatic zones in India, with the exception of higher elevations, colder climates, and dam locations. The trees of *Azadirachta indica* L. are frequently found growing sporadically in farmers' fields and along field borders in India, unaffected by the crops. Since ancient times, people have employed every component of this amazing tree to treat hundreds of different illnesses. Even though neem is highly valued in India for its exceptional healing qualities, new research has significantly raised awareness of the plant internationally, and it is now used in the production of several goods. Neem was shown to be more effective than any other Indian herb at assisting the body in preserving its natural equilibrium and fending off illnesses [9].

Additionally, India's entire medicinal plant trade in 2004–05 was valued at 4,530 crore. The quantity and value of medicinal plant exports from India place it second in the world. A native medicinal plant in India, neem has therapeutic

qualities in all parts of its plant, including roots, seeds, flowers, bark, leaves, and fruit pulp. One type of phytotherapy used in supplementary medicine is neem. Every plant component has been utilized in the Indian Ayurvedic and Unani medical systems and is now a staple of contemporary medicine [10].

According to Ayurvedic literature, neem is well-renowned for its therapeutic qualities, including its cold, bitter, astringent, and caustic bark. It is also used to treat worm infestation, fever, cough, fatigue, and loss of appetite. In addition, it treats wounds, vitiated conditions of kapha, diabetes, vomiting, skin disorders, and excessive thirst. Chemicals found in the leaves along the bark are said to be useful for treating eye conditions and insect venom. It serves as an anti-leprotic and cures vitiligo condition. Its fruits have anti-hemorrhoidal, purgative, bitter, and anthelmintic properties [11].

ETHNOBOTANICAL DESCRIPTION OF *AZADIRACHTA INDICA* L.

Botanical Description

Neem is a fast-growing tree, with a height up to 15–20 mt (49–66 ft), and rarely 35–40 mt (115 to 131 ft). It is evergreen, but in drought conditions, it may shed most or nearly all of its leaves, with wide branches, spreading fairly, and dense roundish crown that may reach a diameter of 20–25 mt (66–82 ft). Mostly on the leaf axils, it bears several flowering panicles. The ovate flower has white oblanceolate petals that smell great and is about 1 cm long. It produces 12–20 mm long, yellow, ellipsoid, and glabrous drupes. The green fruits eventually turn yellow as they mature and have a garlicky scent. In March or April, new blooms and leaves appear (Figs. 1 & 2). The ripening period of fruits depends on the location, but it is mostly between April and August; the fruit pulp is then edible [12].

It usually works effectively in regions that receive 400–1200 mm of rainfall annually. The highest temperatures, with maximum daily temperatures of 50 degrees Celsius, are ideal for its growth. However, it is unable to tolerate prolonged cold or freezing. Although neem thrives in black cotton soils, it can grow in nearly every type of soil, including clayey, saline, and alkaline soils. On dry, stony, saline soils with a waterless subsoil or in areas with a hard, calcareous, or clay pan close to the surface, it performs better than most other trees. It is not tolerant of flooding. Calcium mining is one of its special qualities; it converts acidic soil into neutral soil. Additionally, neem thrives in some acidic soils (Figs. 1 & 2).

CHAPTER 8

Phytochemistry and Pharmacology of *Andrographis paniculata* (Burm. f.) Wall. ex Nees: A Traditionally Significant Herb

Sandeepa Agarwalla¹, Pimily Langthasa² and Pakiza Begum^{3,*}

¹ Department of Botany, Gargaon College, Gargaon, Simaluguri, Assam, India

² Department of Zoology, Gargaon College, Gargaon, Simaluguri, Assam, India

³ Department of Chemistry, Gargaon College, Gargaon, Simaluguri, Assam, India

Abstract: Delving into the world of plants, phytochemistry and pharmacology are vital in unlocking the healing powers these natural wonders hold. Researchers and pharmaceutical scientists are actively exploring the potential and pharmacological properties of herbal plants in response to the side effects of allopathic medicine. *Andrographis paniculata* (Burm. F.) Wall. ex Nees, commonly known as Kalmegh or Green chiretta, is a renowned herbal plant belonging to the taxonomic family Acanthaceae with a worldwide distribution. Since time immemorial, it has been used extensively by tribal and indigenous people as an effective herbal medicine with varied pharmacological activities. The plant in whole (leaves, roots, and stems) or its parts with well-known ethno-medicinal properties have been widely used for treating various ailments in Ayurveda, Siddha, homeopathic and Sri Lanka's traditional medicine systems. Phytochemicals with diverse molecular structures belonging to different chemical classes, including flavonoids, saponins, diterpenes, xanthenes, noriridoides, and volatiles, were identified from this herb. The investigated compounds have been tested for various pharmacological activities, including anti-diabetic, anti-inflammatory, antimicrobial, wound healing, headache, cytotoxicity, anti-protozoal, immunostimulant, anti-infective, anti-angiogenic, hepato-renal protective, antimalarial, and anti-hypertensive properties. Notably, andrographolide, a colourless, crystalline compound with a distinctly bitter taste, unequivocally stands as the pivotal bioactive element of the plant, rendering it a highly promising candidate for the development of novel anticancer drugs. This chapter aims to provide an extensive study of the diverse phytochemicals present in *A. paniculata* and their pertinent pharmacological actions, supporting its ethnomedicinal uses and providing opportunities for future development.

* **Corresponding author Pakiza Begum:** Department of Chemistry, Gargaon College, Gargaon, Simaluguri, Assam, India; E-mail: pakiza.gc20@gmail.com

Keywords: *Andrographis paniculata*, Andrographolide, Anticancer, Antidiabetic, Anti-inflammatory, Antimicrobial, Ayurveda, Bioactive, Diterpenes, Ethnomedicinal, Flavonoids, Herbal, Homeopathic, Immunostimulant, Novel drug development, Pharmacology, Phytochemicals, Saponins, Siddha, Xanthones.

INTRODUCTION

Medicinal flora encompasses species distributed globally that are esteemed for their curative attributes. These flora function as a natural reservoir for the synthesis of pharmaceuticals. Researchers and pharmaceutical scientists are diligently examining the therapeutic potential and pharmacological characteristics of medicinal herbs in response to the side effects linked to conventional treatments, thereby providing safer and more efficacious alternatives to synthetic medications. They occupy a crucial position in traditional healing methodologies, pharmacological applications, and ecological conservation. Their acknowledgment is essential for a multitude of applications. This exploration not only endeavours to substantiate traditional applications but also aspires to discover innovative compounds that may result in novel therapeutic alternatives, thereby reconciling the divide between historical knowledge and contemporary scientific understanding.

The well-known herbal plant of the Acanthaceae family, *Andrographis paniculata* (Burm. F.) Wallich ex Nees, commonly known as “Kalmegh” and “King of bitters,” is extensively used as a therapeutic agent in Indian medicine for the treatment of a wide spectrum of diseases. About 21 species of *Andrographis* are reported to occur in India, of which *A. paniculata* (Burm. F.) Wallich ex Nees is known to be medicinal [1]. In addition to its medicinal uses, *Andrographis* is often incorporated into dietary supplements and herbal formulations, appealing to those seeking natural alternatives for health maintenance. It is incorporated in about 26 Ayurvedic formulations as evidenced from Indian Pharmacopoeia; whereas, in Traditional Chinese Medicine, it is employed for its antipyretic properties [2]. Among the multitude of medicinal flora, it has garnered significant interest from researchers across the globe. Owing to its remarkable antioxidant characteristics, which are frequently associated with potent pharmacological effects, coupled with its ample availability and minimal cultivation requirements, *Andrographis* species may be regarded as one of the most promising plant genera warranting further exploration and application [3, 4]. Extensive research has revealed the wide array of phytochemicals found in it, which can significantly contribute to its beneficial effects, highlighting the importance of integrating traditional knowledge with modern scientific approaches to the plant.

BOTANICAL DESCRIPTION AND TAXONOMIC NOMENCLATURE

A. paniculata is a perennial, branched, herbaceous plant that reaches a height varying between 30 and 110 cm in habitats characterized by moisture and shade. The stem is acutely quadrangular and extensively branched. The leaves are simple, arranged oppositely, lanceolate in shape, and glabrous, measuring from 2 to 12 cm in length and 1 to 3 cm in width, with margins that are acute and entire or exhibit slight undulations; the upper leaves often take on a bractiform configuration and are supported by a short petiole. The inflorescence may be terminal or axillary, forming a panicle that ranges from 10 to 30 mm in length; the bract is diminutive, and the pedicel is notably short. The flowers are characterized by a calyx composed of five small and linear segments; the corolla tube is narrow, approximately 6 mm in length; the limb exceeds the tube in length and is bilabiate, with the upper lip being oblong, white, and featuring a yellowish apex, while the lower lip is broadly cuneate, three-lobed, white with violet markings; the stamens is at number two, inserted within the throat and markedly exerted; the anther is bearded at the base. The ovary is superior and bilocular; the style is notably exerted. The fruit of the plant is erect, linear-oblong, measuring between 1 and 2 cm in length and 2 and 5 mm in width, compressed, longitudinally furrowed on the broader surfaces, and acute at both ends, being thinly covered with glandular hairs. The seeds are exceedingly diminutive and subquadrate in form [5 - 7]. The botanical description and taxonomic hierarchy of *A. paniculata* are mentioned in Table 1 below.

Table 1. *A. paniculata* (Burm. f.) Nees is a member of the following taxonomic groups [5].

Division	Angiosperma
Class	Dicotyledonae
Subclass	Gamopetalae
Series	Bicarpellatae
Order	Personales
Family	Acanthaceae
Subfamily	Acanthoideae
Tribe	Justiciae
Subtribe	Andrographideae
Genus	<i>Andrographis</i>
Species	<i>A. paniculata</i> (Burm. f.) Nees

CHAPTER 9

Phytochemistry and Pharmacology of *Euphorbia*: Research and Development

Ajay Thakur¹, Ruchi Bharti^{1*}, Monika Verma¹ and Renu Sharma¹

¹ Department of Chemistry, University Institute of Sciences, Chandigarh University, Gharuan, Mohali, Punjab, India

Abstract: *Euphorbia* is a genus (with over 2000 species) belonging to the family *Euphorbiaceae* that has a long list of species known for their highly impressive phytochemical and medicinal attributes. This chapter presents a very thorough investigation of the phytochemistry of *Euphorbia* and seeks to review the wide array of bioactive compounds available from different species. Major secondary metabolites, such as diterpenoids, flavonoids, and alkaloids, are presented. The pharmacological activity of *Euphorbia* extracts is reviewed with an emphasis on their activities, such as anti-inflammatory, anticancer, antimicrobial, and antioxidant effects. The chapter also discusses the historical use of *Euphorbia* as a herbal medicine. The integration of traditional knowledge with modern pharmacological research highlights the importance of *Euphorbia* as a valuable source of therapeutic agents. This comprehensive review aims to provide valuable information on the chemical profile of *Euphorbia* species and their potential therapeutic uses.

Keywords: Bioactive compounds, *Euphorbia*, Medicinal plants, Phytochemistry, Pharmacology.

INTRODUCTION

Nature has always been at the heart of human life and development. It supplies us with food, materials for constructing shelters, and fabrics for clothing, making its resources invaluable. Additionally, nature has facilitated transportation, improved farming with natural fertilizers, and enriched our sensory experiences through flavors and scents. Most importantly, it has been a crucial source of medicinal compounds, forming the basis for medicine and healing throughout different cultures and eras, as shown in Fig. (1) [1]. Plants have been the basis of complex ethnomedicinal systems that emerged over generations. These ancestral practices,

* Corresponding author Ruchi Bharti: Department of Chemistry, University Institute of Sciences, Chandigarh University, Gharuan, Mohali, Punjab, India; E-mail: ruchi.uis@cumail.in

firmly based on cultural and empirical wisdom, persist as a wellspring of innovative and inventive solutions for contemporary medicine, deeply embedded in the cultural and therapeutic practices of countries like India [2] and China [3] for millennia. Through the provision of a vast library of bioactive molecules, plants continue to play a crucial role in addressing a broad spectrum of diseases by combining traditional knowledge with modern medical advancements [1].



Fig. (1). Applications of Medicinal Plants from Cosmetics to Healthcare [4-11].

Based on botanical studies, it has been estimated that the global flora contains approximately 250,000 to 350,000 different plant species. However, it is noteworthy that only approximately 35,000 of these species are utilised in traditional and modern medicinal practices to address a wide spectrum of illnesses across different parts of the world [12]. France and Germany have respectively been recognized as world leaders in the design and application of herbal medicines. Interestingly, Germany, with roughly 50% of the population, places high levels of trust in herbal medicines and considers them a trustworthy methodology to treat various diseases [13, 14]. Over the past few years, Pakistan has emerged as a significant trade partner in the global medicinal plants market, making it a valuable contributor to this rapidly expanding sector. The country is

currently the ninth-largest importer of medicinal plants, processing a substantial amount of 11,350 tonnes per year. Furthermore, Pakistan has also become the 10th largest exporter, exporting 8,100 tonnes of medicinal plants to various global markets [15]. Traditional medical practices in China and India utilize around 7,000 different plant varieties, demonstrating that natural resources are relied upon for healthcare [16, 17]. Moreover, the Import-Export Bank of the United States states that trade in products from medicinal plants around the world is growing steadily at around 7% annually [18, 19]. This increasing global relevance of medicinal plants is also illustrated in Table 1, which summarizes the different medicinal plants and their therapeutic activities, highlighting their importance and potential role in promoting medicinal research efforts. This shows the importance of medicinal plants in today's time and how much potential they have in solving the challenges of today.

Table 1. Different medicinal plants and their therapeutic activities.

Plant (Family)	Phytochemicals	Applications	Refs.
<i>Amaranthus hybridus</i> (Amaranthaceae)	Balsams, Resins, Courmarins, Triterpenoids, Tannins, Saponins, Phlobatannins, Flavonoids, Phenols	Source of dietary vitamins, Antidiuretic, Antimicrobial, Antioxidant	[20-22]
<i>Alchornea cordifolia</i> (Euphorbiaceae)	Phenols, flavonoids, saponins, tannins, and alkaloids.	Spasmolytic activity, antidiabetic activity, anxiolytic activity, anti-HIV activity, anti-drepanocytary activity, anti-fertility effect, immunomodulatory activity, anti-depressant effect, and anti-nociceptive activity.	[23, 24]
<i>Anisopus mannii</i> (Apocynaceae)	Steroids, anthraquinones, phlobatannins, tannins, saponins, alkaloids, cardiac glycosides, flavonoids, phenols, and terpenoids.	Analgesic activity, haematological, anti-inflammatory, antimicrobial, antidiabetic activity, and antioxidant activity.	[20, 25]
<i>Pentaclethra macrophylla</i> (Leguminosae)	Glycosides, tannins, reducing sugar, and flavonoids	Anti-Hyperlipidemic activity, antimicrobial activity, analgesic activity, anti-inflammatory activity, and antiulcerogenic activity.	[23, 26]
<i>Thymus vulgaris</i> (Lamiaceae)	Essential oils, saponins, steroids, terpenoids, phlobatannins, alkaloids, tannins, flavonoids, and phenols.	Insecticidal activity, antioxidant properties, anti-viral property, anti-bacterial activity, and anti-inflammatory property.	[20, 27]

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Pankaj Kumar Chaurasia

Dr. Pankaj Kumar Chaurasia, Ph.D. is assistant professor in the PG Department of Chemistry, L.S. College, Muzaffarpur (India). He has more than 8 years of experience in teaching at postgraduate (PG) and undergraduate (UG) levels. He has been awarded with CSIR-JRF (NET), CSIR-SRF (NET) and CSIR-RA. He received Ph.D. in chemistry in 2014. He also received the Research Excellence Award for the two consecutive years. He has more than 100 publications (59 journal publications, 37 book chapters and 12 books) and many are in the pipeline. He has guided one Ph.D. students. He has worked in different areas of chemistry and has research expertise in biological chemistry, biotechnology, microbiology, enzymology, organometallic chemistry and environmental chemistry.



Shashi Lata Bharati

Dr. Shashi Lata Bharati did Ph.D. in chemistry and is working as assistant professor in the Department of Chemistry, North Eastern Regional Institute of Science and Technology, Nirjuli, Arunachal Pradesh (India). She was awarded 'UGC-DSA fellowship' for the meritorious students during her Ph.D. program. She was awarded with UGC-post doctoral fellowship for women in 2013 by UGC New Delhi and worked as post-doctoral fellow in the Department of Chemistry of DDU Gorakhpur University, Gorakhpur (India). She has more than 75 publications including journal papers, book chapters and books with national and international journals/publishers of repute. She has guided many M.Sc. project students and one Ph.D. research scholar. She has expertise in the field of inorganic chemistry, organometallic chemistry, biological chemistry and enzymology.