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Medicinal plants and its therapeutic uses

Edited by
Dr. Birla Kshetrimayum

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Preface

Medicinal plants are an important part of our natural resources as they serve as an important therapeutic agents as well as valuable raw materials for manufacturing of various traditional and modern medicines. The history of medicinal plants used for treating diseases and ailments is probably dates back to the beginning of human civilization. Our forefathers are compelled to use any natural substances that they could find to ease their suffering caused by acute and chronic illness, wound injuries and even terminal illness. Since ancient time plants with therapeutic properties have secured an important place in the healing practices and treatment of diseases. In the many developing countries, traditional medicines are still the mainstay of the healthcare, and most of the drugs and cures from the natural resources such as plants. Even in the develop countries, the raw materials for manufacturing essential drugs are extracted from medicinal plants, harnessing its natural properties of healing and curing diseases. Increasingly more people are turning to herbal remedies especially for treatment of minor ailments. However, the inclination towards the revival and use of medicinal plants has resulted in a few undesirable outcomes. Medicinal plants abundant in supply are not infinite and with the widespread use and extraction, medicinal plants are on the verge of depletion. There are no visible and concerted effort geared towards conservation and wise use of medicinal plants, the supply which dwindling given the threats and increasing demand, a rapid increasing in human population and rampant destruction of plant rich habitats such as tropical forests. At the current rate of consumption and used. The status of medicinal plants is threatened risking our own future benefits and knowledge.

Thus the principal aim of the book is to provide information on the important ethno-medicinal plants of India especially North Eastern India which is part of the Indo Burma biodiversity hotspots of the world about the traditional knowledge of medicinal uses of medicinal plants in the treatment of various diseases by various communities, the phytochemicals and phytochemistry of various medicinal plants including anti-parasitic effects and lastly their biodiversity, sustainable used as well as mode of conservation. I believed that this book is one of the pioneering encyclopedia compilations that can provide information of many different medicinal plants at glance. I think that this book will be useful to the people interested in medicinal plants researches and this book is intended for Scientists, Post-Doctoral Fellows, Academicians and Research Scholars. However, it will also be useful to post graduate and graduate students as well as health professionals. I hope, this book will encourage them to discuss certain innovative things and aspects on the therapeutic uses of medicinal plants, their sustainable uses as well as conservation in order to provide an ideal platform for the isolation, purification and characterization of known bioactive/novel compounds present in these medicinal plants to synthesize future potential drugs against various diseases for the benefit of mankind.

About Editor

Birla Kshetrimayum, Ph.D. is working as a Senior Assistant Professor and teaching Zoology in the Pachuunga University College, Mizoram University, Aizawl, India since the year 2007. He did his Bachelor of Sciences (B.Sc.) from Manipur University, Canchipur and then obtained his Master of Science (M.Sc.) and Doctor of Philosophy (Ph.D.) Degree from the Department of Zoology (Centre for Advance Studies), Panjab University Chandigarh, India. He did his Post-Doctoral Research in a highly competitive International Research project entitled "Role of Zn2+ ion in Cell Signaling and Phosphorylation" sponsored by BBSRC, UK at the Diabetes and Nutritional Sciences Division, School of Medicines, Kings College, University of London, Waterloo Campus, United Kingdom. His field of specialization is Animal Physiology and Biochemistry and has more than 10 years of teaching and research experiences. His area of research interests are trace mineral nutrition research, metals metabolism, metabolic syndrome-X, gene polymorphism in diseases and recently natural products studies. He has to his credit more than 30 research papers in the journals of International repute, 1 books, 2 edited proceedings, and 7(six) book chapters. Some of the high impact factor journals where he published his research works were Coordination Chemistry Review (CCR), Bio Metals, Food and Nutrition Sciences (FNS), Asian Pacific Journal of Tropical Medicine (APJTM), Indian Journal of Experimental Biology (IJEB) etc. One of the research publications from his Ph.D. works was selected as "2nd Best Biomedical Article" released by the US National Library of Medicine in its lists of "World's Top 50 publications" for the year 2005-2012. He is currently acting as an Editorial board member of the 5 Research Journals of International repute and has reviewed more than 20 research papers from the journals of International repute. He has successfully completed 2 major and 3 minor research projects as Principal investigator/Coordinator from the various funding agencies in India like Department of Biotechnology (DBT), New Delhi and University Grant Commission (UGC), New Delhi. 1(one) research scholar has been successfully awarded Ph.D. degree from Mizoram University, Aizawl under his supervision. He has also presented 27 research papers in many International/national level seminars in India as well as overseas countries like

Cambridge, UK, Bangkok, Thailand, Singapore and South Korea etc. He also has organized 4 National level seminars/workshops as a full time "Convener" during the last 5 years. He is currently life member of 5 professional academic bodies in India and abroad namely Indian Sciences Congress Association(ISCA), Kolkata, The Nutrition Society of India, Hyderabad, India Bird Conservation Network (IBCN), Mumbai, North East Research Forum, Guwahati and Asia-Pacific Chemical, Biological & Environmental Engineering Society (APCBEES), Hong Kong.

Forewords

I am happy to learn that **Birla Kshetrimayum, Ph.D** is editing an E-book titled "***Medicinal Plants and its Therapeutic Uses***". I am pleased to learn that the contents of this E-book were outcome of cutting-edge researches carried out by senior and young scientists from different reputed institutions of India.

I am sure this E-book will be useful to other scientists, academicians and students working in the field of natural product research and its allied disciplines.

With best wishes

(Dr. S. Shantikumar Singh)
Assistant Professor
Department of Statistics
Manipur University,
Canchipur-795003 (Imphal),
Manipur

Acknowledgement

Publication of book involves consistent and dedicated mind regarding the strenuous and hard labour put in it. Here, it is a combine sense of pride and great privilege for me to get this golden opportunity to express my profound gratitude and admiration to Professor Wolfgang Maret of Diabetes and Nutritional Sciences Division, Kings College, University of London, who had given me valuable suggestions and encouragements during the of compilation of this book. I am grateful to Dr. Tawnenga, Principal, Pachhunga University College, Mizoram University, Aizawl for providing me necessary facilities during my research works which provide me a platform to carry out an advance research in order to get International recognization in the domain field of natural products researches which ultimately provide me an avenue to act as a single editor of this E-book. I owe my immense gratitude to Dr. Jay Prakash Rajan, Assistant Professor, Department of Chemistry, Pachhunga University College, Mizoram University, Aizawl for his corporation and help. Moreover, I would like to express my warms thanks to all those authors who have contributed their valuable research in this E-book without which this E-book may not be possible and also all those authors whose works have either been consulted or quoted. I am very grateful to Miss Sherryl, Managing Editor, Omics Group International, USA for her technical and editorial input during the preparation of the book. I am also sincerely thankful to my family members, colleagues and students for their constant encouragement and support. Last but not the least, the financial assistance provided to me by University, Grant Commission (UGC-NERO), India, to carry out a cutting edge and breakthrough research in the Ethnomedicinal plants of Mizoram, a north eastern states of India through Minor Research Project is greatly acknowledge

Introduction

Plants that possess therapeutic properties or exert beneficial pharmacological effects of the human body are generally designated as medicinal plants. Medicinal plants naturally synthesize and accumulate some secondary metabolites like alkaloids, sterols, terpenes, flavonoids, saponins, glycosides, tannins, resins, lactones, quinines and volatile oils. The medicinal plants have been used for the treatment of diseases and illness since the ancient times. Ancient Chinese scriptures and Egypt papyrus hieroglyphics describe medicinal uses of plants. Indigenous cultures in Africa and America used herbs in healing while other in developed traditional system (Indian ayurveda and traditional Chinese system) in which herbal therapies are used. Researchers have found that people in different parts of the world used same or similar plants parts for the treatment of the same illness.

Recently the world health organization (WHO) estimates that 75% of the people worldwide rely on the herbal medicines for their primary health care. In Europe countries like Germany and United Kingdom about 600-700 plants based medicines are available and also prescribed by same 70% physicians. In the last 15 years in the United States, public dissatisfaction in connection with side effects and the cost of the prescribe of allopathic medicines combine with an interest in returning to natural and organic remedies has led to an increase in herbal medicines used. During past three decades, the demand and utilization of medicinal plants has increased globally. There is now consensus regarding the importance of medicinal plants and traditional health systems in solving the health care problems, efficacy and safety of medicinal plants in curing various diseases. Because of this growing awareness, the international trade in plants of medicinal importance is growing phenomenally. The documentation of traditional knowledge can ensure local peoples right in the light of intellectual property rights and help avoid adverse impact on local people and the environment. The used of traditional knowledge in sustainable forest management can significantly contribute to the research and development of medicinal plants and reduce associate costs. Traditional knowledge on habitat, habit and use patterns of the wild plants by ethnic communities are essential for a sustainable forest management plan which is essential for restoration and conservation of wild diversity.

In addition to above, plants and their metabolites constituents have a long history of use in modern “western” medicine and in certain systems of traditional medicine, and are the sources of important drugs such as atropine, codeine, dioxin, morphine, quinine. Use of herbal medicines in developed countries has expanded sharply

in the latter half of the twentieth century. In recent years, the use of traditional medicine information on plant research has again received considerable interest. While the western use of such information has also come under increasing scrutiny and the national and indigenous rights on these resources has become acknowledged by most academic and industrial researchers. Meanwhile, the need for basic scientific investigations on medicinal plants using indigenous medical systems becomes imminent. The desire to capture the wisdom of traditional healing systems has led to a resurgence of interest in herbal medicines, particularly in Europe and North America, where herbal products have been incorporated into so-called alternative, "complementary", "holistic" or "integrative" medical systems. Monographs on selected herbs are available from a number of sources, including the European Scientific Cooperative on Phytotherapy, German Commission E and the World Health Organization. The WHO monographs, for example, describe the herb itself by a number of criteria (including synonyms and vernacular names) and the herb part commonly used, its geographical distribution, tests used to identify and characterize the herb (including macroscopic and microscopic examination and purity testing), the active principles (when known), dosage forms and dosing, medicinal uses, pharmacology, contra-indications and adverse reactions. During the latter part of the twentieth century, increasing interest in self-care resulted in an enormous growth in popularity of traditional healing modalities, including the use of herbal remedies; this has been particularly true in the USA. In the European market there are a lot of products derived from natural plants, which are recognized to possess different biological properties, such as antioxidant, antiseptic, diuretic, stimulating the central nervous system, sedative, expectorant, digestive, etc. Some of these plants have been used in traditional medicine since ancient times and are available on market as infusions, tablets and/or extracts. Consumers have reported positive attitudes towards these products, in large part because they believe them to be of "natural" rather than "synthetic" origin, they believe that such products are more likely to be safe than are drugs, they are considered part of a healthy lifestyle, and they can help to avoid un necessary contact with conventional "western" medicine.

Besides these, India has also a long history of traditional medicine and has a vast repository of medicinal plants that are used in traditional medical treatments and around 20,000 medicinal plants have been recorded. To date, however, there has been little rigorous scientific study of these traditional medicines and indigenous plants. The North East Region of India is full of natural resources especially in medicinal and aromatic plants, which are extensively used by the traditional user from time immemorial. Since this region lie in Indo-Burmese mega-biodiversity 'hot spot' region of the world and is the genetic treasure house of rich biological resources for a variety of wild as well as domesticated plants and a secondary vast source of natural products, some of which may have the potential to be developed into new drugs for treatment various diseases. In India the use of traditional medicine is widespread amongst the ethnic people and village dwellers. Although information on these species is available scatteredly and on a piecemeal basis, I felt urgent need to compile this information in one volume for each of reference and use by researches, academia and practitioners. Some of the listed species

in this book are becoming locally rare while some others are currently facing the risk of acute depletion. It is therefore, considered important to bring together the existing information on these species regarding availability, traditional uses, phytochemicals present, conservation and future scope for synthesizing potential drugs against various diseases.

Plants have been traditionally been used as a source of medicine by indigenous people of different ethnic groups inhibiting the hilly terrains for treating various ailments affecting humans and domestic animals. Form the time immoral, they have developed a close ethnobotanical relation with the surrounding flora. They also developed a local and community based traditional knowledge of plants such as food medicine, pesticides, dye, soap and other purposes. Traditional knowledge is adapted to local situations, traditionally shared and handed down to generations by the elderly members of the community. This traditional practitioners are time tested and have thorough experiences, innovations and experimentation, they are sustainable and protect soil and water, natural vegetation and biological diversity of forests in order to bank on this rare and rich pool of knowledge develop through trial and error, documentation of important plants is crucial for recording the records in the consolidated form. Documentation is required to store and manage in all relevant information of the species.

In this book, different chapters from the different authors have been included which cover biodiversity and conservation of medicinal plants, traditional uses of medicinal plants by various communities for the treatment of diseases, ethnomedicinal, phytochemistry and pharmacology of some selected medicinal plants. The photographs of the some of the species of plants reported in this book were provided. For most of the species, photographs of the entire plant, leaf, stem, seeds, flowers and fruits have been given. It is anticipated that this pioneering work on the medicinal plants will be widely used by professionals, students and herbal healers alike for the conservation, wise use, and revival of plants, indigenous knowledge and future research for the isolation of potential drugs against various diseases.

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Biodiversity and Conservation of Medicinal Plants

Sanatombi Rajkumari and K. Sanatombi*

Department of Biotechnology, Manipur University, Canchipur, Imphal-795003, India

***Corresponding author:** Dr. K. Sanatombi, Department of Biotechnology, Manipur University, Canchipur, Imphal-795003, India; Tel: 0385-2435233; E-mail: ksanatombi@rediffmail.com

Abstract

Medicinal plants are the principal economic resource for health care purposes which are used throughout human history since time immemorial. Millions of world's populations rely mainly on medicinal plants as herbal medicine and these plants are cultivated to meet their needs. Thus, it constitutes a significant part of their subsistence, need and income. Biodiversity of valuable medicinal plants satisfy the expansion of regional and international markets for cultural and economic purposes. The role and contributions of medicinal plants to healthcare, cultural and economic reasons for the well-being of people have been increasingly acknowledged over the past few decades. These increasing demands have been met by over- harvesting of spontaneous flora and have resulted in severe habitat loss, agriculture encroachment and genetic diversity depletion. Therefore, conservation and sustainable utilization of medicinal plant species have become tremendously important. Effective biodiversity conservation comprises of two main areas: in-situ conservation and ex-situ conservation. Conserving medicinal plant resources demands the need for intensive management, more research and increased level of public awareness for their socio-economic upliftment. Biodiversity conservation and management of medicinal plant populations and their potential habitat can provide significant base for the conservation of natural habitats in the future.

Introduction

Medicinal plants have been greatly used in most countries as a vast integral part of traditional herbal medicine. The widespread use of wild and harvested medicinal plants as ethnomedicines has been described in the Vedas and the Bible. They also provide the only form of health care sources which are easily available to the vast poor community at cheap prices. Therefore, demand for natural products with medicinal properties is hugely increasing in recent years and many such plants are traded within and across different countries as they have no side-effects and non-narcotic. Moreover, establishing pharmaceutical industries for development of plant based therapeutic drugs has become a commercialization trend and this growing dependence on medicinal has indeed led to their vast extraction and overexploitation. In addition, many plant species are investigated for their active constituents and pharmacological activity. Although some drugs of botanical

origins are manufactured through transformation of the bioactive chemicals present in them, many are extracted directly from plants. This, in turn, poses a severe threat to their biodiversity, natural habitat and genetic stocks if not sustainably managed.

Another good reason to conserve medicinal plant populations is for the purpose of genetic conservation. Biodiversity conservation via cultivation of medicinally valuable plants can be utilized to enhance current and future demands for large volume production of plant-based drugs and herbal preparations. It is also a means for relieving wild populations from harvest pressure and allows meticulous and skillful post-harvest handling. Thus, through cultivation of medicinally valuable plants for biodiversity conservation, quality controls can be achieved and it may also provide the opportunity for the economic development of the medicinal plant species as an important commercial crop as well.

Conservation, for instance, are associated with seed-banks, environment information systems or protected biological reserves. Conservationists should have a profound knowledge about identification, morphology and ecology of medicinal plants. They should mostly be concerned with management of plant species and socio-economic structures of local societies where they are grown. There are significant global benefits that could be easily achieved by supporting biodiversity conservation of medicinal plants with the active participation of traditional medicinal practitioners, academics, researchers, and field personnel.

Biodiversity of Medicinal Plants

Biodiversity is often a varietals measure of the health of biological systems and plays a predominant role by contributing significantly towards livelihood and development of the global human population. It comprises all natural ecosystems, agricultural ecosystems, wild and domesticated species.

Medicinal plants are widely distributed across diverse habitats and environment on Earth. There exists no exact figure for their distribution in different regions and varies greatly. It is estimated that about 35,000-70,000 number of plant species with medicinal value are distributed worldwide [1,2] including 7500 in India [3]; 2237 in Mexico [4]; 2527 in North America and 10,000-11,250 in China [5-7]. Based on their habits, these medicinal plants are comprised of trees (33%), herbs (32%), shrubs (20%), climbers and grasses (12%) and lower plants like lichens, algae, ferns etc. (3%). A larger proportion of medicinal plant species belong to the plant families Asteraceae, Euphorbiacae, Laminaceae, Fabaceae, Rubiaceae, Poaceae, Acanthaceae, Rosaceae and Apiaceae. More than 800 species of these medicinal plants are used in medicinal industry for commercial production where about 90% are collected from wild [8].

Types of Biodiversity

Medicinal plants are distributed across diverse habitats and landscapes. Different types and levels of biodiversity exist among the plant species. They are discussed as below:

Genetic diversity

It is defined as diversity in genetic characteristics of plant species which belong to different genera of the same family. Such biodiversity provides the vital conditions to adapt with different biotic and abiotic environmental changes, thus, serving a significant importance in the continuity of a species. Loss of genetic diversity can indeed result in loss of desirable characteristics of species reducing its ability to function its fundamental role in the whole ecosystem.

Species diversity

It is defined as the diversity of different plant species belonging to the same genus. Such diverse species shows variation in their morphology, habitat, distribution and reproductive behavior.

Ecosystem diversity

This type of diversity is considered as the largest type of biodiversity and defined as the variation of an ecosystem, including both biotic and abiotic component, found in the region. Different types of ecosystems exist over the whole planet such as aquatic ecosystems, terrestrial ecosystems, deserts, wetlands, coral reefs etc. Ecosystem diversity includes large scale of genetic and species diversity, showing abundance of plant biodiversity due to different ecological niches.

Agro biodiversity

Diversity which exists among different varieties of wild and cultivated clones and hybrids of plant species is defined as agro biodiversity. Examples include cropland, forage land, orchard, and ornamental ecosystems. Such type of diversity is rightly illustrated in several species like *Ocimum sanctum*, *Papavar somniferum, Azadirachta indica*, etc.

Biodiversity is also categorized at various regional, national and global levels. Plant diversity also exists depending upon agro-ecological zones in a country. Crop diversification has been recommended to further strengthen regional diversity.

Concerns Related to Medicinal Plants

Major concerns are loss of biological diversity and plant resources. A large numbers of medicinal plant species are globally threatened by various kinds of biotic and abiotic factors, both in developed and developing countries [9,10]. They include:

Over exploitation

Medicinal plants are being over exploited by pharmaceutical industries and efforts made to domesticate them are little. This, in turn, has a profound effect on pharmaceutical industries (Ayurvedic, Unani and Homeopathic drug factories), with insufficient supply of plant resources.

Unscientific exploitation

Plants are being extracted for various purposes. However, no proper studies on reproductive biology of the plant are conducted and hence, the revital and replacement of plants are tremendously hampered.

Environmental degradation

Natural calamities including floods, earthquakes cyclones, typhoons, sand dunes and soil erosion are some of the environmental factors that adversely affect biodiversity of flora. Extraction of plants for purposes other than medicinal uses and intensive cultivation as a natural consequence of feeding the increasing human population also have adverse effects on plant biodiversity. Further, human activities like uncontrolled and unscientific grazing and pollution are some of major threats to our biodiversity which can lead to the extinction of species [11-13].

Human population

Increasing human population has caused enormous biotic pressure on natural resources, which in turn, has resulted in deforestation and climatic changes in several parts of the world. Ozone depletion, greenhouse gases, industrial pollution and acid rain are some climatic changes. Excessive use of fertilizers and pesticides for crop cultivation have caused ill effects on soil health and adversely affected natural flora in several parts of the world.

Even though, new molecular biology and gene transfer technology has certainly opened new prospects in food security, the adverse effect of such efforts on plant biodiversity and sustainable development has been cautioned [14]. There is immediate need to promoting

scientific research on traditional medicine and collaboration work, whereby the scientific research should be conducted on safety, adequacy and quality of traditional medicine as proposed by World Health Organization (WHO).

Conservation of Medicinal Plants

There arises a strong and urgent need to conserve medicinal plants which are increasingly facing major threats of various environmental, socio-economic and institutional factors. Because of over harvesting of species and degradation of their habitats, much of medicinal plant species has become threatened and endangered.

Even if medicinal plants species are cultivated on millions of hectares and thousands of botanical gardens are created, medicinal plants can still become extinct if viable breeding populations are not protected and conserved in the wild. The main purpose of conservation is effective sustainable development of valuable bio-resources and germplasm without any harm to natural habitats and ecosystems. Proper identification, collection, characterization, evaluation, propagation, disease elimination, storage and distribution are some of the major activities which are generally involved in sustainable conservation of important plant resources. If urgent conservation programme are not undertaken, there is great danger of losing these priceless biodiversities.

Conservation strategies are defined as sustainable use and maintenance of species and different ecological processes which are essential for survival and various economic activities of human populations. Conservation of plant resources must involve an integrated and systematic scientifically oriented program involving socio-economic and ecological systems interactions. It requires a team effort and co-operation involving a wide range of disciplines and institutions. This will indeed help in developing a consensus on what needs to be done and assigning task to various institutions for the conservation of biodiversity. Also, the participants will be motivated to undertake the task and monitor its progress. Another way is a national strategy which involves organizing a regional and/or national workshop which will bring involvement and participation of experts on different aspects of the subject area to analyze the situation, proposed objectives, define priorities and draw up a plan of action. In order to implement this strategy, it is essential to work in co-operation and partnership with local plant collectors and herbalists who use medicinal plants. WHO has already collaborated with the Ministries of Health in setting up developmental programs for utilization of medicinal plants in sustainable way.

Types of Conservation Strategies for Medicinal Plants

Biodiversity conservation and development strategies are broadly categorized in two types:

***In-situ* conservation**

It is defined as conservation of a germplasm in its natural habitat along with several wild relatives having genetic diversity. It is considered as cost-effective and high priority preservation of the existing biological diversity. Some of the *in-situ* methods of conservation are as follows:

National parks and sanctuaries: These are protected areas covering the biological diversity and genetic diversity in its pristine condition, devoid of human interference. Many eco-development programs are set up and operated around National Parks and Sanctuaries with a main view to preserve the variability of populations, revitalize the area with less adverse harm from infrastructure development and creation of new improved varieties.

Biosphere reserves: These are areas of land or water, usually encompass all terrestrial, coastal and marine ecosystem, that is protected by law in order with a view to support biodiversity conservation and reduce human impact on environment. These are considered

as sustainability support sites with prevalence of rich abundance of genetic resources of wild crop relatives. Usually nominated by national governments, these areas are under the jurisdiction of the state where they are located.

Man and the Biosphere Programme (MAP), launched in 1971 by United Nations Educational, Scientific, and Cultural Organization (UNESCO), is a scientific programme which was established with the aim to promote cooperation on research and development, improvement of relationship between human populations and their existing environments and share experienced knowledge on interlinked issues like biodiversity loss, climate change and sustainable development. There are 669 biosphere reserves located in 120 countries [15].

A Biosphere reserve mainly consists of three areas. They are:

(a) Core zone – This is the most strongly protected area to conserve biological diversity of plants and animals. They are protected and made safe from various impact of human population.

(b) Buffer zone – This is the second zone and surround the main core zone. It provides areas for recreation, travel, tourism and environmental research.

(c) Transition zone – This is the last part of a biosphere reserve which provides space for local communities for managing the resources found in the area through fisheries, farming and various other activities.

Sacred groves: These are patches of vegetation which are usually protected on the basis of cultural and traditional religious practices. There is no separate scheme for the conservation of sacred groves. However, studies have been conducted by NGOs and research organizations like National Afforestation and Eco-Development Board (NAEB) to evaluate the status of sacred groves under the forest protection and improvement programme.

On-farm conservation: This type of conservation has been gaining importance globally recently as it provides an easy way of conservation which involves maintenance of farm areas and traditional agriculture systems by farmers in a cost-effective manner.

Home gardens: Home garden conservation is very similar to on-farm conservation, but this type is usually done in smaller scale. Common examples are home gardens which consist of a wide variety of species such as fruits, vegetables, medicinal plants, etc.

Few limitations associated with *in-situ* conservation are high-cost maintenance of huge number of genotypes and increased risk of losing germplasm due to environmental threats.

***Ex-situ* conservation**

This involves conservation and long-term preservation of plants in location outside their natural habitat by maintaining plants in farm fields, home gardens, botanical gardens and plant tissue culture repositories. The importance of this type of conservation is the rapid development of alternative supply sources of medicinal plants in huge quantities and low price in order to compete with wild medicinal plant stocks cultivated by gatherers [16].

Botanical gardens/arboreta: Botanical gardens are gardens, often run by scientific research organizations, which maintain documented collections and cultivations of broad range of wild plant species displayed along with their botanical names. Its main purpose is exploration, educational research and biodiversity conservation of threatened and endangered plant species. The Royal Botanical Garden, Kew (London) was established in 1759 and since then, the importance of establishing a Botanical garden was realized.

Gene banks: Also known as Field Gene Bank (FGB)/Field Repository/Clonal Repository, serves as a means of conserving indigenous and exotic plant germplasm. Their main purposes are to act as the reservoir of collected elite plant sample, maintain it and ensure its availability to global human population. This type of conservation gives easy access to

conserve material for scientific research purposes, even though their maintenance is rather expensive.

Seed bank: Seed Bank provides the most efficient and effective method for conservation of orthodox seed (desiccation tolerant which be stored for longer durations). In this conservation process, sealed seeds are stored and maintained in medium- term storage facilities (temperature of 0°C to 50°C and relative humidity of 15% to 20%) and long-term storage facilities (stored at colder temperatures, -20°C to -180°C). Most seed samples remain viable for 20- 30 years and up to 100 years in medium-term and long- term storage depending upon the type of seed, their quality and specificity of storage environment. Seeds are usually the most convenient materials for germplasm conservation as many plants are propagated through seeds. Apart from this, seeds occupy relatively small space and are easily transportable. Quarantine rules, seed health and seedling vigor rules are taken into account while exchanging seeds and propagules between different countries/organizations for various purposes.

Cryopreservation method: Cryopreservation has become another important scientific technology for biodiversity conservation and sustainable development. It is defined as preservation of germplasm in frozen state at an ultra-low temperatures of -165°C to -196°C using liquid nitrogen by bringing them to a non-dividing zero metabolism state. Some of the new cryopreservation techniques are:

Vitrifications: This is the process of direct exposure of cells to cryoprotectants which are highly concentrated (5–8 M), followed by rapid freezing, thus leading to dehydration but avoiding the formation of ice crystals in cells of seeds-propagule. This technique is employed successfully in the preservation of somatic embryos and synthetic seeds.

Encapsulation-dehydration: In this technique, cells are encapsulated in alginate beads and cultured on high sucrose concentration medium, followed by air-drying (usually, silica gel and airflow) and directly transferred to liquid nitrogen.

Two-step freezing: This technique involves incubation of seeds-propagules or tissue culture regenerants in a mixture of cryoprotectants having concentration of 1–2 M, causing moderate cell dehydration, followed by slow freezing (1°C/min down to app –35°C).

DNA conservation (storage at -20°C): This method is relatively simple, easy, cheap and widely applicable. Recently, genetic engineering has evolved and resulted in manipulation and transfer of desirable genes for production of transgenic plants. DNA Libraries are being established and now it has become essential to develop strategies on how and where to use the germplasm stored in the form of DNA [17].

***In vitro* (tissue culture) conservation:** This type of conservation involves *in vitro* large scale multiplication of plants and its storage in the form of shoot tips, meristems, axillary buds, embryos, callus and cell suspension. The essential requirements for *in vitro* conservation techniques are creation of environment and light controlled culture rooms, laminar airflow, autoclave, trained scientists or technicians. Information of those plant species required for *in vitro* conservation is also desirable. *In vitro* gene banks offers advantages in that it is often inexpensive, easy to maintain and effective storage systems [18].

Future Potentials

The conservation of medicinal plants is necessarily a long term project requiring the development and organization supported by educated staff and general public that is aware of conservation issues. Improvement in national education standards and campaigns that promote the importance of habitat will help in biodiversity conservation. Research information related to identification of threatened medicinal plants, areas of high biological diversity at the macro scale and properties specific medicinal plants at the microscale should use the complementary skill of the conservation biologists. Various public sectors, Institutes and NGOs should develop agro technique in order to provide large scale improved

quality planting material to the cultivators. Creation of mass awareness among rural folk about the usefulness of medicinal plants and encouraging them for cultivation of medicinal plants will be useful for conservation and sustainable use of plant biodiversity.

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Traditionally Used Medicinal Plants Belongs to Family Asteraceae for the Treatment of Cancer in Mizoram, Northeast India

Garima Singh, Ajit Kumar Passari, Bhim Pratap Singh and N. Senthil Kumar*

Department of Biotechnology, Aizawl, Mizoram University, Mizoram -796 004, India

***Corresponding author:** Dr. N. Senthil Kumar, Department of Biotechnology, Aizawl, Mizoram University, Mizoram -796 004, India; E-mail: nskmzu@gmail.com

Abstract

The traditional knowledge and use of medicinal plant species from the plant family Asteraceae was reviewed for the treatment of several types of cancers in Aizawl District, Mizoram, Northeast India. Traditional healers and patients suffering from various cancers in the study area were interviewed with the help of local translators to congregate the information for the use of medicinal plants against several prevalent cancers in this part of India. In the present review, we reported 22 plant species which were commonly used for the treatment of various cancers and ulcer. The most common used plant for the treatment of various cancers is *Mikania micrantha* followed by *Ageratum conizoids*. Leaves are the most common part used. The present review outlined the traditional information along with the major phytochemical compounds obtained from the listed plants which may be responsible for their traditional values in the selected study area. We hypothesized that the information could improve the traditional anti-cancer recipes and might contribute to a better national or international health system in future.

Keywords: Anticancer; Asteraceae; Mizoram; Phytochemicals; Traditional Medicinal Plants

Introduction

Plants have always been the important source for the nutrition and therapeutic usage against a notable number of human ailments. Recent phytochemical studies of medicinal plants supported the effectiveness of folkloric medicines. From the ancient time, the plants have been used for curing various diseases and infections. Cancer is the stage of uncontrolled growth of several cells, which can colonize and spread to distant sites of the body. It has many health consequences and can lead to death. In males the most common prevalent types of cancers are lung, prostate, colorectal, stomach, and liver cancers whereas, breast, colorectal, lung, uterine cervix, and stomach cancer are most prevalent in women's. On an average 30% deaths occur due to cancer can be prevented by avoiding key risk factors like tobacco or smoked foods. There is a serious need of the natural cancer control plans to prevent or inhibit the spread of cancer especially in low and middle income countries

like India. Recently, World Health Organisation (WHO) has initiated and promoted Cancer Control Programme (CCP) all around the world with a main focus to promote national cancer control policies and ongoing programmes. One important parameter of this programme is to set norms and standards, spread awareness, more importantly encourage evidence based prevention by using traditional information's mainly in remote areas where the medical facilities are limited.

For the treatment of different types of cancers many traditional plants were used by the local practioners. If we look into the phytochemistry of few plants then the discovery of compounds like paclitaxel, vinblastine, vincristine, the camptothecin derivatives are the plant derived agent that made history for the treatment of various cancers. Still many active phytochemical compounds from traditionally used plants are under clinical trial for the promising cancer cure.

Among the plants, family Asteraceae is the largest flowering plant family comprising around 1,600 genera and 30,000 species [1]. The plants are well known to produce foodstuffs, cooking oils, ornamental plants and medicinal plants. Phytochemical studies of number of Asteraceae plants have revealed the presence of various chemical compounds like alkaloids, polyphenols, phenols, flavonoids, terpenes, essential oils etc. Sesquiterpene lactones are the major phytochemicals in the family that have various biological activities. They are supposed to possess antibacterial, antiviral and anticancer potential [2-4].

Mizoram is a small and hilly state possesses rich biodiversity of medicinal plant, with 90.68% forest cover [5]. It lies between 21° 56' N-23° E latitude and 92° 16'-93° 26'N longitude, [6]. Mizo, the local population possesses unique cultures and indigenous practices endemic to this region. Local tribes traditionally use many plants for the treatment of cancer, tuberculosis, diabetes, arthritis skin diseases, allergies etc. There exist traditional practitioners which prescribes herbal preparations in the form of decoctions, teas or to chew orally or the pastes to apply externally.

Cancer in Mizoram: An Overview

Cancer is the uncontrolled growth of cells in the body leading to the death of an individual. Cancer starts with changes in normal cell that include irregulation of cell division and cell death, cell proliferation, invasion, angiogenesis and metastasis. Deformed mass of cells could locate inside the tissue without metastasize or it could invade the other tissues or other part of body. It is a worldwide killer disease that causes more than 7 million deaths per year worldwide. Till date, more than 100 types of cancers have been identified which are classified into different groups such as carcinoma, leukemia, lymphoma and myeloma, and central nerve system by National Cancer Institute (NCI). Major causes for the cancer are the factors, such as dietary habits, smoking, alcohol consumption, infectious viruses, radiation etc [7]. The lifestyle factors seem to be associated for Mizoram having the highest stomach cancers in India [8].

In the recent years, enthusiasm for the use of traditional medicines against many diseases especially for cancer has begun. Discovery of vinca alkaloids, vinblastine, vincristine podophylotoxins like anticancer agents from plants led to the search of novel chemotypes [9]. Plant derived chemotypes are moderate cytotoxic and found to be effective on tumor cells *in vivo* with less side effects comparative to conventional treatment methods [10,11]. According to a European Survey by the use of herbal medicines in the cancer treatment were escalated to 13.9% after the diagnosis of cancer from 5.3% before the diagnosis of cancer [12]. In Mizoram around 89 plants species belonging to 56 families and 68 genera are used as herbal medicines for the cure of various ailments [13]. There are also several reported and few unreported plants which were traditionally used for the treatment of various types of cancers. The present study documented twenty three most commonly used traditional medicinal plants used by the local tribes for the treatment of several kinds of cancers in

Mizoram, India. We also listed out the method of preparation and the pharmacological importance of these plants as reported elsewhere. From Mizoram which falls under Indo-Burma biodiversity hotspot, this is the first report about the traditional plants belongs to the family Astreaceae having anticancerous potential. The present review will open up the field for the pharmaceutical peoples to understand the chemical composition of the selected plants in future.

Material and Methods

There are many Ethnomedicinal plants used by the local people of Mizoram for the treatment of cancer-suspected diseases and other health problems. Information of the plants used in the treatments of cancer was collected personal with local herbal practitioners and the patients suffering from villages in Aizawl, Mizoram, India (Figure 1). Though they were not very much open about how to prepare the herbal mixture, but gave some glimpses of the name of the plants and for what diseases the plants may be useful. For some traditional medicinal plants like *Anaphalis adnata* and *Leucomeris decora* there is no literature available but still are important traditional medicinal plant. The output plants list consists of local name (mizo) and the common name of the plant. Other information viz. flowering season of the plant, major phytochemicals isolated and the bioactivities were assayed through the literature search. Following are the plants noted from the family Asteraceae used in the herbal preparations for the cancer and other diseases by the Mizo tribal peoples as well.

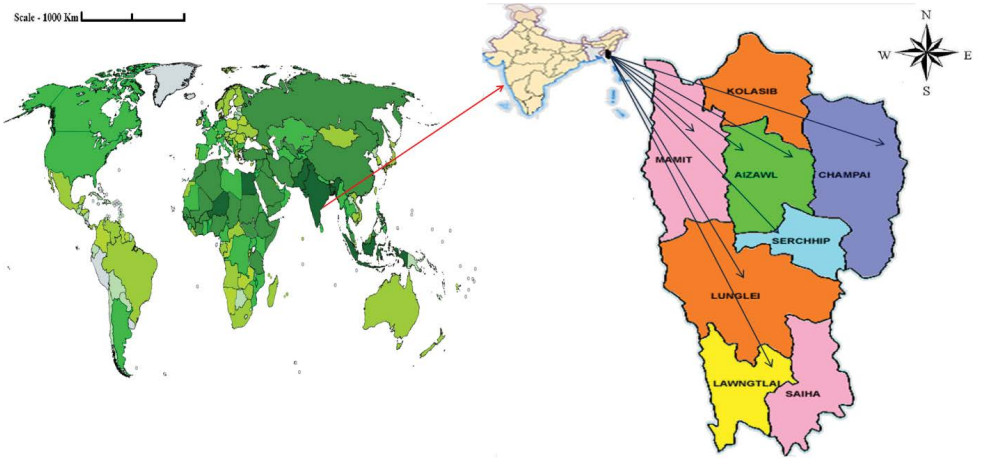

Figure 1: Map showing the sample collection sites from different districts of Mizoram, Northeast India.

Acmella oleracea/ Spilanthus acmella

Local name: An-sa-pui/ An-ka-sa-kir (mizo)

It is also known as toothache plant. The flowering season is during October- December of every year. Major phytochemicals reported from the plant are Spilanthol (*N*-isobutyl amides), [14] saturated and unsaturated alkyl ketones, alkamides, hydrocarbons, acetylenes, lactones, alkaloids, terpenoids, flavonoids, and coumarins. All the plant parts, flowers, leaves, roots, stems and aerial parts are used in herbal medicines. Leaves and stem boiled with water was used for the treatment of stomach trouble and flower head is chewed to have a relief in toothache.

The whole plant paste is used for snake bite. The particular plant is been reported to possess analgesic, antioxidant, anti-inflammatory [15,16], antifungal [17] and anticancer activities [18].

Adenostemma lavenia

Local name: Vai-len-hlo-suak (mizo)

It is also known as sticky daisy and the flowering season in between March-January. Major phytochemicals reported from this plant are Adenostemmoside, Adenostemmoic acid [19]. Traditionally the leaf paste is applied on cuts and wound, insect and caterpillar bites [20], found the *Adenostemma lavenia* plant extract is effective against MK-1 and B16F10 cell lines as well which further proves the potential of existence of anticancerous compounds.

Ageratum conizoids

Local name: Vailenhlo (mizo)

It is also known as goat weed and the flowering season are in February-March or August-September every year. Among the reported phytochemicals from *A. conizoids* are mono and sesquiterpenes, triterpene and sterols, chromene, chromone, benzofuran and coumarin, flavonoids, alkaloids etc. [21]. The plant is traditionally reported to be used for curing various kinds of diseases including tuberculosis, skin diseases, fevers, cuts and wounds. In Mizoram this plant is been used from many years by the local healers for the treatment of stomach cancer. The method of preparation is that the plant roots are cleaned and boiled with the rhizome of *Curcuma longa* and leaves of *Mikania micrantha* in water and the decoction is given orally [22].The plant is also reported by several researchers all around the world to possess antibacterial [23], wound healing, anti-inflammatory, antianalgesic, antipyretic [21] and cytotoxic properties [24].

Anaphalis adnata

Local name: Khaw-te-mei-bu (mizo)

It is commonly known as pearly everlasting and the flowering season for this plant is during May-October. Traditionally the boiled juice of the leaves is applied on cuts and wound to get relieve from infections.

Artemisia vulgaris

Local name: Sai (mizo)

It is also known as Mugwort. The flowering occurs in the plant during January. Few of the reported phytochemicals from *A. vulgaris* are flavones (luteolin, luteolin-7- glucoside), flavonols (kaempferol, quercetin, rutin), coumarins (coumarin, 6,7-dimethoxy-coumarin) [25]. The plant is traditionally used to cure a wide range of ailments including malaria, bacterial infections, inflammation, menopausal and menstrual disorders. Traditionally decoction of the roots or leaves is given orally in fever, stomach-ache, asthma etc. The plant has showed significant cytotoxicity against HL-60 leukemic [26], HEPG2 [27], Human prostate cancer PC-3, Human breast carcinoma T47D and colon cancer RKO [28] cancer cell lines cells.

Bidens pilosa

Local name: Vawk-pui-thal (Mizo)

It is also known as Black-jack and the flowering season in during February to April every year. The plant is very well studied and many major phytochemicals are reported like terpenoids, phenylpropanoids, aromatics, porphyrins, flavonoids, [29]. *B. pilosa* is been reported for the treatment of various diseases such as inflammation, immunological disorders, digestive disorders, infectious diseases, cancers, metabolic syndrome, wounds, and many others [30]. Generally whole plant is been used in herbal medicinal. Among the

specific parts, aerial parts like leaves, shoot and stem are also been used as an ingredient in teas or herbal medicines in several countries. Its shoots and leaves (dried or fresh) are utilized in sauces and teas. Sundarajan et al., 2006 and kumari et al., 2009 determined the anticancer activity of *B. pilosa* extract against HeLa, KB, HepG2, CaCO2 and MCF7 cancer cell lines [31,32].

Blumea lanceolaria

Local name: Buar-ze (mizo)

It is commonly known as lanceleaf blumea ans gives flowers during February-April. The plant is well studied for its phytochemical constituents and few major compounds reported are methyl thymol, p-Cymene, and l-hexadecanol [33]. The local tribes of Mizoram used juice of *Blumea* leaves to treat stomach ulcer, asthama, tuberculosis, skin diseases, sores, scabies etc. Rosangkima and Prasad 2004 determined the antitumor activity of *B. lanceolara* leaves against murine ascites Dalton's lymphoma in mice [34].

Chromolaena odorata/Eupatorium odoratum

Local name: Tlang-sam (mizo)

It is also known with the name of Christmas bush and give flowers during December-January. Some of the important phytochemicals reported from this palnts are 5-hydroxy-7,40–dimethoxyflavanone, 20-hydroxy-4,40,50,60–tetramethoxychalcone, and 1,6-dimethyl-4-(1-methylethyl)naphthalene (cadalene) [35]. Traditionally, the leaf juice is applied on fresh cuts and wound to fight against infections and it is been reported to have several activities like antibacterial [36,37], anticancer [35,37,38], antifungal [39], anti-inflammatory [40,41] and anti-malarial [42,43]. The plant could be an interesting candidate for the discovery of the novel bioactive therapeutically active agents.

Chrysanthemum indicum

Local name: October-par (mizo)

It is also known as chrysanthemum, the plant flowers during October till March. The plant is not well studied for the presence of phytochemicals, only few reported compounds are from sesquiterpenes. Traditionally the flowers are used to make tea for digestive purpose. In several other countries the *C. indicum* is used for the treatment of colitis, stomatitis, cancer, fever, sores, vertigo, inflammation and hypertension. Plant is also been reported to possess anti-inflammatory [44], hepatoprotective [45], antimicrobial [46-48] and anticancer properties [49].

Cirsium shansiense

Local name: Len- hling (mizo)

It is also known as Canadian thistle which mainly flowered during October every year. Few of the reported phytochemicals from this plant are ciryneol C, scopoletin, pectolinarigenin-7-O-glucopyranoside, acacetin and 6,7-dimethoxycoumarin [50]. Traditionally the plant is been used for the treatment of different ulcers and also used as diuretic, haemostatic and anti-inflammatory. The plant also has antimicrobial [50,51] and anticancer [52] potential.

Crassocephalum crepidioides

Local name: buar-thau (mizo)

It is also known as Thickhead and the flowering season for this plant are in May to December. Few of the broad phytochemicals reported from this plant are tannins, flavonoids, steroids, coumarins [53]. Traditional medicinal uses of the plants are that the leaf juice is taken for indigestion and stomachache. Leaf paste is applied to heal cut and wounds to

fight against microbial infections. Different plant parts are also been used in the herbal preparations for the treatment of fever, hepatitis and inflammations. The plant is reported to possess hepatoprotective [54], antitumor [55,56], and antibacterial [57] activities.

Cyanthillium cinereum

Local name: Buar (mizo)

It is also known as purple fleabane and gives flowers mainly during February. Traditionally plant decoction is used to treat urinary tract infections and fevers. *Cyanthillium cinereum* has therapeutic potentials against dysentery, diarrhea, cough, cholera, impotency colic pain night-blindness [58] asthma [59] and cancer [60].

Dichrocephalum integrifolia

Local name: Vawk-ek-a-tum-tual (mizo)

The plant flowers during May-June. Some of the reported phytochemicals from this plant are stearic acid, stigmasta-7, 22-dien-3-ol, alpha-amyrin, epifriedelanol, methyl stearate and tritetracontane [61], eudesmane [62]. Traditionally the plant is been reported having antimicrobial [63,64] as well as anticancer [64] potential. Plant is traditionally used for wound healing, to treat mouth and stomach ulcers and microbial infections.

Galinsoga parviflora

Local name: sazu(pui)chaw (Mizo)

It is also known as quick weed and the flowering season is during June to September every year. Some of the reported phytochemicals obtained from *G. parviflora* are galinsosides A and B [65]. Traditionally the leaves and stem of the plant are been used in the herbal preparation for fever, diarrhea, cuts and wound. *G. parviflora* is also reported to have hepatoprotective, hypoglycemic, antioxidant, cytotoxic, and antimicrobial activities [66].

Helianthus annuus

Local name: Ni-hawi (mizo)

It is commonly known as sunflower and the flowering season is in August to September. Major phytochemicals reported are Heliespirone [67], Heliannuol E [68], Helikauranoside A [69]. Medicinally the plant is used as food and medicine all around the world and most importantly the seeds are been used for the production of cooking and essential oil. Leaves, stem, flower and seed oil all possess active principle and plant has potent antioxidant and also possess antimicrobial [70,71], anti-inflammatory [72] and anticancer potential [73,74]. Traditionally the leaf paste is applied to wounds, swellings, and insect bites. Flowers are taken as tea for the treatment of malaria and lung diseases.

Inula cappa

Local name: Hmei-thai-sa-tul (mizo)

It is also known as sheep's ear and flowers during September and October. Sesquiterpens lactones [75,76], and phenolic glycosides [77] are reported as major phytochemicals from this plant. Traditionally the leaf juice of *Inula cappa* is been used locally for the treatment of jaundice. Decoction of the root is also been used to treat peptic ulcer, indigestion and fever.

Leucomeris decora

Local name: Tlangham (mizo)

The plant flowers during February to March every year. It is an Asteraceae shrub and been used traditionally for curing many ailments especially the leaves and stem. The plant becomes locally rare due to rapid habitat destruction and fragmentation, together with

unrestricted collection for medicinal use. Thus it has been listed in the IUCN red list of threatened species [78].

Mikania micrantha

Local name: Japan-hlo(mizo)

It is also known as bitter vine and flowers during December till January each year. Mikanolide: a sequiterpene dilactone [79], is the major phytochemical reported from this plant. It is a perennial vine of which leaves are used to treat fever, diarrhea, dysentery, insect bites, scorpion sting and cuts by traditional peoples. Several reports are available for its anticancer and antitumor activities [80-82].

Senecio scandens

Local name: Sai-ekk-hlo(mizo)

The plant flowers in February and March. Several phytochemicals like pyrrolizidine alkaloids and sesquiterpenes [83], jacaranone [84,85], phenolic acids [86] were reported from *S. scandens*. In Mizoram local practitioners are using this plant for the treatment of stomach cancer and other different type of cancers. Juices of the leaves are applied to chronic ulcers. Pyrrolizidine alkaloids recovered from this plant are proven to be hepatotoxins and carcinogens [87]. Plant has shown potent antimicrobial [88,89], anti-inflammatory [90], antitumor [91] and anticancer activity [92] as well.

Siegesbeckia orientalis

Local name: Ansa-pui-suak(mizo)

It is commonly known as st. paul's wort, flowers during October-November every year. Several phytochemicals like sesquiterpene lactone: orientin [93], diterpenoids: Kirenol and ent-16β,17-Dihydroxy-Kauran-19-Oic Acid (DHKA) [94]. *S. orientalis* is been reported for anti-inlammatory [95,96], anti-proliferative [97] and anticancer activity [98]. Leaves paste is applied against snakebites and insect bites. Decoction of the aerial part is given to treat allergies, skin diseases, rheumatic arthritis and inflammatory diseases.

Sonchus arvensis

Local name: Khuang-lawi (mizo)

It is also known as corn sow thistle which give flowers during September till December. Few of the phytochemicals reported from this plant are sesquiterpene lactones [99], flavonoids [100] and terpenes [101]. The plant has been used in folk medicine for the treatment of jaundice, cough, bronchitis, chronic fevers and inflammation. It has been reported to possess anti-inflammatory and antipyretic effect in rats [102] along with antioxidant and cytotoxic [103] activities.

Tithonia diversifolia

Local name: Bawng-pu-pang- par (mizo)

It is also known as Mexican sunflower and the flowering season is during November-December. Tagitinins, tirotundin, flavones [105] were reported as major phytochemicals from *T. diversifolia*. The plant is generally grown for ornamental purpose but possess medicinal properties as well. Traditionally the plant is been used for the treatment of diabetes mellitus, stomach pains, indigestion, sore throat and liver pains [103]. Flower head is used by local healers for the treatment of wounds and bruises. Plant seems to have an anti-inflammatory [104] anti-diarrhoeal [105], anti-amoebic and spasmolytic activities [106,107].

Conclusion

We documented twenty two traditionally used medicinal plants used by the local tribes

of Mizoram, Northeast, and India for the treatment of several types of cancers and other human ailments. The paper also describes the important information like their local name, flowering season and major phytochemical compounds investigated from these plants elsewhere. As due to over utilization and population explosion, these plants which were used in local health traditions are gradually becoming extinct. The present review will alert the environmentalists and researchers to take steps to preserve or conduct modern scientific studies of these traditionally important plants. These types of studies not only can lead to probable discoveries of new bioactive pharmacologically useful compounds, but also such discoveries can be an encouragement for the preservation of the forest region. We conclude that domestication of these traditionally important wild medicinal plants should be of utmost importance for the sustainable development.

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Traditional Medicinal Plants Used For Various Skin Diseases and Cosmoceuticals in Manipur, North-East India

W. Radhapiyari Devi*

Medicinal plant and Horticultural Resources Division, Institute of Bio resources and Sustainable Development, Imphal-795001, Manipur, India

***Corresponding author:** Dr. W. Radhapiyari Devi, Medicinal plant and Horticultural Resources Division, Institute of Bio resources and Sustainable Development, Imphal-795001, Manipur, India; Tel: 09089811056; E-mail: radhawang@gmail.com

Abstract

The present investigation is an attempt to find out ethnopharmacological application of medicinal plants to cure skin diseases and in folk cosmetics. The study adopted the interviewing method covering 35 different ethnic communities as respondents from various districts of Manipur at different locations reflecting a multicultural pluralistic society with rich traditional knowledge on the use of medicinal plants. While collecting information local language was adopted and was queried for the type of herbal cure for skin diseases. A total of 241 plants belonging to 95 families and 192 genera have been documented for their therapeutic use against skin diseases and as herbal care. The most dominating families were Asteraceae, Euphorbiaceae, Lamiaceae, Caesalpiniaceae, Poaceae, Rubiaceae and Moraceae. The analysis of habits shows that, shrubs were represented the highest. The highest mode of preparation methods were extract (23%), decoction (21%), paste (18%) and juice (15%). Out of the total only 10 plants species showed 100% fidelity. The most important species according to their fidelity is *Mallotus philippensis,* this was used for treating ringworm and boils. Herbal product for beauty care range from enhancement of cosmetic, skin lotion, hair lotion, skin glow, hair promoter, anti-dandruff, sun burn, nail injury and facial. The people of Manipur seem to be well known for using medicinal plants to its culture and tradition to cure skin diseases and herbal cares. The results of this study may support the use of different medicinal plants by the different tribes of this region for the treatment of skin diseases. Results of this study may be used as a basis for further phytochemical and pharmacological investigations for the search of new single entity pharmaceutical ingredients or characterized and standardized multicomponent botanical products which may be useful for the treatment of different skin diseases and fungal infections.

Keywords: Cosmetic; Medicinal Plants; Manipur; Skin Diseases

Introduction

The use of plants as medicine is widespread throughout the world. Medicinal plants have been used as sources of medicine in virtually all cultures of human curiosity and need. According to WHO, herbal medicines serve the health needs of about 80% of the world's

population, especially for millions of people in the vast rural areas of developing countries. About 2,500,000 species of higher plants and the majority of these have not been examined in detail for their pharmacological activities. Medicinal plants are used globally and have a rapidly growing economic importance in the healthcare system of local communities and it is the main source of medicine for the majority of the rural population. Rise in population, cost of treatment for common ailments, side effects of allopathic drugs and development of resistance have led to increase emphasis on the use of herbs as source of medicines.

The use of the medicinal plants for curing disease has been documented in history of all civilization. In spite of all the medical advances, only 2 percent of the world's plant species have ever been tested for their medicinal potential. Certain Indian medicinal plants which have antimicrobial properties are reported based on folklore information [1-8] and a few attempts are made on inhibitory activity against certain pathogenic micros [8-10]. Traditional medicinal resources, especially plants, have been found to play an important role in the management of dermatological conditions [11,12].

The people of Manipur have a very rich traditional knowledge on the use of herbal extracts associated with its long multicultural history to cure skin infection. Hence, Manipur is considered to be the Gold mine of well-practiced knowledge of traditional herbal medicine. Interestingly, Manipur falls within Indo-Burma Centre of Biodiversity Hot Spots of global significance [13] with high medicinal values used for remedial and curative therapy.

Recently, the practice of herbal medicine has been declining in the very places where it has been once developed and nurtured by oral tradition. This may in future lead to the loss of valuable information about the plants used [14]. The demand for herbal medicines is increasing rapidly due to their lack of side effects. Further, as health care costs continue to escalate, the attraction for low-cost remedies has stimulated consumers to re-evaluate other potential alternatives [12,15-24]. To our knowledge no systematic ethno botanical study of medicinal plants used in Manipur for curing skin diseases has been made. Keeping these things in mind we explored the knowledge available with the native people to cure different skin diseases prevalent in this region using medicinal plants. Here we report the ethno botany of herbal plants, which are claimed to be useful in curing dermatological diseases by the people of Manipur.

The extensive use of these herbal drugs by the local people in treating various types of skin disorders might therefore be justified by their antimicrobial activities against different micros, which are known to be responsible for causing various skin infections [25-29].

The proposed documentation work is done as a part for the study and development of antifungal herbal extracts/drugs from certain medicinal plants based on the traditional/ folklore knowledge of Manipur.

Materials and Methods

Study site

The study area is situated between the latitudes of 23°80´ N - 25°68´ N and longitudes of 93°3´ E - 94°78´ E with an area of 22,327 sq km. Further, the state falls in the biogeography tri junction of 3 distinctive biogeographically regions: extensions of Himalayan region, Oriental region of India and the Malayan Archipelago. The varied climatic condition facilitates the development of various microbial skin infections. This cup-shaped land has a series of hill ranges. Manipur is considered as a sensitive border state, which is bounded by Nagaland on the north, Mizoram on the south, Myanmar on the east, and Assam on the west (Figure 1). It shares a 352 km long international border line with Myanmar. Out of its total area, approximately 90% area is characterized by hills, which further surrounds the 10% of plain area. The climate of Manipur is largely influenced by the topography of this hilly region which defines the geography of Manipur under the influence of sub-tropical monsoon

climate as it is just near the Tropic of Cancer. The state has tropical to temperate climate depending upon elevation of 790 meters above the sea level. This north eastern corner of India is blessed with a generally amiable climate though the winters can be a little chilly. The maximum temperature recorded in the summer months of Manipur is 32°C. In winter the mercury often falls to subzero temperature making it frosty in the wintertime. The coldest month in Manipur is January and July experiences the maximum summer temperature. The ideal time for tourism in the state, in terms of the climate of Manipur, is from the months of October till February, when the weather remains bright and sunny without the scorch of the sun. Manipur experiences a remarkably erratic distribution of rainfall varying from 110 cm to 350 cm and average annual rainfall is about 207.77 cm. Wet Temperate Forest, Pine Forest, Wet Hill Forest, Semi Evergreen Forest, Teak Gurjan Forest are the forest types of this area. Though the state enjoys all the three seasons of summer, winter, and monsoon; precipitation dominates the valley for most of the year. To sum up, Manipur enjoys salubrious climate round the year. Manipur has a population of 2,388,634. Of this total, 58.9% live in the valley and the remaining 41.1% in the hilly region. With 987 females per 1000 males, Manipur has a balanced sex ratio. Manipur has a large rural population and comparatively much lower urban population. The population density in Manipur is 107 per square kilometers. The state is inhabited by 35 different ethnic groups at different locations, indicating a multicultural pluralistic society with rich traditional knowledge on the use of medicinal plants. The main ethnic groups of the areas are Meetei, Meetei Pangan, Mao, Maram, Anal, Chiru, Chothe, Koireng, Lamkang, Maring, Moyon, Tangkhul, Thangal, Paomei, Tarao, Monsang, Mizo, Hmar, Paite, Gangte, Simte, Kuki, Thadou, Kom, Purum, Sukte, Zou, Ralte, Moyong, Kharam, Ziangmei, Laingmei, Rongmei, Sema, Kacha Naga.

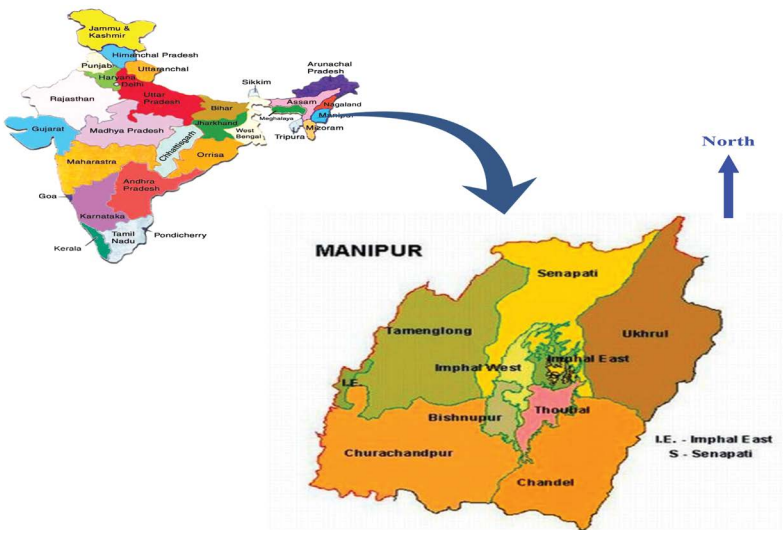

Figure 1: Map indicating the local of the study area, Manipur, India.

Interviews

Resource persons of different ethnic communities from various districts of Manipur, as respondents were selected carefully for the study by interviewing to collect information in the local language and were queried for the type of herbal cure known to them for skin diseases. The study was carried out by interviewing respondents in remote sites (lack of health facilities, poverty and extensive use of medicinal plants). In total 150 informants were interviewed on their management of various fungal diseases. The respondents were; old age men (50%), women (23%) and traditional healers (27%) those who heals themselves or have

a tradition of healing in their families and had knowledge on the medicinal use of the plants for the said purpose. As for the present study, methods adopted [30] were followed with slight modifications under the local context. The interviews included questions that target the local people's perception of names of various skin diseases, the names of plants, parts of plants used, methods used in preparation and mode of application of the drugs. The data were tabulated to include the botanical name, family, local name, parts used, preparation and popular use.

Preservation and identification of plant species

Plants were collected in flowering and fruiting conditions during January to November and confirmed by the ethnic communities to ensure that proper plants have been collected and compared with the related so-far published flora of the region [24,31-33] and for the authentic identification thereof, flora and monographs have been consulted especially Flora of British India, Flora of Assam, Flora of India [34-38]. Botanical identification was done with the help of local taxonomists and Botanical survey of India, Kolkata. The botanical name was written as in International Plant Name Index (IPNI) database. Skin diseases were compiled and the number of plants used against was estimated. Keeping these things in mind we explored the knowledge available with the native people to cure skin diseases prevalent in this region using medicinal plants. Here we report the ethno botany of herbal plants, which are claimed to be useful in curing various skin diseases by the people of Manipur.

Quantitative analysis

The Fidelity Level (FL) was used to determine the most important plant species used for treating certain diseases by the local herbal practitioners and literate elders in the study area. It was calculated by the following formula: FL(%) = Np x 100/N, [39] where Np is the number of the informants who provided the information of a plant species used to treat certain ailments, and N is the number of informants who utilized plants as medicines for treating any given ailments.

Results and Discussion

General analysis of the data

A total of 241 plants belonging to 95 families and 192 genera have been documented for their ethno pharmacological application against skin diseases and in folk cosmetics as enlisted in Table 1. This could be a great interest for the development of novel drugs as the exploration of therapeutic activity-bearing ingredients may be easier from the remedies which involve merely the use of single plant. The most dominating families were Asteraceae, Euphorbiaceae, Lamiaceae, Caesalpiniaceae, Poaceae, Rubiaceae, Moraceae [8,40-42]. The analysis of habits show that shrubs were represented the highest among other habits.

Plant Name	Voucher	Family	Local Name	Parts used	Ailments	Preparation	FL
Abrus precatorius Linn.	WR1	Fabaceaae	Chaning	Seed	Hair promoter	Extract	16.7
Acalypha indica Linn.	WR2	Euphorbiaceae	Haying mathi	Leaf	Scabies, ringworm, urticaria	Juice	23
Acacia oxyphylla Graham	WR3	Mimosaceae	Thaonam	Dark and fruit	Anti-dandruff	Decoction	12
Achyranthes aspera Linn.	WR4	Amaranthaceae	Khujumpere	Leaf	Boils, skin eruption, acne, insect bite, ringworm, scabies	Decoction, infusion	100
Aconitum nagarum Slapf.	WR5	Helleboraceae	Apin tumphai	Whole plant	Ringworm	Extract	80
Acronychia pedunculata (Linn.) Miq.	WR6	Rutaceae	Heijrang-macha	Root, bark	Scabies	Extract	45
Adhatoda vasica Nees	WR7	Acanthaceae	Nongmangkha angouba	Leaf	Scabies, wart, urticaria	Powder	35

Aeschynanthus hookeri Clarke	WR8	Gesneriaceae	Utangbi	Leaf	Facial spots	Extract	12
Ageratum conyzoides Linn.	WR9	Asteraceae	Khongjainapi	Leaf	Ringworm, hair wash	Extract	46
Ageratum houstonianum Mill.	WR10	Asteraceae	Khongjainapi	Leaf	Scabies, hair wash	Extract	45
Anisomeles indica (Linn.) O. Ktze	WR11	Lamiaceae	Thoiding angouba	Seed	Hair oil	Extract	88
Ajuga macrosperma Wall.var.	WR12	Lamiaceae	Chinggi-sangbrei	Leaf	Hair lotion	Decoction	45
Albizia odoratissima Benth.	WR13	Mimosaceae	Uyil	Bark, leaf	Leprosy	Extract	55
Alisma plantago-aquatica Linn.	WR14	Alismataceae	Kakthrum	Rootstock, flower, fruit	Sore	Extract	50
Allium sativum Linn.	WR15	Alliaceae	Chanam	Bulb	Boils, wart	Extract	60
Aloe vera Linn.	WR16	Liliaceae	Ghrita kumari	Pulp of leaf	Boils, burn, sun burn, skin lotion, hair promoter	Extract	80
Alpinia galanga Willd.	WR17	Zingiberaceae	Kanghu	Rhizome	Ringworm, scabies, sore, acne, wart	Powder	85
Amaranthus spinosus Linn.	WR18	Amaranthaceae	Chengkruk tingkhangpanbi	Shoot Leaf	Wart, sore, astringent Boils, burn	Crush Paste	35
Amaranthus tricolour Linn.	WR19	Amaranthaceae	Chengkruk	Root Shoot	Nail injury Sore	Crush Crush	20
Anotis foetida (Dalz.) Benth. & Hook.f.	WR20	Rubiaceae	Khut-chappi	Roots	Boils	Paste	20
Aphanamixis polystachya Wall.	WR21	Meliaceae	Heirangkhoi	Leaf	Alopecia	Paste	30
Areca catechu Linn.	WR22	Arecaceae	Kwa	Nut	Hair promoter	Paste	25
Argemone mexicana Linn.	WR23	Papaveraceae	Khomthongpee	Latex	Scabies	Juice	30
Argyreia nervosa (Burm.f.) Boj.	WR24	Convolvulaceae	Uritusonbi	Leaf	Boils, acne	Poultice	12
Artemisia maritima Linn.	WR25	Asteraceae	Laipakngou-manba	Bark	Antiseptic	Juice	50
Artemisia nilagirica (Clarke) Pamp.	WR26	Asteraceae	Laipakngou	Leaf	Hair lotion, scabies,	Extract	35
Artemisia parviflora Roxb.	WR27	Asteraceae	Laipakngou	Leaf	Hair lotion, scabies	Extract	30
Artocarpus heterophyllus Lamk.	WR28	Moraceae	Theibong	Rachis	Boils	Roast	18
Artocarpus lakoocha Roxb.	WR29	Moraceae	Harikokthong	Bark, fruit Latex	Acne, skin eruption, boils, antiseptic Boils	Powder Juice	100
Asparagus officinalis subsp. prostratus (Dumort.) Corb.	WR30	Liliaceae	Nunggarie	Leaf	Boils	Paste	65
Asplenium nidus Linn.	WR31	Aspleniaceae	U-nappi	Fronds	Hair wash	Decoction	37
Azadirachta indica A. Juss.	WR32	Meliaceae	Neem	Leaf Seed	Boils , small-pox Ringworm, acne, urticaria	Poultice Decoction	58.7
Bambusa arundinacea (Retz.) Willd.	WR33	Poaceae	Saneibo	Shoot	Ring worm, alopecia	Decoction	23.4
Bambusa nutans Wall. ex. Munro	WR34	Poaceae	Utang	Leaf	Small-pox, chicken-pox, ringworm	Boil	31.2
Bambusa oliveriana Gamble	WR35	Poaceae	Warak	Shoot	Ringworm, alopecia	Fermentation	45.1
Bambusa tulda Roxb.	WR36	Poaceae	Saneibi	Leaf	Small pox, chicken pox, burn	Boil	20.6

Basella alba Linn.	WR37	Basellaceae	Urok-shumbal	Leaf	Boils, burn	Extract	22.6
Bauhinia acuminata Linn.	WR38	Caesalpiniaceae	Chingthao angouba	Bark, leaf	Leprosy	Paste	35.1
Bauhinia purpurea Linn.	WR39	Caesalpiniaceae	Chingthao	Bark, root	Insect bite, leprosy	Extract	24.7
Bauhinia variegata Linn.	WR40	Caesalpiniaceae	Chingthao	Bark	Leprosy	Extract	37.5
Bixa orellana Linn.	WR41	Bixaceae	Ureirom	Seed	Warts, acne	Extract	42
Blumea hieracifolia (D. Don) DC.	WR42	Asteraceae	Ching-terapaidi	Leaf	Hair lotion, scabies	Decoction	34
Brucea javanica (Linn.) Merr.	WR43	Simaroubaceae	Heining	Leaf	Acne, sore, hair lotion, anti-dandruff	Poultice	46.8
Bryophyllum pinnatum (Lam.) Kruz	WR44	Crassulaceae	Manahidak	Leaf	Boils, insect bite, burn	Crush	42
Buddleja asiatica Lour.	WR45	Buddlejaceae	Shamei	Leaf	Scabies, wart, acne	Extract	49.2
Buddleja paniculata Wall.	WR46	Buddlejaceae	Shani	Root	Skin eruption, sore	Crush	32
Callistemon linearis (Schrad. & J.C. Wendl.) Sweet	WR47	Myrtaceae	Tiyup Lei	Flower, leaf	Hair lotion	Decoction	35
Calotropis procera (Willd.) R.Br.	WR48	Asclepiadaceae	Angkot	Leaf Latex Root	Eczema, snake bite, carbuncle Ringworm Leprosy	Extract Juice Extract	78.4
Canarium bengalense Roxb.	WR49	Burseraceae	Mekruk	Resin	Urticaria	Extract	57.8
Cannabis sativa Linn.	WR50	Cannabaceae	Ganja	Leaf	Insect-bite, burn	Pasted	67.4
Capparis tenera Dalz.	WR51	Capparidaceae	Kakyel khujin laba	Leaf	Acne, scabies	Decoction	45.8
Carica papaya Linn.	WR52	Caricaceae	Awathabi	Latex of raw fruit Fruit pulp	Remove freckles from the skin blemishes, Skin lotion	Juice Paste	68.5
Cassia alata Linn.	WR53	Caesalpiniaceae	Daopata	Leaf	Ringworm, scabies, boils, herpic	Juice	100
Cassia fistula Linn.	WR54	Caesalpiniaceae	Chahui	Root-bark	Ringworm	Decoction	78
Cassia hirsuta Linn.	WR55	Caesalpiniaceae	Thounam	Young twigs	Ringworm	Paste	65.4
Cassia laevigata Willd.	WR56	Caesalpiniaceae	Thounam	Young leaf	Ringworm	Boil	67.3
Cassia sophera Linn.	WR57	Caesalpiniaceae	Thounam	Young leaf	Ringworm	Extract	45.6
Cassia tora Linn.	WR58	Caesalpiniaceae	Thounam	Young leaf, seed	Skin eruption, ringworm	Extract	30
Centella asiatica (Linn.) Urban	WR59	Apiaceae	Peruk	Whole plant	Boils, anti-dandruff, hair promoter	Powder	69
Chenopodium album Linn.	WR60	Chenopodiaceae	Monshaobi	Leaf	Alopecia	Extract	67
Citrus reticulata Blanco	WR61	Rutaceae	KoMola	Rachis	Acne	Juice	45
Colocasia esculenta (Linn.) Schott	WR62	Araceae	Paan	Petiole	Insect-bites	Juice	65
Commelina benghalensis Linn.	WR63	Commelinaceae	Wangden-khoibi	Whole plant	Leprosy, boils, burn	Decoction	67
Conyza japonica Less.	WR64	Asteraceae	Terapaibi manbi	Leaf	Urticaria, scabies.	Boil	68.7
Coriandrum sativum Linn.	WR65	Apiaceae	Phadigom	Leaf	Acne	Paste	56
Crepis japonica (L) Benth.	WR66	Asteraceae	Terapaibi-macha	Leaf	Burn, scabies	Boil	68.2
Croton caudatus Geisel.	WR67	Euphorbiaceae	Apintuphi	Leaf, root	Skin eruption	Extract	54.3
Cucurbita maxima Duchesne	WR68	Cucurbitaceae	Mairel	Pulp	Boils, burn	Poultice	58.3
Cucurbita pepo Linn.	WR69	Cucurbitaceae	Mairel	Leaf	Burn	Crush	55
Curculigo orchioides Gaertn.	WR70	Amaryllidaceae	Kali musli	Rhizome	Acne, urticaria	Powder	56.8

Curcuma domestica Valeton.	WR71	Zingiberaceae	Yaingang	Leaf, rhizome	Small pox, chicken pox, scabies, facial, boils	Paste	100
Cuscuta reflexa Roxb.	WR72	Cuscutaceae	Urisanamachu	Leaf	Urticaria	Decoction	76
Cyathea gigantea (Wall. Ex Hook.) Multum	WR73	Cyatheaceae	U-chagrang	Frond	Hair promoter, urticaria	Boil	34.3
Cyathula prostrata Linn. (Blume)	WR74	Amaranthaceae	Kabo napimacha	Root	Acne, wart	Decoction	44.5
Cymbopogon citratus Linn. Stapf	WR75	Poaceae	Haona	Leaf	Scratchon skin, hair lotion	Boil	59
Cyperus rotundus Linn.	WR76	Cyperaceae	Shembang kakthum	Rhizome	Sore	Extract	60.1
Dactyloctenium aegyptium (Linn.) P. Beauv.	WR77	Poaceae	Pungphai	Whole plant	Small pox, skin allergy	Extract	67.8
Datura metel Linn.	WR78	Solanaceae	Sagohidak	Leaf, root, seed	Ringworm, boils, wart	Decoction	88
Datura stramonium Linn.	WR79	Solanaceae	Sagohidak	Leaf Fruit	Boils Anti-dandruff, hair promoter	Paste Juice	67
Dicrocephala latifolia DC.	WR80	Asteraceae	Lalukok	Whole plant	Anti-dandruff, hair promoter	Decoction	43
Dillenia indica Linn.	WR81	Dilleniaceae	Heigri	Fruit	Anti-dandruff, hair promoter	Decoction	32
Dioscorea alata Linn.	WR82	Dioscoreaceae	Ha	Tuber	Leprosy	Juice	59.7
Diplospora singularis Korth.	WR83	Rubiaceae	Thingsai in Mizo	Leaf	Urticaria	Paste	67.3
Dipterocarpus turbinatus Gaertn.f.	WR84	Dipterocarpaceae	Yingou	Oleo-resin	Ringworm, scabies	Warm	45.9
Drynaria quercifolia (Linn.) J. Smith	WR85	Polypodiaceae	Utangbi	Frond	Boils	Paste	56
Eclipta prostrate Linn.	WR86	Asteraceae	Uchisumbal	Whole plant	Eczema, blacking of hair	Paste	76.4
Eucalyptus citriodora Hook.	WR87	Myrtaceae	Nasik	Leaf	Hair lotion	Decoction	34.1
Eupatorium odoratum Linn.	WR88	Asteraceaee	Kambilei	Leaf	Wart, sore	Juice	37.6
Eupatorium birmanicum DC.	WR89	Asteraceae	Langthrei	Leaf	Acne, burn	Paste	67.8
Euphorbia antiquorum Linn.	WR90	Euphorbiaceae	Tengnou	Leaf Latex	Wart Boils	Juice Juice	32.6
Euphorbia hypericifolia Linn.	WR91	Euphorbiaceae	Tengnou	Whole plant	Skin eruption	Warm	21.1
Euphorbia neriifolia Linn.	WR92	Euphorbiaceae	Tengnou	Latex	Skin eruption	Juice	13.8
Euphorbia thymifolia Linn.	WR93	Euphorbiaceae	Tengnou	Leaf	Urticaria, ringworm	Crush	65.4
Eryngium foetidum Linn.	WR94	Umbelliferae	Awaphadigom	Whole plant	Ringworm	Crush	76.2
Ficus benghalensis Linn.	WR95	Moraceae	Khongnangbot	Root	Hair lotion	Decoction	32
Ficus glomerata Roxb.	WR96	Moraceae	Heibong	Latex Fruit, root, bark	Boils Skin eruption, leprosy	Paste Decoction	56.3
Ficus hispida Linn.	WR97	Moraceae	Ashi-Heibong	Leaf, bark Fruit, seed Latex	Ringworm Scabies Boils	Decoction Paste Juice	60.2
Ficus palmata Forks	WR98	Moraceae	Heibam	Latex	Boils	Juice	34.5
Ficus religiosa Linn.	WR99	Moraceae	Sanakhongnang	Bark	Boils, scabies	Decoction	32
Ficus semicordata F. Ham	WR100	Moraceae	Heirit	Latex	Boils	Juice	30

Fumaria vaillantii Loisel.	WR101	Papaveraceae	Changkruk manbi	Whole plant	Boils	Paste	42.7
Glycosmis pentaphylla (Retz.) Correa	WR102	Rutaceae	Yong-komla	Leaf, root	Eczema, hair lotion, urticaria, scabies	Extract	92
Gmelina arborea Roxb.	WR103	Verbenaceae	Wang	Leaf	Boils	Extract	80
Goniothalamus sesquipedalis Hook.f & Thorns.	WR104	Annonaceae	Leikham	Leaf	Small pox Ringworm, scabies, wart, boils	Smoke Extract	100
Gossypium arboreum Linn.	WR105	Malvaceae	Lashing	Flower, seed	Scabies, sore	Paste	65
Gouania tiliaefolia Lam.	WR106	Rhamnaceae	Uri	Bark, root Leaf	Hair wash Sore	Decoction Crushed	32
Gynocardia odorata R.Br.	WR107	Flacourtiaceae	Chalmugra	Fruit	Scabies, wart, urticaria	Decoction	30
Hedera nepalensis K.Koch.	WR108	Araliaceae	Hurim – Rongmei	Leaf	Hair wash	Decoction	14.7
Hedychium spicatum Ham.	WR109	Zingiberaceae	Takhelei hanggammapal	Rootstock	Small pox, burn	Crush	67
Heliotropium indicum Linn.	WR110	Boraginaceae	Leihenbi	Leaf	Boils, insect bite	Paste	54.6
Hemidesmus indicus(L) R. Br.	WR111	Asclepiadaceae	Kwa manbi	Root Stalk leaf	Skin eruption Sore	Decoction	56.2
Hibiscus cannabinus Linn.	WR112	Malvaceae	Sougree	Leaf Stem	Skin eruption, hair lotion Sore	Decoction Decoction	45
Hibiscus rosa-sinensis Linn.	WR113	Malvaceae	Jubakusum	Leaf	Hair lotion	Decoction	21
Hiptage benghalensis Linn. (Kurz)	WR114	Malpighiaceae	Madhabi	Leaf	Sore, acne, urticaria, scabies.	Paste	35.8
Holigarna longifolia Buch. Ham.ex Roxb.	WR115	Anacardiaceae	Kherai	Bark	Scabies, boils	Extract	45.3
Holmskioldia sanguinea Retz.	WR116	Verbenaceae	Kharam leithong	Leaf	Hair wash	Decoction	28.3
Homonoia riparia Lour.	WR117	Euphorbiaceae	Wangchu in Kuki	Leaf	Anti-dandruff	Boil	32.5
Houttuynia cordata Thunb.	WR118	Saururaceae	Toningkok	Leaf, rhizome	Burn, skin eruption	Extract	35.8
Hydnocarpus kurzii (King) Warb.	WR119	Flacourtiaceae	Uhan	Flower, fruit Leaf	Eczema, acne, sore Wart	Decoction Paste	45
Impatiens balsamina Linn.	WR120	Balsaminaceae	Khujang	Leaf Flower	Nail injury, hair lotion, ringworm Burn, anti-dandruff	Juice Juice	100
Impatiens chinensis Linn.	WR121	Balsaminaceae	Khujang	Leaf	Burn	Juice	45
Imperata cylindrica (L.) Beauv.	WR122	Poaceae	Imom	Whole plant	Hair lotion	Decoction	23
Jasminum diversifolium Kobuski	WR123	Oleaceae	Kundo	Root	Ringworm	Extract	58
Jasminum multiflorum Burm. f.	WR124	Oleaceae	Waruk Kundo	Leaf	Sore	Paste	34
Jasminum nervosum Lour.	WR125	Oleaceae	Kundo	Root	Ringworm	Extract	45
Jatropha curcas Linn.	WR126	Euphorbiaceae	Awakege	Latex Seed	Sore Wart, hair promoter	Juice Extract	67
Jatropha gossypifolia Linn.	WR127	Euphorbiaceae	Kege-mangi	Leaf	Leprosy, scabies, wart, urticaria	Extract	62.7
Kaempferia galanga Linn.	WR128	Zingiberaceae	Yai-thamnamanbi	Rhizome	Hair lotion	Extract	31
Lactuca sativa Linn.	WR129	Asteraceae	Salad	Stem, root	Burn	Poultice	43.7
Lagenaria siceraria (Mol.)Standl.	WR130	Cucurbitaceae	Khongdrum	Fruit, leaf	Acne, alopecia	Juice	39.8

Leea crispa Linn.	WR131	Vitaceae	Koknal	Leaf	Hair wash	Decoction	31
Lens culinaris Medic.	WR132	Leguminosae	Mukswori	Seed	Skin glow	Paste	20.6
Leucas aspera Spreng.	WR133	Lamiaceae	Mayang Lambum	Leaf	Skin eruptions, insect-bites, scabies, eczema, psoriasis	Juice	100
Lindernia crustacea (L.) F. Muell.	WR134	Scrophulariaceae	Namguak – Rongmei	Whole plant	Boils, urticaria, ringworm, sore	Poultice	69.6
Linum usitatissimum Linn.	WR135	Linaceae	Thoiding amuba	Seed	Burn	Paste	19.6
Ludwigia clavelliana Gomez de la Maza & Molinet	WR136	Euphorbiaceae	Tebo	Whole plant	Burn, urticaria	Poultice	37.3
Luffa cylindrica (Linn.) M.J.Roem.	WR137	Cucurbitaceae	Shebot	Seed	Wart, eczema	Roast	47.7
Lycopodium cernuum Linn.	WR138	Lycopodiaceae	Leishing	Whole plant	Skin eruption	Embract	34.2
Lycopodium clavatum Linn.	WR139	Lycopodiaceae	Leishing	Whole plant	Skin eruption	Poultice	28
Lyonia ovalifolia (Wall.) Drude	WR140	Ericaceae	Tlangham – Mizo	Young leaf, bud, flower	Skin allergy	Juice	30.5
Mallotus philippinensis Muell.-Arg.	WR141	Euphorbiaceae	Ureirom- laba	Fruit Leaf	Scabies, ringworm Boils	Powder Powder	100
Mangifera indica Linn.	WR142	Anacardiaceae	Heinou	Fruit	Wart, sore	Raw	68.4
Manihot esculenta Crantz.	WR143	Euphorbiaceae	U-mangra	Leaf	Wart, sore, eczema, scabies	Extract	82.1
Melanorrhoea usitata Wall.	WR144	Anacardiaceae	Kheu	Bark	Skin allergy, leprosy	Extract	56
Melastoma malabathricum Linn.	WR145	Melastomaceae	Yachubi	Bark, leaf, root	Skin eruption, antiseptic	Extract	35
Melia azedarach Linn.	WR146	Meliaceae	Sheizak	Leaf, flower, seed, bark Fruit	Small pox, anti-dandruff, hair promoter Boils, acne, scabies	Paste Paste	100
Melothria heterophylla (Lour.) Cogn.	WR147	Cucurbitaceae	Lamgi-shebot	Leaf	Burn, acne, wart	Extract	78.2
Meriandra strobilifera Benth.	WR148	Lamiaceae	Kanghuman	Leaf	Antiseptic	Decoction	62.1
Merremia umbellata ssp. umbellata (Linn.) Hall. f.	WR149	Convolvulaceae	Voktesentil-Mizo	Leaf	Burn, anti-dandruff	Poultice	57.3
Meyna spinosa Roxb.	WR150	Rubiaceae	Heibi	Leaf Fruit	Hair wash Skin glow, boils	Decoction Extract	34.4
Mezoneurum enneaphyllum (Roxb.) Wight & Arn	WR151	Caesalpiniaceae	Kangol	Young fruit	Hair lotion	Decoction	37
Michelia champaca Linn.	WR152	Magnoliaceae	Leihao	Leaf, flower	Hair wash	Decoction	32
Microcos paniculata Linn.	WR153	Tiliaceae	Heitoop	Bark, leaf, fruit	Small pox, eczema, urticaria	Extract	67
Mikania micrantha Kunth	WR154	Asteraceae	Uri-hingchabi	Leaf	Ringworm, boils, wart	Paste	72
Milleltia pachycarpa Benth.	WR155	Fabaceae	Ngamuyai	Root	Scabies, urticaria	Decoction	46
Mimosa pudica Linn.	WR156	Mimosaceae	Kangphal Ikaithabi	Leaf, root Leaf	Urticaria, scabies Boils	Decoction Decoction	59.6
Mirabilis jalapa Linn.	WR157	Nyctaginaceae	Mugalei	Seed Leaf	Skin lotion Boils	Extract Paste	54.7
Mucuna monosperma DC.	WR158	Fabaceae	Mei-siarvyntim	Pod	Burn	Paste	72
Murdania nudiflora (Linn.) Brenan	WR159	Commelinaceae	Tandal pambi	Whole plant	Burn, urticaria, sore	Extract	87

Mussaenda frondosa Linn.	WR160	Rubiaceae	Hanurei	Root Leaf	Leprosy Hair lotion	Extract Decoction	78.5
Mussaenda glabra Vahl	WR161	Rubiaceae	Hanurei	Leaf	Hair lotion	Decoction	34.1
Mussaenda roxburghii Hook.f.	WR162	Rubiaceae	Hanurei	Leaf	Hair lotion	Decoction	35.5
Nelumbo nucifera Gaertn.	WR163	Nymphaeaceae	Thambal	Root, flower, seed	Skin eruption, leprosy, skin glow	Raw	22.6
Nerium oleander Linn.	WR164	Apocynaceae	Kabilei	Root Leaf Root-bark	Boils Wart, insect-bites Wart	Paste Extract Extract	56.2
Nicotiana tabacum Linn.	WR165	Solanaceae	Hidak mana	Leaf, seed	Insect bite, skin eruption, wart, boils	Extract	91.3
Nyctanthes arbortristis Linn.	WR166	Oleaceae	Singalei	Leaf Seed	Urticaria, sore Antidandruff	Extract Roast	74.2
Nymphaea nouchali Burm.f.	WR167	Nymphaeaceae	Tharo	Seed	Sore	Extract	62.1
Nymphoides hydrophyllum (Lour.) Kuntze	WR168	Menyanthaceae	Tharo-macha	Stalk, leaf	Antiseptic	Decoction	32
Ocimum americanum Linn.	WR169	Lamiaceae	Mayangba	Leaf	Alopecia	Crush	56.9
Ocimum gratissimum Linn.	WR171	Lamiaceae	Uhang amuba	Leaf	Hair lotion	Decoction	44.8
Ocimum sanctum Linn.	WR170	Lamiaceae	Uhang	Seed Leaf	Sore Ringworm	Poultice Juice	79.6
Oldenlandia umbellata Linn.	WR172	Rubiaceae	Lin marei	Whole plant	Burn	Paste	23.5
Ophiopogon wallichianus Hook.f.	WR173	Haemodoriaceae	Ching-charot	Leaf	Hair lotion	Decoction	40.1
Opuntia dillenii (Ker-Gawl) Haw.	WR174	Cactaceae	Meipokpi	Phylloclade	Boils, burn	Poultice	34.1
Opuntia monacantha Haw.	WR175	Cactaceae	Meipokpi	Phylloclade	Burn	Juice	62
Oxalis corniculata Linn.	WR176	Oxalidaceae	Yensil	Whole plant	Hair lotion	Crush	55.9
Pandanus odoratissimus Linn.	WR177	Pandanaceae	Ketukee	Leaf	Leprosy, small pox, scabies	Paste	83.4
Parkia roxburghii G. Don	WR178	Mimosaceae	Yongchak	Bark, leaf	Wart	Extract	77.5
Pavetta indica Linn.	WR179	Rubiaceae	Kukurchura	Leaf, root	Boils	Poultice	34
Perilla frutescens (Linn.) Britton	WR180	Lamiaceae	Khamela	Leaf	Hair lotion	Decoction	17.7
Phlogacanthus thyrsiflorus Nees	WR181	Acanthaceae	Nongmangkha sanamachu	Inflorescence	Small pox, scabies	Paste	39.6
Phyla nodiflora (Linn.) Greene	WR182	Verbenaceae	Chinglengbi	Leaf	Boils	Poultice	32.4
Phyllanthus emblica Linn.	WR183	Euphorbiaceae	Heigru	Fruit	Blacking of hairs	Juice	45
Phyllanthus urinaria Linn.	WR184	Euphorbiaceae	Chakpa heikru	Leaf	Leprosy, burn	Juice	65
Plantago erosa Wall ex Roxb	WR185	Plantaginaceae	Yempat	Leaf, seed	Boils	Roast	69.7
Plectranthus coesta Buch. Ham	WR186	Lamiaceae	Khoiju-man	Leaf	Hair lotion	Decoction	34
Plectranthus ternifolius D. Don.	WR187	Lamiaceae	Khoiju	Leaf Leaf, inflorescence	Small pox Hair lotion	Smoke Decoction	93.2
Plumbago indica Linn.	WR188	Plumbaginaceae	Mukaklei	Root	Wart, leprosy	Paste	65.2
Plumbago zeylanica Linn.	WR189	Plumbaginaceae	Telhidak angouba	Root	Wart, boils	Decoction	56.9

Plumeria acuminata Ait.	WR190	Apocynaceae	Khagi-leihao	Root-bark Latex	Sore Urticaria	Decoction Juice	69.7
Pogostemon elsholtzioides Benth.	WR191	Lamiaceae	Wichou	Seed Leaf	Sun burn Insect-bite	Paste	53.2
Pogostemon purpurascens Dalz.	WR192	Lamiaceae	Shangbrei	Leaf	Hair lotion	Decoction	32.6
Polygonum chinense Linn.	WR193	Polygonaceae	Angom yenshil	Leaf	Acne, wart	Paste	45.8
Polygonum hydropiper Linn.	WR194	Polygonaceae	Lilhar	Leaf, root	Boils, sore	Extract	34.2
Portulaca oleracea Linn.	WR195	Portulacaceae	Leipak-kundo	Whole plant, seed	Burn, alopecia, anti-dandruff	Crush	42.4
Premna mucronata Roxb.	WR196	Verbenaceae	Upongtha	Leaf, latex	Boils	Juice	37.5
Prunus persica (L.) Batsch	WR197	Rosaceae	Chumbrei	Leaf	Hair lotion	Decoction	35
Psidium guajava Linn.	WR198	Myrtaceae	Pungdol	Leaf, bark	Wart, sore	Decoction	58.4
Pterospermum acerifolium Willd.	WR199	Sterculiaceae	Kuakla	Flower, bark	Small pox	Decoction	69
Ranunculus hyperboreus Rotlb.	WR200	Ranunculaceae	Lallucauba	Whole plant	Boils, wart, sore, acne	Paste	63.2
Rhus chinensis Mill.	WR201	Anacardiaceae	Heimang	Leaf, fruit	Acne, boils, hair lotion	Decoction	73.4
Rosa indica Linn.	WR202	Rosaceae	Adugulap	Flower	Skin glow	Raw	31.2
Rotala indica (Willd.) Koechne	WR203	Lythraceae	Ishing kundo	Leaf	Antiseptic, ringworm	Juice	21.4
Rumex nepalensis Spreng.	WR204	Polygonaceae	Torong khongchak	Leaf	Ringworm, scabies, burn	Paste	69.6
Rungia repens (Linn.) Nees	WR205	Acanthaceae	Kharmor	Leaf	Ringworm	Crush	72.2
Saccharum officinarum Linn.	WR206	Poaceae	Chu	Shoot	Small pox	Juice	66.5
Saccharum spontaneum Linn.	WR207	Poaceae	Mom	Leaf	Burn	Juice	53.2
Sagittaria sagittifolia Linn.	WR208	Alismaceae	Koukha	Rhizome, rootstock Leaf	Boils, abscesses Urticaria, sore	Paste Juice	48.4
Santalum album Linn.	WR209	Santalaceae	Char chandan	Bark	Sun burn, insect-bite	Paste	78.4
Sapindus trifoliatus Linn.	WR210	Sapindaceae	Kekru	Fruit	Anti-dandruff, hair wash	Extract	44.5
Schefflera hypoleuca (Kurz) Harm	WR211	Araliaceae	Chom	Root	Boils	Extract	56.7
Scutellaria discolor Colebr.	WR212	Lamiaceae	Yenakhat	Whole plant	Boils, sore, acne	Extract	58.3
Sesamum orientale Linn.	WR213	Pedaliaceae	Thoiding amuba	Leaf Seed	Hair promoter Burn, anti-dandruff	Extract Paste	79.8
Sesbania grandiflora (L.) Pers.	WR214	Fabaceae	Houwaima	Bark	Small pox	Infusion	67
Siegesbeckia orientalis Linn.	WR215	Asteraceae	Sampakpi	Leaf	Acne, wart, sore, skin lotion	Juice	72
Smilax zeylanica Linn.	WR216	Liliaceae	Keisum	Root	Sore	Crush	54
Solanum erianthum D. Don.	WR217	Solanaceae	Lamkhamen	Shoot	Burn	Paste	59
Solanum melongena Linn.	WR218	Solanaceae	Khamel Barmasika	Leaf	Boils, burn, sun burn	Juiced	68.3
Solanum nigrum Linn.	WR219	Solanaceae	Leipungkhangga	Shoot	Boils	Decoction	56.3
Sonchus asper (Linn.) Hill	WR220	Solanaceae	Khomthongpee	Leaf, latex	Boils, wart	Juice	60.3
Spilanthes acmella Murr.	WR221	Asteraceae	Lalu-kowba	Flower, leaf, seed	Sore	Paste	49.8

Stellaria media (Linn.) Vill.	WR222	Caryophyllaceae	Yenrum-keirum	Leaf	Boils	Crush	55.2
Stephania hernandifolia Wf.	WR223	Menispermaceae	Thangga uriangangba	Leaf	Sore	Juice	61.3
Tagetes erecta Linn.	WR224	Asteraceae	Sanalei	Leaf	Boils, carbuncles, scabies	Paste	75.8
Tectona grandis Linn.f.	WR225	Verbenaceae	Chingsu	Kernel	Scabies, hair promoter	Roast	69.5
Telosma cordata (Burm f.) Merr.	WR226	Asclepiadaceae	Koubru yai	Root	Boils, leprosy	Extract	70.5
Terminalia citrina Roxb. ex Flem	WR227	Combretaceae	Manahei	Fruit, bark	Leprosy, wart, acne	Paste	89.3
Tetrastigma lanceolarium (Roxb.) Planch.	WR228	Vitaceae	Menjas	Leaf	Boils	Poultice	44
Tinospora cordifolia (Willd.) Miers ex Hook.f. & Thoms	WR229	Menispermaceae	Ningthoukhongli	Whole plant Root	Sore, antiseptic Leprosy	Extract	89.6
Toona ciliata M. Roem.	WR230	Meliaceae	Tairel	Leaf	Eczema, urticaria, small pox, chicken pox.	Decoction	71.4
Triumfetta tomentosa Noronha	WR231	Tiliaceae	Lamgi leeching	Twig	Sore	Crush	54
Vitex negundo Linn.	WR232	Verbenaceae	Urikshibi	Leaf, root, fruit	Ringworm, sore	Crush	78.5
Vitex trifolia Linn.	WR233	Verbenaceae	Urikshibi	Seed	Scabies, sore, anti-dandruff, hair promoter	Paste	70.3
Vitis vinifera Linn.	WR234	Vitaceae	Angur	Sap of young branches	Skin eruption	Paste	71
Xanthium strumarium Linn.	WR235	Asteraceae	Hameng sampakpi	Fruit	Small pox, ringworm	Juice	100
Xylosma longifolium Clos.	WR236	Flacourtiaceae	Nongleisang	Leaf, bark	Ringworm, scabies, acne	Extract	79.4
Zanthoxylum acanthopodium DC	WR237	Rutaceae	Mukthrubi	Seed	Ringworm, greying of hairs	Extract	69.7
Zanthoxylum limonella Alston	WR238	Rutaceae	Ngang	Seed, bark	Alopecia	Extract	77.3
Zingiber zerumbet (L.) Smith.	WR239	Zingiberaceae	Shingkha	Rhizome	Leprosy, burn, sore	Crush	78.7
Ziziphus jujuba Mill.	WR240	Rhamnaceae	Boroi	Leaf Fruit	Scabies Boils	Crush	56.8
Ziziphus mauritiana Lam.	WR241	Rhamnaceae	Boroi	Seeds	Boils	Extract	50.5

Table 1: Medicinal plants used by people of Manipur for skin diseases and cosmetic aspects.

Methods of drug preparation and administration

Different parts of native plants were used for medicine by the key respondents. Our analysis revealed that overall, 31 kinds of plant-parts were selected ranging from root, leaf, shoot, flower, bark, seed, fruit, rhizome, tuber, latex, rootstock, frond, resin, phylloclade, pod, root-bark, inflorescence, kernel, stalk leaf, bulb, bud, nut, fruit pulp, petiole and in some cases the whole plant. Leaf was most frequently used plant-part, constituting 54.62% of the whole followed by root (12.2%), bark (10.1%), and fruit (9.24%) and 13.84% were the remaining plant-parts [43-45] that compared with the previous ethnobotanical studies.

The total number of preparation methods for the medicinal materials was fifteen (15). Among the highest mode of preparation methods were extract (23%), decoction (21%), paste (18%) and juice (15%). From the data presented in Table 1, we observe that remedies can be divided into three classes: those that use (i) a single plant, (ii) two plants and (iii) more than two plants. These various preparation modes were twice or triple times diversified compared to the outcomes of the other previous studies [45-50]. The majority of the traditional medicines

were prepared using water as the medium. The mode of application was topical, confined to the affected portion of the body but in certain cases it was also administered orally. In regard to the skin conditions, the preparations were applied more than two times daily until healing was evident.

Skin medicinal aspects

Analyses on the mode application of the herbal preparations identified 22 different skin diseases like ringworms, sores, scabies, chickenpox, smallpox, insect bite, snake bite, skin eruption, burns, acnes, warts, boils, urticaria, skin allergy, antiseptics, leprosy, alopecia, herpic, eczema, psoriasis, carbuncle, abscesses [45,49,51]; it appears that the people had some idea about the systemic mode of the disease/disorder (Figure 2).

Cosmetic aspect

We also found that the people of the state use herbal product for beauty care ranging from enhancement of cosmetic, skin lotion, hair lotion, skin glow, hair promoter, anti-dandruff, sun burn, nail injury, facial (Figure 2). Many plants used for enhancing beauty were also applied for therapeutic use. We therefore classified the plants into those that are solely used either for therapeutic or cosmetic purpose and those that have dual use – cosmeceuticals [49].

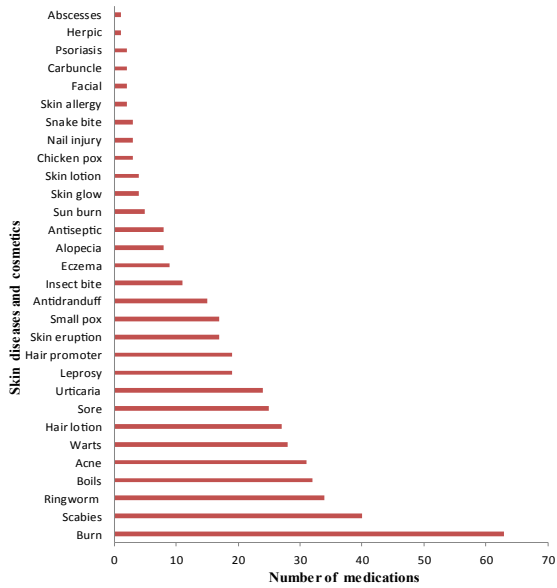

Figure 2: Number of medications used to treat skin diseases and cosmetic aspects.

Antimicrobials investigations

Skin diseases such as boils, carbuncles, eczema are caused by bacteria. Boils was the most common bacterial disease cited in the study area and local inhabitants use 61 remedies to cure this infection [52]. Further investigations indicated that, inhabitants of the area use 36 remedies to treat ringworms which were fungal infections. Viruses also damaged the skin and cause infections like small pox, warts and leprosy which explored 17, 32 and 19 remedies respectively. Some plant species used for skin diseases and cosmetic have been reported for their antimicrobial activities, like alcoholic, aqueous, hexane, chloroform, petroleum ether, extracts from various plant-parts [8,49].

Fidelity Level (FL)

We analyzed the categories with the major agreements to highlight the most important plants in each category. The plants which were mentioned only once were not considered in this analysis for better accuracy. Nevertheless, 10 plant species showed 100% fidelity. It seems that the informants trend to reply on one specific plant species for treating one ailment rather than selecting same plant for a more diverse uses.

Analyzing each of the ailments having important medicinal plants (FL 100%), for the treatment of ringworms were *Achyranthes aspera*, *Cassia alata*, *Goniothalamus sesquipedalis, Impatiens balsamina*, *Mallotus philippinensis*, *Xanthium strumarium*. Also, the following were in usage for treating boils: *A. aspera*, *Artocarpus lakoocha*, *C. alata*, *Curcuma domestica*, *G. sesquipedalis*, *I. balsamina*, *M. philippinensis, Melia azedarach*. Next, for acnes were *A. aspera*, *Artocarpus lakoocha*, *G. sesquipedalis*, *M. azedarach*. For scabies were *A. aspera*, *C. alata, C. domestica*, *G. sesquipedalis*, *Leucas aspera*, *M. philippinensis*, *M. azedarach* (Table 1).

Looking at the correlation between the ailments that have been mentioned many times and their Fidelity Level it was found out that *M. philippinensis* or the plant use for the treatment of ringworm and boils was the most prevalent one from the total plants covered by the study.

Conclusions

One of the main goals of an ethno pharmacological field study is to provide the main plants in a region used to perform further phytochemical and pharmacological studies. In this work, we used only one quantitative tool to perform the selection. The significance of orally transmitted traditional knowledge will be emphasized more with the announcement of the Nagoya [8,53]. Particularly, knowledge about the traditional treatments among other traditional knowledge is expected to increase in demand because of its economic value. Comparatively, more diverse and less numbers of medicinal plants were recorded which seems to indicate a rapid ongoing process of traditional knowledge leak due to the inhabitants' reliance on the modern medical system. However, the results of this study will be of essential use to those who are tired from overwhelming urbanization and industrialization since they demonstrate great potential not only as nature-friendly medicinal materials, but also as health care methods and naturopathies. In the present study we identified as many as 241 plants used by the people of Manipur to cure skin diseases and herbal cares. Further, extensive ethno botanical and ethno pharmacological study may lead to the discovery of more plants and compounds for skin care and cure.

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Ethnomedicinal Plant Used By the Garo Tribe of South Garo Hills, Meghalaya, India

Dilip Kumar Roy[1], Aupam Das Talukdar[2], Manabendra Dutta Choudhury[2], Bipin Kumar Sinha[3], Sanjoy Singh Ningthoujam[4], Deepa Nath[5] and Prakash Roy Choudhury[2*]

[1]Botanical Survey of India, Shillong, Meghalaya, India

[2]Department of Life Science & Bioinformatics, Assam University, Silchar, Assam, India

[3]Botanical Survey of India, Kolkata, India

[4]Department of Botany, Ghanapriya Women's College, Imphal, Manipur, India

[5]Department of Botany &Biotechnology, Karimganj College, Karimganj, Assam

***Corresponding author:** Dr. Prakash Roy Choudhury, Asst. Professor, Department of Life Science & Bioinformatics, Assam University, Silchar, Assam, India; Tel: +91 94017 58966; Fax: 03842 270920; E-mail: prchoudhury15@gmail.com

Abstract

Garo tribe, in most of the remote areas of South Garo Hills district of Meghalaya, India use medicinal plants for their primary needs in all medical aspects due to lack of modern facilities in the district. But this indigenous therapeutic knowledge of the community is fading away rapidly due to lack of proper documentation. The present investigation has been made to document the plants used by the Garo tribe to treat different diseases and to determine their importance by quantitative analysis. The study was based on ethnomedicinal field survey covering a period of 2 year from 2012 to 2014. The ethnomedicinal information was collected by using semi-structured questionnaires from different medicine man. Collected data were analyzed through relative frequency of citation and informant consensus factor to determine culturally significant plants. A total 98 plant species belonging to 91 genera and 46 families have been documented. Family Leguminosae was documented to have highest number of plants (7 sp.). Leaves were the most frequently used plant parts and most of the medicines were prepared in the form of decoction and administered internally. F_{IC} values of the present study indicated that there was a high agreement in the use of plants in the treatment of III-defined symptoms. *Aegle marmelos, Averrhoa carombola* and *Cissus quadrangularis* are the top three plants with RFC value of 0.83, 0.72 and 0.72 respectively. The top three plants with higher RFC value documented during the survey may be taken under consideration for further pharmacological study. Moreover, continued documentation concerning conservation and sustainable used of Garo medicinal plant heritage is required, which should be publicized to younger generation.

Keywords: Ethnomedicinal Plant; F_{IC}; Garo Tribe; RFC; South Garo Hills District

Introduction

Plants have played a key role in the traditional healthcare system of human beings since the dawn of medicine. Over the past few decades, the traditional knowledge on the use of medicinal plants against various ailments has been widely acknowledged across the world [1]. According to the World Health Organization (WHO), 80% of the world's population in developing countries uses traditional medicine [2]. The reliance of this large population may possibly due to the good accessibility to the plants, good affordability of the herbal material as compared to conventional drugs and the widespread ethnic knowledge and expertise among the local communities [3]. Now a day, the assessment of ethnobotanical information has received special attention to gather knowledge of natural resources for their scientific and economic exploitation [1]. A number of active principles from of herbal origin were isolated and introduced as potential drugs in modern system of healthcare with the advancement in the techniques of phytochemistry and pharmacology [4].

India is one of the 17 mega biodiversity countries of the world. Meghalaya comes under the globally recognized Indo-Burma biodiversity hotspot which is host to a remarkable biodiversity that includes a high proportion of endemic, rare and endangered species. Its varied topography and high annual precipitation makes the state one of the richest biodiversity belt of the region and harbors about 3128 species of flowering plants contributing about 18% of total flora of the country [5].

Garo Hills, Khasi Hills and Jaintia Hills are three main regions of Meghalaya in terms of tribal composition. The state has an estimated population of about 2,964,007 [6]. The three principal tribes of Meghalaya are the Garo, Khasi and Jaintia. The Garo tribe belongs to Tibeto-Burman subfamily of Sino-Tibetan linguistic group [7].

The Garo Hills comprises of five districts namely North Garo Hills, West Garo Hills, South West Garo Hills, South Garo Hills (SGH) and East Garo Hills districts, predominated by the Garo tribe which constitutes 96.54% of the total population. It is the second largest tribe after the Khasi in Meghalaya along with other indigenous inhabitants viz. Hajongs, Rabhas, Koches, Rajbansis, Kacharis and Dalus [8].

Recent trend in ethno-medicinal studies produces a number of works in northeast Indian state. In the state of Meghalaya, ethnomedicinal works have been done basically on the Khasi and Jaintia tribes [9-14] and only a few sporadic works on the Garo tribe [15-18]. However, no attempt has been made so far to document the ethnomedicinal plants of SGH district in concern with traditional knowledge of Garo tribe. Therefore, the present study was conducted to document the use of medicinal plants used by Garo tribe residing in SGH district of Meghalaya, India.

Materials and Methods

Study area

SGH district, one of the 5 districts of Garo Hills is situated in the south-west corner of Meghalaya. It is bounded by international border with Bangladesh in the South, West Garo Hills district in the West, East Garo Hills district in the north and South West Khasi Hills district in the east. The district lies between 25°25'N to 25°27'N Latitude and 90°30'E to 90°66'E Longitude extending an area of 1850 sq. km with 1186 sq. km of forest coverage having Balpakram-Baghmara Landscape in its heart. The district is predominated by the Garos and shifting cultivation is their main occupation.

Field survey

During the ethnomedicinal survey from 2012 to 2014 in SGH district of Meghalaya, India in connection with the Approved Research Programme of Botanical Survey of India, Eastern

Regional Centre, Shillong, Meghalaya, efforts were made to record the ethnomedicinal plants used by the Garo tribe. Field surveys have been undertaken covering all the seasons for gathering the information on plant species used in traditional herbal medicine in different villages namely Rompa, New Rompa, Hatisia, Durbeta, Kanai, Mahadeo, Moheskhola, Rongra, Karauni and Siju in and around Balpakram-Baghmara Landscape (25°9'N to 25°22'N latitude and 90°37'E to 90°60'E longitude) of SGH district (Figure 1).

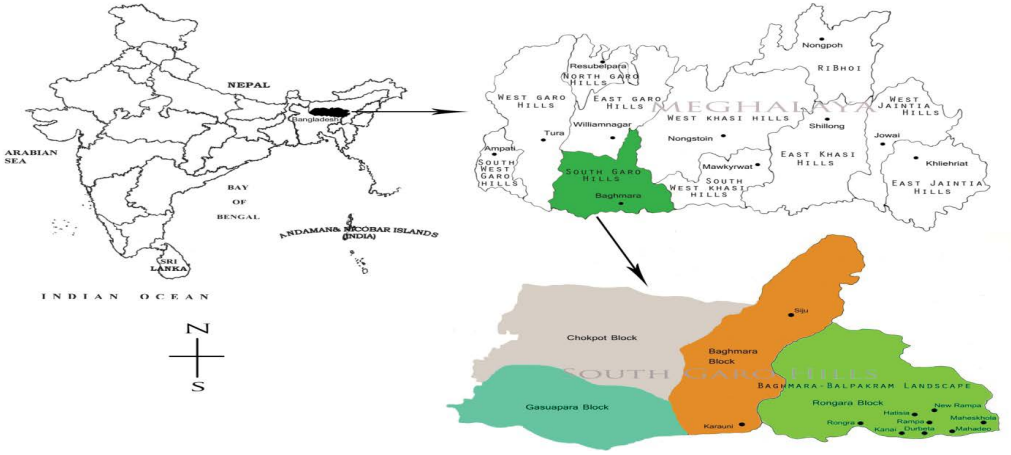

Figure 1: Map showing study area.

Data collection and interviews

The information were collected from 18 (13 men and 5 women) traditional practitioners locally called ojhas in different villages. All the interviewees were in the age range of 45-75 years. The data were collected through direct interview and discussion in local Garo language and sometime in English using educated forest personal as translators following the semi structured questionnaire [19]. In course of the interviews, information on ethnomedicinal plants, their local names, plant parts used in respective diseases and methods of administration were recorded. The scientific term for various ailments mentioned by the informants in the survey has been standardized and grouped under different disease categories according to Cook [20].

Plant collection, preservation, identification and deposition in herbarium

The plants have been collected in flowering and fruiting stages. The whole process of collection, pressing and preparation of herbarium specimens were in accordance to the conventional herbarium techniques [21]. The specimens were identified with the help of different Floras and Monograph specially Flora of British India [22], Forest Flora of Meghalaya [23] and Flora of Assam [24-27]. The identities of the specimens were finally confirmed by consulting ASSAM herbarium in Botanical Survey of India (BSI), Shillong. All the voucher specimens have been deposited to the ASSAM herbarium, BSI, Eastern Regional Centre, Shillong for future references.

Data analysis

The data collected during the study were analysed by the following methods.

Relative Frequency of Citation (RFC): The RFC is obtained by the equation RFC = FC/N (0 < RFC < 1) where, FC is the frequency of citation i.e., the number of informants who mention the use of the species and N is the total number of informants interviewed in the survey [28]. This index shows the local importance of each species.

Informant consensus factor (F_{IC}): Informant Consensus factor or Informant Agreement Ratio (IAR) was one of popular quantitative approaches for identifying the relative importance of medicinal plants with the ailment categories in a particular culture. The present index was initially developed by Trotter and Logan [29] and later on modified by Heinrich et al., [30]. The present index calculated on the basis of the following equation-

$$F_{IC} = Nur - Nt/(Nur - 1)$$

Where, Nur stands for the number of use reports for a particular use category and Nt stands for the number of taxa used for a particular ailment category by all informants. The indices could reflect the homogeneity in the use of plants in the ailment categories among the informants of the study area. As many species may be associated with the same disease, this factor becomes significant tool for determining the most used plant species for treating a particular ailment. A higher F_{IC} value indicates the use of relatively few plants by the informants in the treatment of a particular ailment category whereas a lower F_{IC} value indicates that there are disagreement among the informants with regard to use of a particular plant for treating a particular ailment category.

Results

The present investigation on ethnomedicinal plants was carried out from 2012 to 2014 in SGH district of Meghalaya. Total 98 plant species belonging to 91 genera and 47 families have been reported by 18 Garo medicine men and women in about 35 different ailments. Collected data were tabulated with the family name in alphabetical order followed by species name, voucher number, vernacular name, habitat, relevant frequency of citation, plant part(s) used, ailments treated, preparation, application and relevant ethnobotanical/ pharmacological citation (Table 1).

Family and botanical name	Voucher number	Vernacular name	Habit	RFC#	Part(s) used	Used in	Preparation	Application
Acanthaceae Justicia adhatoda L.	DKR130889	Alot-gipak	S	0.50	Bk	Cough & Cold	Juice	I
Justicia gendarussa Burm. f.	DKR125437, 125445, 125495	Dojajjiipe	S	0.22	St	Bone fracture	Paste	E
Phlogacanthus thyrsiflorus Nees	DKR125438, 125601,129446	A lot-gitchok	S	0.38	Lf	Dysentery	Juice	I
					Bk	Jaundice	Juice	I
Acoraceae Acorus calamus L.	DKR130875	Pachhi	H	0.61	Rz	Indigestion, cough, asthma	Decoc	I
Amaryllidaceae Crinum amoenum Ker Gawl. ex Roxb.	DKR125968, 125646	Gorobokchi jota	H	0.39	Tb	Bone fracture	Paste	E
Apiaceae Centella asiatica (L.) Urb.	DKR125971, 130112	Monmuni	H	0.44	Wp	Gastric, Dysentery	Juice	I
Apocynaceae Calotropis gigantea (L.) Dryand.	DKR125697, 125940, 125625	Khimbar	S	0.61	Lf	Headache	Paste	E
Rauvolfia serpentina (L.) Benth. ex Kurz	DKR125440, 125605	Dogrik	S	0.38	Rt	Jaundice	Decoc	I
Wrightia antidysenterica (L.) R.Br.	DKR125474, 125493	Bolmatara	T	0.33	Rt	Dysentery	Decoc	I
Aquifoliaceae Ilex umbellulata (Wall.) Loes.	DKR129476	Boltajong	T	0.17	Bk	Indigestion	Decoc	I
Araceae Colocasia esculenta (L.) Schott	DKR125926	Ajokdiki	H	0.16	Tb	Abortion	Decoc	I

Lasia spinosa (L.) Thwaites	DKR129470	Chonggi	H	0.39	Lf	Cuts & wounds, gastric	Paste	E, I
Asparagaceae Asparagus racemosus Willd.	DKR125932, 125970	Kizhangu	H	0.50	Rt	Sexual weakness, ulcer	Decoc	I
Bignoniaceae Oroxylum indicum (L.) Kurz	DKR130893	Kiringbol	T	0.33	Bk	Jaundice	Decoc	I
Stereospermum tetragonum DC.	DKR125510, 129722	Bolsil	T	0.22	Bk	Dizziness	Decoc	I
Bromeliaceae Ananas comosus (L.) Merr.	DKR130877	Anaros	H	0.50	Rt	Gonorrhea, skin debridement, arthritis	Decoc	I
Combretaceae Terminalia bellirica (Gaertn.) Roxb.	DKR125512	Bahera	T	0.44	Fr	Gastritis, Jaundice	Powder	
Compositae Ageratum conyzoides (L.) L.	DKR125394, 130115	Namining	H	0.61	Lf	Cut & wounds, diarrhea, boils, fever	Paste, juice	I, E
Artemisia nilagirica (C.B.Clarke) Pamp.	DKR 125955	Nakdue	S	0.61	Lf	Jaundice, scabies, itching, wounds	Decoc, paste	I, E
Spilanthes acmella (L.) L.	DKR125385	Santusem	H	0..39	Lf	Toothache	Paste	E
Chromolaena odorata (L.) R.M.King & H.Rob.	DKR130116	Samsimari	S	0.44	Lf	Cut &Wounds, fever	Paste, juice	E, I
Mikania micrantha Kunth	DKR125990	German-pila	S	0.38	Lf	Cuts & wounds	Paste	E
Convolvulaceae Cuscuta reflexa Roxb.	DKR130885	Durimit-budu	H	0.38	Wp	Jaundice	Decoc	I
Costaceae Cheilocostus speciosus (J.Koenig) C.D.Specht	DKR130883	Diki-ahuda	S	0.22	Rz	Jaundice	Powder	I
Crassulaceae Bryophyllum pinnatum (Lam.) Oken	DKR129602	Samjangi	H	0.44	Lf	Irregular menstruation, dysentery	Juice	I
Cucurbitaceae Benincasa hispida (Thunb.) Cogn.	DKR130859	Akaru	H	0.38	Sd	Profuse bleeding from uterus, epilepsy	Roasted	I
Coccinia grandis (L.) Voigt	DKR130087	Du-chuja	S	0.27	Rt	Stomach ache, diabetes	Paste	E
Cucurbita maxima Duchesne	DKR130884	Akaru-gitchak	S	0.22	Sd	Profuse bleeding from uterus	Roasted	I
Momordica charantia L.	DKR130891	Kolacita	S	0.16	Lf	Piles	Juice	E
Cyperaceae Cyperus rotundus L.	DKR125370	Ganechi	H	0.44	Rz	Jaundice, wonds	Juice	I
Dilleniaceae Dillenia pentagyna Roxb.	DKR125302	Agachi	T	0.5	Fl, Bk	Fever, diabetes	Juice, powder	I
Euphorbiaceae Croton caudatus Geiseler	DKR125996	Sawaka	S	0.27	Bk	Malaria, diabetes	Decoc	I
Croton joufra Roxb.	DKR125653	Matmi	T	0.5	Bk	Paralysis, diarrhea	Decoc	I
Euphorbia hirta L.	DKR130887	Katri	H	0.33	Tw	Leucorrhea, diarrhea	Juice	I
Jatropha curcas L.	DKR130888	Mandalchi	S	0.27	Lf	Malaria, rheumatism	Latex	I

Jatropha gossypiifolia L.	DKR125935	Mandalchi	S	0.5	Lf	Stomachache, headache	Latex	I
Manihot esculenta Crantz	DKR129600	Simuldiki	S	0.28	Lf	Ringworm	Paste	E
Fagaceae Castanopsis indica (Roxb. ex Lindl.) A.DC.	DKR125523, 125545	Chakko	T	0.33	Lf	Headache	Paste	E
Hypoxidaceae Curculigo orchioides Gaertn.	DKR130181. A	Shakti-bindu	H	0.27	Rt	Sexual weakness	Decoc	I
Lamiaceae Callicarpa arborea Roxb.	DKR130879	Akon	T	0.61	Lf	Paralysis, diabetes	Paste	I
Clerodendrum indicum (L.) Kuntze	DKR130882	Bodimdim	S	0.38	Lf	Dysentery, asthma	Juice	I
Clerodendrum infortunatum L.	DKR125657	Sam-makhi, Samsikhs	S	0.22	Rt	Dysentery	Decoc	I
Leucas aspera (Willd.) Link	DKR130890	Dumkolos	H	0.22	Lf	Rhinitis	Juice	E
Ocimum tenuiflorum L.	DKR129598	Tulshi	S	0.33	Lf	Cough & Cold, fever	Juice	I
Lauraceae Cinnamomum tamala (Buch.-Ham.) T.Nees & Eberm.	DKR125462, 129686	Tezibol	T	0.61	Bk	Beriberi, diabetes	Decoc	I
Litsea cubeba (Lour.) Pers.	DKR129612	Zeng-jil	T	0.11	Bk	Headache	Paste	E
Lecythidaceae Careya arborea Roxb.	DKR125463	Ghimbeel	T	0.38	Bk	Dysentery, piles	Decoc	I
Leguminosae Bauhinia purpurea L.	DKR129433, 129617	Megong	T	0.44	Bk	Bone fracture, leprosy	Paste	E
Cassia fistula L.	DKR130880	Sinaru	T	0.44	Lf, Bk	Arthritis, Jaundice	Decoc	I
Senna tora (L.) Roxb.	DKR125984	Doneru	S	0.44	Sd	Ringworm	Powder	E
Mimosa pudica L.	DKR125387	Smit-chip	S	0.33	Lf	Boil	Paste	E
Mucuna bracteata DC.	DKR125942	Wakmi	S	0.33	Sd	Sexual weakness	Roasted	I
Ormosia robusta Baker	DKR125524, 130155	Sanachi-bloma	T	0.05	Bk	Jaundice	Decoc	I
Saraca asoca (Roxb.) Willd.	DKR129496, 125327	Khom-kol	T	0.38	Fl	Uterine disorders	Juice	I
Lythraceae Lagerstroemia speciosa (L.) Pers.	DKR125987, 129782	Asaribol	T	0.38	Rt	Jaundice	Decoc	I
Malvaceae Abutilon indicum (L.) Sweet	DKR130874	Hathkapali	S	0.54	Lf	Headache, Liver disorder	Paste	E
Bombax ceiba L.	DKR129766	Bolchu	T	0.44	Bk	Bone fracture, indigestion	Paste	E
Urena lobata L.	DKR125359	Domachiok-budu	S	0.39	Rt	Bone fracture, dog bite	Paste	E
Melastomataceae Melastoma malabathricum L.	DKR125681, 125972, 125460, 125477	Kakkuchi	S	0.44	Lf	Cuts & wounds, dysentery	Paste	E
Osbeckia nepalensis Hook. f.	DKR130895	Kakuchi	S	0.22	Rt	Body pain	Paste	E
Meliaceae Azadirachta indica A.Juss.	DKR130860	Neem	T	0.5	Bk	Jaundice, gingivitis	Decoc	I
Munronia pinnata (Wall.) W. Theob.	DKR125345	Samskar	S	0.38	Rt	Diarrhea	Decoc	I

Menispermaceae Cyclea peltata (Lam.) Hook.f. & Thomson	DKR129654	Nirkhut	S	0.5	Rt	Small Pox, jaundice	Decoc	I
Tinospora sinensis (Lour.) Merr.	DKR130139	Lengkot-budu	S	0.27	Tb	Piles	Decoc	I
Nepenthaceae Nepenthes khasiana Hook.f.	DKR125519, 125909	Memang-kakshi	S	0.27	Pt	Leprosy	Sap	E
Nymphaeaceae Nymphaea nouchali Burm.f.	DKR130892	Aplak	H	0.44	Rz	Irregular period	Paste	I
Oxalidaceae Averrhoa carambola L.	DKR130016	Kamagga	T	0.72	Fr	Jaundice	Juice	I
Oxalis corniculata L.	DKR130894	Ladawke	H	0.38	Wp	Onychomycosis	Paste	E
Phyllanthaceae Phyllanthus emblica L.	DKR130896	Ambri	T	0.33	Bk	Dysentery	Decoc	I
Piperaceae Piper longum L.	DKR129402	Golmoris	C	0.50	Fr	Cough & Cold, menstrual pain	Powder	I
Plantaginaceae Plantago major L.	DKR125949	Chakurblang	H	0.38	Lf	Cut & wounds	Paste	E
Scoparia dulcis L.	DKR125363	Sam-Goldak	S	0.33	Wp	Headache	Paste	E
Rhamnaceae Ziziphus jujuba Mill.	DKR130900	Angkil	T	0.22	Rt	Influenza	Decoc	I
Rubiaceae Hedyotis scandens Roxb.	DKR125368	Kimprong	S	0.38	Rt	Stomach pain, cough	Juice	I
Morinda angustifolia Roxb.	DKR125334, 125491, 125557	Chenong	S	0.44	Rt	Dysentery	Decoc	I
					Bk	Jaundice	Decoc	I
Mussaenda glabra Vahl	DKR129599	Gardek	S	0.38	Rt	Jaundice	Decoc	I
Paederia foetida L.	DKR125354	Pashum	S	0.44	Lf	Indigestion	Juice	I
Spermacoce neohispida Govaerts	DKR130878	Ramasam	H	0.39	Lf	Stomach pain, wounds	Juice	I
Rutaceae Aegle marmelos (L.) Corrêa	DKR125933	Belethi	T	0.83	Tw, Bk	Cough & Cold , diarrhea, jaundice, dysentery	Decoc	I
Micromelum integerrimum (Buch.-Ham. ex DC.) Wight & Arn. ex M. Roem.	DKR125415	Bol-bisi	T	0.28	Bk	Toothache, gastric	Powder, Decoc	E, I
Murraya paniculata (L.) Jack	DKR125442	Kamini	T	0.38	Lf	Fever	Juice	I
Zanthoxylum rhetsa DC.	DKR 130341	Chilong	T	0.27	Rt	Jaundice	Paste	I
Smilacaceae Smilax ovalifolia Roxb. ex D.Don	DKR130103	Narang-wa	S	0.33	Lf, Rt	Boil, body pain	Paste,	E
Solanaceae Physalis divaricata D. Don	DKR130897	Chichithopa	H	0.5	Tw	Gastritis	Juice	I
Solanum melongena L.	DKR130898	Bareng	S	0.44	Rt	Toothache, beriberi	Powder, Decoc	E, I
Theaceae Schima wallichii Choisy	DKR125309, 125977,125499	Boldo-kaki	T	0.5	Lf	Cut & wounds	Paste	E
Urticaceae Boehmeria macrophylla Hornem.	DKR125973, 129737	Gilgra	S	0.33	Lf	Dysentery	Paste	I

Vitaceae Cissus quadrangularis L.	DKR130881	Samritchu	S	0.72	Rt, St	Bone fracture, irregular menstruation	Paste, juice	E
Cissus repanda (Wight & Arn.) Vahl	DKR130236	Tazabudu	S	0.39	Lf, Rt	wounds, dysentery	Paste, Decoc	I
Tetrastigma thomasianum Planch.	DKR125320	Wakkarang	S	0.16	Bk	Bone fracture	Paste	E
Leea indica (Burm. f.) Merr.		Ganggipetop	S	0.50	Rt	Beriberi, allergy	Decoc, paste	I, E
Xanthorrhoeaceae Aloe vera (L.) Burm.f.	DKR130876	Diki-kamchon	H	0.67	Lf	Jaundice, eczema, wounds	Decoc	I
Zingiberaceae Curcuma angustifolia Roxb.	DKR125679	Diki-Katonggisim	H	0.61	Rz	Stomach pain, stomatitis	Juice	I
Curcuma montana Roxb.	DKR130221	Diki-Katonggisim	H	0.61	Rz	Jaundice	Decoc	I
Curcuma zedoaria (Christm.) Roscoe	DKR130219	Jalam-dike	H	0.55	Rz	Jaundice, cough	Decoc	I
Hedychium coccineum Buch.-Ham. ex Sm.	DKR130331	Samriching	H	0.44	Rz	Headache, rheumatism	Paste	E
Zingiber officinale Roscoe	DKR130899	Reching	H	0.27	Rz	Jaundice	Decoc	I
Zingiber zerumbet (L.) Roscoe ex Sm.	DKR130345	Adadari	H	0.33	Rt	Convulsion in children	Decoc	I

Table 1: Plant species used by the Garo tribe in South Garo Hills district of Meghalaya.

H - Herb; S - Shrub; T - Tree; C - Climber; #RFC - Relative Frequency of Citation; Lf - Leaf; Rt - Root, Bk - Bark, St - Stem; Rz - Rhizome; Wp - Whole Plant; Sd - Seed; Fl - Flower; Tb - Tuber; Tw - Twig; Pt - Pitcher; Fr - Fruit; Decoc - Decoction; I - Internal; E - External.

Out of 46 families, most predominant are Leguminosae (7 spp.), Zingiberaceae (6 spp.), Euphorbiaceae (6 spp.), Rubiaceae (5 spp.), Lamiaceae (5 spp.), Compositae (5 spp.), Cucurbitaceae (4 spp.), Rutaceae (4 spp.), Vitaceae (4 spp.), Malvaceae (3 spp.), in terms of number of species used (Figure 2). Amongst the collected plants, shrubs comprise 42 species followed by herbs (29 sp.), tree (28 sp.) and climber (1 sp.).

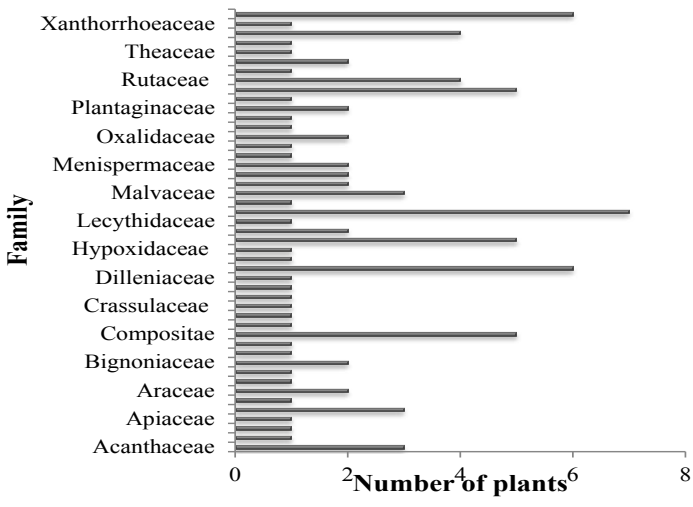

Figure 2: Number of plants per family used in SGH.

Out of various plant parts used as medicine (Figure 3), usage of leaf has shown highest percentage of 29% followed by root (21%), bark (20%) , rhizome (8%), seed (4%), whole plant (4%), fruit (3%), tuber (3%), twig (3%), flower (2%), stem (2%) and pitcher (1%).

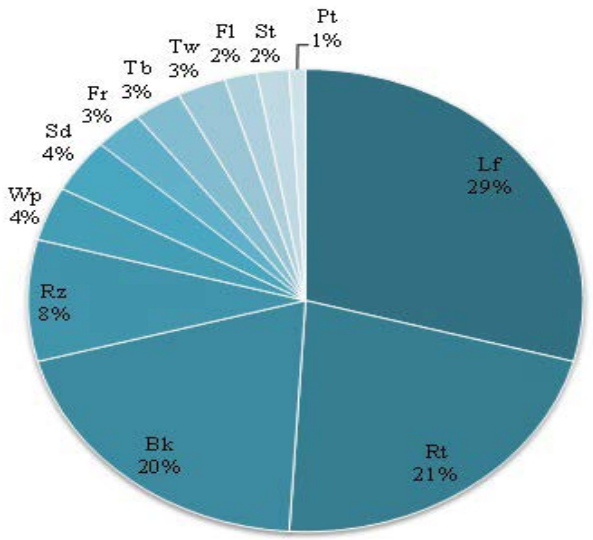

Figure 3: Percentage of plant parts used.

The most prevalent forms of preparation of medicine are decoction (36%), which is followed by paste (31%), juice (21%), powder (6%), roasted (3%), latex (2%) and sap (1%) (Figure 4).

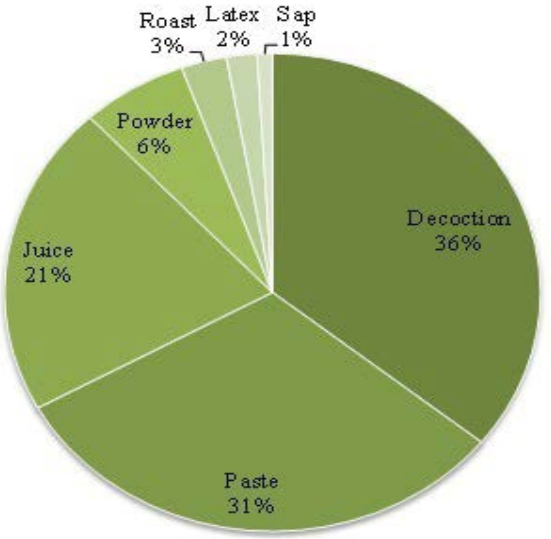

Figure 4: Mode of preparation of traditional therapy in SGH.

The herbal medicines are either applied Externally (E) or taken Internally (I). Internal application of plants is more frequent (66%) in the present study area than external

application (33%). Out of 33 ailments, herbal medicines are applied externally in 11 ailments namely body pain, boil, bone fracture, cut and wounds, headache, joint pain, leprosy, onychomycosis, paralysis, ringworm, toothache and taken orally in 22 ailments viz. abortion, irregular period, after delivery, beriberi, convulsion of children, cough and cold, diarrhea, dysentery, fever, gastritis, gonorrhea, indigestion, jaundice, malaria, paralysis, piles, profuse bleeding from uterus, rhinitis, sexual weakness, small pox, stomach pain, uterine disorders. The most common ailments are jaundice, dysentery, bone fracture, cut and wounds, headache, indigestion, cough and cold, irregular period and ringworm. Maximum 20 species are found to be used in the remedies of jaundice followed by dysentery (13 sp.), bone fracture (8 sp.), cut and wounds (7 sp.), headache (6 sp.) and indigestion (5 sp.).

Diseases recorded in the present study area have been categorized under 15 disease categories based on the human body system (Table 2). Among them highest F_{IC} value has been shown by III-Defined symptoms (1) followed by nutritional disorders (0.78).

Disease category	Number of Use Reports (Nur)	Number of Taxa (Nt)	Informants consensus index factor (F_{IC})
III-Defined symptoms	2	1	1
Nutritional disorders	24	6	0.78
Genitourinary system disorders	45	11	0.77
Endocrine system disorder	27	7	0.77
Respiratory system disorders	52	13	0.76
Infections/infestations	124	30	0.76
Pain	56	14	0.76
Muscular-skeletal system disorders	55	14	0.76
Nervous system disorders	30	8	0.76
Mental disorders	13	4	0.75
Pregnancy/birth/puerperium disorders	5	2	0.75
Inflammation	5	2	0.75
Skin/subcutaneous cellular tissue disorders	37	10	0.75
Digestive system disorders	164	43	0.74
Injuries	63	17	0.74

Table 2: Informants consensus factor (F_{IC}) for various disease categories.

Based on the information provided by the interviewee, the highest cited plant is *Aegle marmelos* with RFC value of 0.83. Other plants with prominent RFC value are *Averrhoa carombola* (0.72), *Cissus quadrangularis* (0.72), *Aloe vera* (0.67), *Acorus calamus* (0.61), *Callicarpa arborea* (0.61), *Ageratum conyzoides* (0.61), *Artemisia nilagirica* (0.61), *Calotropis gigantea* (0.61), *Cinnamomum tamala* (0.61), *Curcuma angustifolia* (0.61) and *Curcuma montana* (0.61).

Discussion

The present survey indicates a high level of consensus within the ethnic Garo community. In this current work, the informant consensus of medicinal plant usage by the Garo people of SGH, Meghalaya resulted in F_{IC} ranging from 0.74 to 1 per disease category. The highest F_{IC} (1.00) is observed for use category related to III-defined symptoms, but only one species viz., *Stereospermum tetragonum* was recorded for dizziness in this category. This finding suggested that there is a well-defined selection criterion for this use category [31]. However, the plant in this use category was cited by only two informants, indicating that the species may be effective for specific treatments, yet the knowledge rests with only a few people, making it vulnerable to extinction [32].

Similarly, in case of *Nepenthes khasiana,* the main attribute for getting endangered is its endemicity to the state of Meghalaya, India [33] and intensive exploitation by the local inhabitant for its medicinal uses. The species has a much localised distribution in the

Jarain area of the Jaintia Hills [34] and the Baghmara area of the Garo Hills of Meghalaya. During the current survey, 10 out of 18 informants mentioned the plant for treating leprosy which demarcates most of the surveyed traditional practitioners is exploiting the plant for its therapeutic use. Therefore, it validates the present conservation status of the plant.

Among the ethnomedicinal plants documented during the survey, *Aegle marmelos, Averrhoa carombola* and *Cissus quadrangularis* are the top three frequently cited plants. The used of twig and bark of *A. marmelos* by the Garos is very effective in curing cough & cold, diarrhea, jaundice, dysentery. In Ayurveda and in various folk medicines, the leaves and bark of *A. marmelos* are used extensively to treat ailments including diarrhea, jaundice and dysentery [35]. *C. quadrangularis*, commonly known as the "bone setter," referred to as "Asthisamdhani" in Sanskrit and "Harjod" (Har means bone and jod means to attach) in Hindi because of its ability to join bones [36]. Nadkarni [37] in his Materia Medica describes the root as most useful for bone fractures, with similar mode of application. Relevant use of this plant has also been reported in the neighboring state of Tripura [38]. The use of *A. carombola* fruit in treating jaundice is found very common by the Garo tribe of SGH district. In Maharastra, India 2-3 ripened fruit of this plant are consumed daily for 15-20 days to get rid of Jaundice [39]. The plant has also been reported against jaundice in the sub-Himalayan parts of Uttarakhand, India [40].

Leaves and root were the most used plant part, which agrees with most other ethnobotanical studies [31,38,41]. The explanation is possibly that leaves are the most vulnerable parts of plants and therefore contain more bioactive secondary compounds to defend themselves from herbivores [42]. From a management perspective, gathering of leaves is more sustainable than gathering of underground parts, stem, bark, or entire plants [43]. However, roots are the second most preferred part, possibly because they contain high levels of bioactive compounds related to their function as a sink for compounds produced by the plants [32].

Conclusion

Aegle marmelos, Averrhoa carombola and *Cissus quadrangularis* are the top three plants analyzed during the present investigation. These plants can be further studied for their pharmacological activity and active compound. Scientific and systematic collections of medicinal plants may be done by responsible authority for commercial purposes, which can be beneficial for the local inhabitants as well as the nourishment for the natural ecosystem.

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Ethno-Medicinal Plants Used By the South West Khasi Hills District Community of Meghalaya, India

Sh. Bidyasagar Singh[1*], S.K. Tripathi[2] and B. P. Mishra[3*]

[1]NERCORMP- KCRMS, West Khasi Hill District- 793119, Meghalaya
[2]Department of Forestry, Mizoram University, Aizawl – 796004, Mizoram
[3]Department of Environmental Science, Mizoram University, Aizawl – 796004, Mizoram

***Corresponding author:** Dr. Sh. Bidyasagar Singh, NERCORMP- KCRMS, West Khasi Hill District- 793119, Meghalaya, India; E-mail: shaikhombidyasagar@yahoo.co.in

Abstract

Medicinal plants play a vital role for the development of new drugs and form the backbone of the traditional communities for their daily needs of curing ailments. Information on the uses of these medicines is communicated within the community verbally and there is general lack of proper recording of these plants and their uses. In recent years, uses of medicinal plants are increasingly solicited through the tradi-practioners for the treatment of different ailments of the communities. The present study was carried out on medicinally important plants used by the South West Khasi Hills District community of Meghalaya, and recorded a total of 56 medicinal plant species belonging to 53 genera and 41 families. The study showed that *Achyranthes aspera* and *Celastrus peniculatus* were most important species used for curing many diseases. The leaves were the most frequently used plant parts followed by root, bark, fruit, stem, seed, and whole plant to cure various diseases. The unproportioned use of plants and their parts is threatening the survival of critical plants in the region. Therefore, there is a need to conserve the plant resources on the ground level for the benefit of local communities and sustainable use of these species.

Keywords: Ailments; Sustainable Development; Traditional Medicine; Tradipractioners

Introduction

Natural ecosystems mainly forests have been considered as the storehouse of biodiversity and used as a source of medicinally important plants for millennia. Plants produce number of chemical compounds for biological functions like defense against insects, fungi and herbivorous mammals and more than 12, 000 chemical compounds have been isolated so far which are believed to be less than 10% of the total [1,2]. These chemical compounds originated from plants mediate their effects on the human body through the process similarly to those already known for the chemical compounds in the conventional drugs and so the herbal medicine works similarly as the conventional medicines. Therefore, plant-based system continues to play an essential role in primary health care of population still

today. Medicinal Plants have been used for thousands of years to flavor and conserve food, to treat health disorders and to prevent many diseases including epidemics [3].

The use of herbal plants to treat human ailments is universal among non-industrialized societies and is often more affordable than purchasing modern medicines. The World Health Organization (WHO) estimated that 80% of the population in the countries of Asia and Africa continent presently use herbal medicine for primary health care remedies. This has led to increase the total annual global value of pharmaceutical plants over US $ 2.2 billion in 2012 [4]. WHO has recognized the importance of traditional medicine and has created strategies, guidelines and standards for botanical medicines [5]. Plants with medicinal properties enjoyed the highest reputation in the indigenous systems of medicine all over the world, and still constitute one of the major sources of drugs in modern as well as traditional systems of medicine in spite of tremendous development in the field of synthetic drugs and antibiotics [6].

Indigenous people living in particular areas depend on the use of wild plants or plant parts to fulfill their needs and often have considerable knowledge on their uses for the plant diversity for food, cloth, shelter, for the treatment of their regular ailments, utilize the plants and manage to conserve it to some extent for future use [7]. Forest degradation followed by unsustainable use of forest products has resulted not only in environmental degradation but also threatened the livelihood security of millions of people particularly in developing countries. Therefore, conservation of natural resources has held utmost importance for mankind's survival and sustenance. Protections of a large number of medicinal plants in sacred forests of different parts of India are some of the well documented studies [8-11] that can provide a natural wealth for food, fiber and medicinal uses of tribal population inhabiting the area.

Traditional medicine healing practice is not only concerned with curing of diseases but also with the protection and promotion of human physical, spiritual, social, mental and material wellbeing [12]. The importance of medicinal plants to treat human ailments and community characteristic in most parts of Northeast of India has been described by various studies [13-18]; however, there are still only few studies describing such studies for the state of Meghalaya [19-21]. Meghalaya is rich in its floral diversity and contributes about 18% of total flora of country [22]. There are about 3128 species of flowering plants in the state of which 40% of total flora of state is endemic. Herbal drugs obtained from plants are believed to be much safer; this has been proved in the treatment of various ailments [23]. Traditional medicine and ethnobotanical information play an important role in scientific research, particularly when the literature and field work data have been properly evaluated [24]. Medicinal plants have always been the principle form of medicine in India. Therefore, the present study was carried out to identify the use of medicinally important plants by the communities of West Khasi Hills District of Meghalaya based on primary and secondary resources and suggested action for conservation of threatened plants of the region based on their unjudicial uses.

Material and Methods

The study was carried out in part of Mawkyrwat, South West Khasi Hills District which is 37 km far from the West Khasi Hills District under the Mawkyrwat block, Meghalaya, India. It lies between latitudes 25.3625° N and longitudes 91.4556° E. The elevation ranges is 1534.82 m asl. The climate is monsoonal with distinct warm-wet and cold-dry periods. The monsoon strikes in this area in the middle of May to the middle of September, which sometimes extends to late September and first week of October. The western and southern parts of the state are warmer than the central upland where mean minimum temperature stands at 20°C. Average maximum and minimum temperatures and annual rainfall in the state varies from 5°C to 32°C, and 4,000 mm to 11,436 mm, respectively.

The study was conducted during 2014-2015 with suitable questionnaires in selected villages. Information was collected from elder people and traditional healer who have sound knowledge about plants and their uses. The species were identified with the help of herbarium of the BSI, Eastern circle, Shillong and counter checked with the help of Flora of Assam [25], Flora of Meghalaya [26] and other regional and local floras.

Results and Discussion

In the present study, a total 56 plants species belonging to 41 families and 53 genera were recorded. The information on different ethno-medicinal use of the plant species to treat various ailments recorded during the period of survey are given alphabetically in Table 1 and the photographs of some plants and consulting are given in Figure 5. Based on life forms there were: 52% tree, 23% shrub, 14% Herb and 11% climber (Figure 1). Trees are the main sources of medicines followed by shrubs, herbs, climbers. The present study shows that almost all plant parts are used as medicine. Rubiaceae was the most dominant family representing 5 species followed by Anacardiaceae, Lauraceae, Solanaceae (3 species each), Fabaceae, Moraceae, Plantaginaceae, Rutaceae and Verbenaceae (2 species each) and the remaining thirty two families were represented by a single species (Figure 2). People use several methods to prepare medicines from local herbs and plant materials traditionally. Sometime they use different parts of the plants and sometime whole plants. The parts of plants used for medicinal purpose were leave, root, bark, stem, seed etc. The study focuses the use of plant parts i.e. leave 26%, root 19%, and bark 17%, fruit 13%, stem 10%, seed 9% and whole plant 6% to cure various diseases (Figure 3). The maximum use of leave, root and bark indicates that these parts may have strong medicinal properties. Most of the medicinal plants are taken internally or applied externally and used in juice form which is extracted from different parts of a plant followed by paste, fresh plants and plant parts and powder form. Some of the plant parts used in medicines is single or either mixed with other ingredients. These medicinally important plants are used to cure various ailments including diarrhea, cold, cough, fever, stomachache, snake bite, skin disease, toothache, diabetes bone fracture etc. The finding revealed that maximum plants species are used to cure various ailments such as diarrhea, cold, cough, fever, stomachache, dysentery etc. However, minimum plant species used to cure diabetes, blood pressure, toothache, asthma, diuretic etc. (Figure 4). The study further showed that a single plant species *Achyranthes aspera* and *Celastrus peniculatus* frequently used to cure many diseases. Ethno-medicinal plants have special meanings to the communities in the sense that they contribute to many lives in term of health support, income generation and food security [27]. During our survey we have found that most of the elderly persons/traditional healers have greater knowledge upon the utilization of medicinal plants compare to younger generation. They are practicing this method since time immemorial and have been passed for every generation to generation. There is a great danger that this knowledge will be lost in the future due to lack of interest by younger people. However, interaction with younger generation of the village, they showed lack interest in practices. Most of literature who worked in ethno-medicinal studies also presented the same. But due to over exploitation of these valuable resources, there is tremendous pressure on some of the plant species which is resulting in reduction of their population. It is, therefore extremely essential to cultivate and conserve plant species in their environment and to conserve the indigenous knowledge for curing various diseases. The need for integration of indigenous knowledge for sustainable development and conservation of natural resources receive more recognition. To encourage local community towards traditional healthcare systems, there is ample scope of the credit should be given to the persons having such knowledge development of reward system will add a new dimension for protection of medicinal plant as well as restoration of land.

Sl. No	Scientific Name	Family	Local Name	Parts Used	Ailments
1	Abroma augusta (L.) L.f	Malvaceae	Dieng tyrkhum	Leaves, Bark, Roots, Seeds	Amenorrhoea, Abortifacient, Dysmenorrhoea, Diabetes, Menstrual disorders, Gonorrhoea, Sinusitis, Uterine tonic
2	Achyranthes aspera L.	Amaranthaceae	Sohbyrthid	Seeds, Roots, Leaves	Piles, Diuretic, Boils, Abscess, Painfull delivery, Antifertility, Rabies, Antidiabetic, Pneumonia, Menstrual disorders, Insect stings and Snakebite
3	Adenanthera pavonina L	Fabaceae	Dieng thing	Leaves, Bark, Stem, Heartwood	Colonorrhoea, Haematuria, Ulcers, Gout, Burning sensation, Hyperdipsia, Giddiness, Dysentery and Haemorrhages
4	Alangium chinense (Lour.) Harms	Cornaceae	Dieng skhorkhla	Leaves	Snakebite, Carminative, Circulation, Contraceptive, Hemostatic, Numbness, Poison, Rheumatism and Wounds
5	Antidesma diandrum(Roxb.) B.Heyne ex Roth	Euphorbiaceae	Dieng japew	Leave	Bile complaints
6	Aphanamixis polystachya (Wall.) R.N. Parker	Meliaceae	Dieng rata	Bark, Seeds	Liver disorders, Tumours, Ulcers, Worms, Skin diseases, Leprosy, Jaundice, Haemorrhoids, Rheumatoid Arthritis and Myalgia
7	Argyiera nervosa (Burm.f.) Bojer	Convolvulaceae	Jatapmasi	Roots, Leaves	Rheumatism, Boils, Skin diseases, Syphilis, Nerve tonic, Eczema, Ringworm, Itchings and Swellings
8	Aristolochia tagala	Aristolochiaceae	Sohrynkhiah	Leaves, Roots	Stomachache, Snakebite, Toothache, Rheumatism and Tonic
9	Berberis wallichiana DC.	Berberidaceae	Dieng matshynrang	Root, leave	Swelling, Snake bite, Cough
10	Careya arborea Roxb	Lecythidaceae	Sohkundur	Flowers, Bark, Leaves, Fruits	Thermogenic, Alexeteric, Antipyretic, Pruritus, Tumours, Cough, Dyspepsia, Colic, Haemorrhoids, Worms, Dysentery, Urorrhoea, Leucoderma, Fits, Smallpox, Ulcers and Vaginal raptures
11	Celastrus paniculatus Willd	Celastraceae	Meilalih	Bark, Leaves, Seeds	Stimulant, Aphrodisiac, Rheumatism, Strengthening Memory, Antidote on Opium Poisoning, Expectorant, Appetiser, Cardiotonic, Diuretic, Anti-Inflammatory on Itching & Skin diseases, Paralysis, Asthma, Leucoderma, Beri-Beri and Sores
12	Cinnamomum bejolghota (Buch. Ham) Sweet	Lauraceae	Dieng lasisirmot	Bark	Urinary troubles, Gall Bladder stones and Liver complaints
13	Clerodendrum colebrookianum Walp.	Verbenaceae	Diengjalemkynthei	Bark, Leaves, Roots	Rheumatism, Malaria and Blood Pressure
14	Clerodendrum serratum (L.) Moon.	Verbenaceae	Phlangrilong	Bark, Leaves, Roots	Asthma, Cough, Scrofulous Affection, Dropsy, Fever and Syphilis
16	Cordia dichotoma G.Forst.	Boraginaceae	Diengmong	Bark, Leaves, Fruits	Constipation, Dyspepsia, Fever, Diarrhoea, Leprosy, Skin diseases, Helminthiasis, Gonorrhoea and Ringworm
17	Costusspeciosus (J.Konig) C.Specht	Zingiberaceae	Krahhei-iang	Rhizome	Astringent, Stimulant, Anthelmintic, Cough, Catarrhal, Fever, Dyspepsia, Skin diseases, Worms and Snakebite

18	Curcuma longa L.	Zingiberaceae	Shynrai	Rhizome	Stomachic, Blood purifier, Cold, Vermicide, Antiseptic, Antiperiodic, Diabetes, Leprosy and Sore Throat
19	Dillenia pentagyna Roxb.	Dilleniaceae	Dieng sohbar	Fruits, Leaves	Carbuncles, Chest Complaints, Cholera, Dysentery, Fever, Sores, Cough and Astringent
20	Elaeocarpus sphaericus L.f	Elaeocarpaceae	Dieng sohlangskei	Seeds, Fruits	Cough, Bronchitis, Neuralgia, Cephalalgia, Anorexia, Fits, Manic conditions, Melancholia and Mental disorders
21	Engelhardtia spicata Lechen ex. Blume	Juglandaceae	Dieng lamba	Bark, Leaves	Sedative, Carminative, Anthelmintic, Diuretic, Rheumatism, Itches & Burns, Fever, Asthma, Leprosy and Epilepsy
22	Erythrina stricta Roxb.	Fabaceae	Dieng songdkhar	Bark, leaves	Stomachic, Digestive, Anthelmintic, Fever, Asthma, Leprosy
23	Ficus hispida L.f.	Moraceae	Dieng lapong	Leaves, Seeds, Bark, Fruit	Ringworms, Dysentery, Purgative, Ulcer
24	Garuga pinnata Roxb.	Burseraceae	Dieng sohpjiarshynrang	Roots, Stem, Leaves, Flowers, Galls	Pulmonary Affections, Cornea Opacity, Asthma, Vermifuge, Obesity, Splenomegaly, Foul Ulcers and Odontalgia
25	Gloriosa superba L	Colchicaceae	Malabar glory lily	Tuber	Abortifacient, Stimulant, Anthelmintic and Leprosy
26	Grewia multiflora Juss	Tiliaceae	Dieng tyrbhong	Fruit, Root	Shin disease, Diarrhoea, Dysentery
27	Gynocardia odorata R.Br.	Achariaceae	Dieng sohliang	Fruits	Leprosy and Skin diseases
28	Hedyotis scandens Roxb.	Rubiaceae	Jyrmiskie	Whole plant	Gastralgia, Gastric Ulcers, Heartburns, Colic, Vulnerary and Wounds
29	Holarrhenna antidysenterica (L.) Wall.	Apocynaceae	Dieng jamew	Bark, Seeds	Amoebic Dysentery, Vaginitis, Diarrhoea, Jaundice, Fever, Bladder stone and Tuberculosis
30	Houttuynia cordata Thunb.	Saururaceae	Jamyrdoh	Leaves, Roots	Stomachache, Cholera, Dysentery and Diuretic
31	Lindera pulcherrina (Wall.) Benth	Lauraceae	Dieng jaburit	Bark	Cold, Cough, Worm
32	Litsea sebifera Lour.	Lauraceae	Dieng jalowan	Bark, Leaves, Berries	Demulcent, Astringent, Diarrhoea, Dysentery, Anodyne, Antidote, Bruises, Wounds, Rheumatism and Antiseptic
33	Micromelum pubescens Bl.	Rutaceae	Dieng sohsat	Leaves, Roots	Cough
34	Paederia scandens (Lour.) Merr.	Rubiaceae	Jiasohmusem	Roots, Whole plant, Leaves	Bacillary Dysentery, Urinary Lithiasis, Dysuria, Dyspepsia, Gastritis, Enteritis, Convalascing Persons and Rhematism
35	Passiflora edulis Sims	Passifloraceae	Sohbrab	Leaves, Fruits	Jaundice, Dysentery and Diarrhoea
36	Pavetta indica L.	Rubiaceae	Dieng longtham	Roots, Fruits, Leaves	Diuretic, Visceral Obstruction, Jaundice, Headache, Urinary Diseases, Dropsy, Boils, Itches, Nose Ulcers and Haemorrhages
37	Piper nigrum L	Piperaceae	Sohmarit	Fruits	Anti-Blennorliagic, Stomachic, Dyspepsia, Malaria, Haemorrhoids, Delirium, Tremors and Migraine
38	Plantago erosa L.	Plantaginaceae	Krah shit	Leaves, Roots, Seeds, Whole plant	Burns, Cuts, Tooth & Earaches, Enuresis, Pyorrhea Alveolaris, Depression & Insomnia, Itching & Burning Urticaria, Chilbains, Pruritus, Bee sting, Bleeding Piles, Astringent and Febrifuge.

39	Portulaca oleracea L.	Portulaceae	Jehesia	Whole plant	Antiscorbutic, Diuretic, Scurvy, Liver, Kidney, Spleen & Bladder diseases, Cardio-Vascular disorder, Dysuria, Haematuria, Gonorrhoea, Sore Nipples and Mouth Ulcers
40	Prunus nepalensis L.	Rosaceae	Sohiong	Leaves, Fruit	Astringent, Acrid, Refrigerant and Diuretic
41	Rhus succedaenia L	Anacardiaceae	Dieng khlaw	Fruits	Astringent, Tonic, Expectorant, Diarrhoea, Dysentery
42	Rubia cordifolia L	Rubiaceae	Sohmisem	Roots	Inflammation, Antiseptic, Dysentery, Vulnerary, Diuretic, Ophthalmic, Febrifuge, Rheumatoid Arthritis, Neuralgia, Cephalalgia, Helminthiasis, Leprosy, Leucoderma, Pruritus, Wounds, Ulcers, Tuberculosis, Pharyngitis and Diabetes
43	Scoparia dulcis L	Plantaginaceae	Krahlebekor	Whole plant	Inflammation, Febrifuge, Diuretic, Coryza, Hyperthermia, Sore Throat, Cough, Erythema, Measles, Boils and Impetigo
44	Semecarpus anacardium L.f.	Anacardiaceae	Dieng sohbhala	Fruits	Liver tonic, Arthritis, Antiseptic, Cardiotonic, Sudorific, Febrifuge, Beri-Beri, Cancer, Sciatoca, Neuritis, Diabetes and Ulcers
45	Solanum khasianum C.B.Clarke	Solanaceae		Berries	Inflammations, Arthritis and Hormonal
46	Solanum nigrum L	Solanaceae	The Black Night Shade	Whole plant	Ulcers, Skin Diseases, Dysentery, Laxative, Asthma
47	Solanum torvum Sw	Solanaceae	Diengsohnang	Leaves, Fruits	Wounds and Cough
48	Sonchus arvensis L.	Asteraceae	Kilanjiat	Whole plant, Roots, Seeds	Jaundice, Diuretic, Diaphoretic, Antiseptic, Coughs, Phthisis, Bronchitis, Asthma, Pertusis and Demulcent
49	Spondias pinnata (L. f.) Kurz	Anacardiaceae	Dieng sohpier	Bark, Fruits	Refrigerant, Dysentery, Rheumatism, Dyspepsia
50	Streblus asper Lour.	Moraceae	Dieng sohkhyrdang	Roots, Bark, Leaves, Latex	Thermogenic, Vulnerary, Inflammation, Ulcers, Sinusitis, Elephantiasis, Boils, Haemorrhages, Cough, Bronchitis, Fits, Diarrhoea, Dysentery, Fever and Syphilis
51	Swertia chirayita (Roxb.ex Fleming) H. Karst	Gentianaceae	Sharita	Whole plant	Stomachic, Febrifuge, Diarrhoea, Malaria and Weakness
52	Symplocos laurina (Retz.)	Symplocaceae	Dieng japei	Bark	Ophthalmic, Haemostatic, Asthma, Bronchitis, Dropsy, Arthritis, Ulcers, Tumours, Leprosy, Skin diseases, Fever, Ulemorrhagia, Haemorrhages, Dyspepsia, Flatulence and Leucorrhoea
53	Taxus baccata L	Taxaceae	Dieng blei	Leaves, Bark	Emmenagogue, Asthma, Cancer, Bronchitis and Spasms
54	Terminalia chebula Retz.	Combretaceae	Bolartak	Fruits	Laxative, Inflammation of Mouth & Mucous Membrane, Bleeding & Ulceration of Gums, Cough, Wounds and Scalds
55	Toddalia asiatica (L.) Lam	Rutaceae	Soh sat	Roots, Fruits, Leaves, Flowers	Diaphoretic, Anti Periodic, Anti Pyretic, Anti Bacterial, Vulnerary, Odontalgia, Paralysis, Malaria, Dyspepsia, Colic, Flatulence, Nausea, Epilepsy and Wasp-Stings

56	Xeromphis spinosa (Thunb.) Keay	Rubiaceae	Diengmakasingkhlaw	Fruits, Bark	Abortifacient, Antiseptic, Diarrhoea, Dysentery, Bruises, Cuts, Inflammation, Vulnerary, Febrifuge, Sudorific, Spasms, Sprains, Gout, Wounds, Tumours, Amenorrhoea and Dysmenorrhoea

Table 1: Plant species used by local community for treating in various ailments.

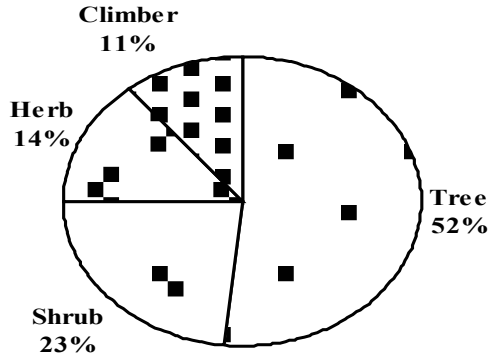

Figure 1: Different life forms of medicinal plants collected.

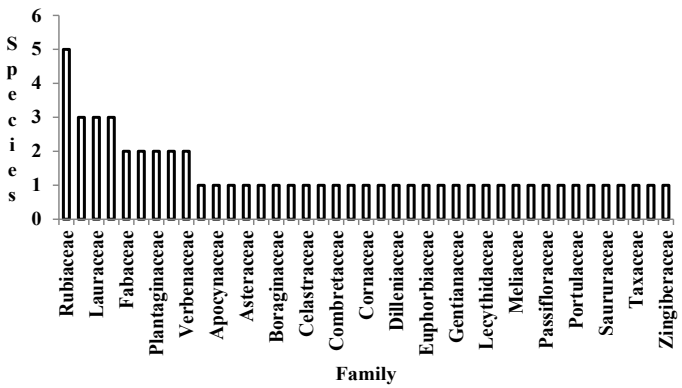

Figure 2: Family distribution of medicinal plants in study area.

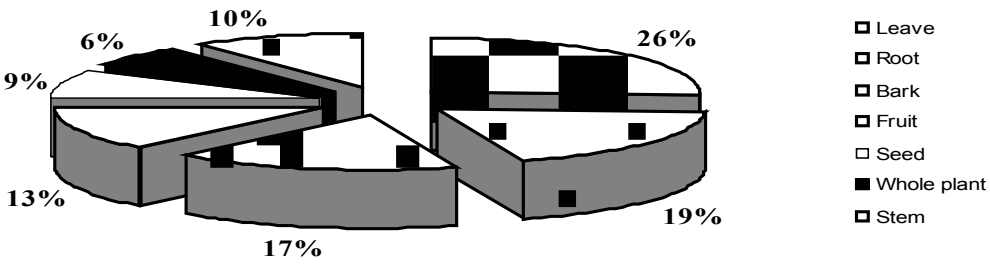

Figure 3: Plants parts used as medicine.

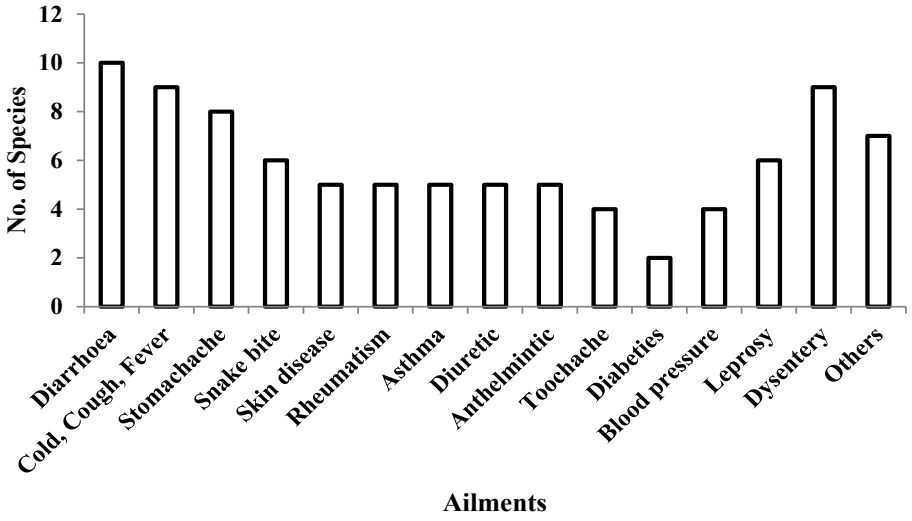

Figure 4: Plant species used for various ailments.

Figure 5: Photographs of some medicinal plants. (A). Tradi-practioner consulting bone fracture, (B). *Swertia chirayita*, (C). *Achyranthes aspera*, (D). *Plantago erosa*, (E). *Solanum torvum*, (F). *Solanum nigrum*, (G). *Prunus nepalensis*, (H). *Passiflora edulis*, (I). *Costus speciosus*.

Conclusion

The rural populations inhabiting the villages in Meghalaya are strongly dependent on locally available medicinal plant resources either directly or through tradi-medicinal-practitioner for their medicinal requirements. The introduction of allopathic drugs decreased the

degree of human dependency on medicinal plants up to certain extent. But because of the unavailability of timely expertise and cost associated with the allopathic drugs, the demand for medicinal plants is increasing in this village as a result of recognition of the non-narcotic nature, lack of side effects, easy availability of many herbal drugs and their effectiveness. Since the indigenous traditional knowledge of medicinal plants and therapies are transmitted orally for centuries and so the part of information is becoming extinct due to absence of proper documentation. To save the indigenous knowledge associated with medicinal plants, raising awareness in the people and form traditional healer association is mandatory. This study emphasizes the need to properly document medicinal plants of the region which are being used traditionally used, to conserve basic plant resources on ground level and to utilize them sustainably for the greater societal benefit.

Acknowledgement

The authors are highly grateful to the local communities who shared their traditional knowledge on herbal medicine with us to complete this piece of work desirably.

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Carex baccans Nees, an Anthelmintic Medicinal Plant of Northeast India

***B. Roy and B. R. Giri**

Parasitology Laboratory, Department of Zoology, North-Eastern Hill University, Shillong 793022, Meghalaya, India

***Corresponding author:** Dr. B Roy, Department of Zoology, North-Eastern Hill University, Shillong 793022, Meghalaya, India; Tel: +91364 2722331; E-mail: bishnuroy12@rediffmail.com

Summary

India, especially northeast India is one of the biodiversity hotspot and well known for rich culture of traditional medicine against different ailments and diseases. *Carex baccans* Nees (family: Cyperaceae) is a crimson seeded sedge native to India, Sri Lanka and China, traditionally used by the Jaintia tribe of Meghalaya, India to cure intestinal helminth infections. The plant is also used against measles, fever, hypertension, dysmenorrhoea, chincough, leucorrhea, fracture and gynaecological problems in different traditional culture. *In vitro* and *in vivo* exposure of cestode parasites to crude root-tuber extract of *C. baccans* and its active compounds resveratrol and *α*-viniferin have revealed the effective anthelmintic property of the plant. Phytoproducts treated *R. echinobothrida* showed extensive deformation and distortion of whole body, formation of lesions, loss of spines and destruction of tegumental surface. Ultrastructural observations on the phytoproducts exposed parasites revealed damages in the glycolcalyx layer followed by sub-tegumental cyton, altered nucleus, disrupted nuclear membrane, chromatin condensation, vacuoles formations and granulation of cyton, which are characteristic of a generalized stress condition compared to the control. Crude extract of the plant and its active principles also reduced activities of some key tegumental enzymes, energy metabolism related enzymes and neurotransmitter related enzymes, leading to paralysis and death of the treated parasites. Thus *C. baccans* revealed to be an effective anthelmintic plant.

Keywords: Anthelmintic*; Carex baccans;* Medicinal Plant; *Raillietina echinobothrida*

Abbreviations

ATP: Adenosine Triphosphate;

DAPI: 4, 6′-Diamidine-2-Phenylindole Dihydrochloride;

EPG: Egg per Gram;

MTT: 3-(4,5-Dimethyl-Thiazol-2-Yl)-2,5-Diphenyltetrazolium Bromide;

PZQ: Praziquantel;

TUNEL: Terminal Deoxynucleotidyl Transferase-Mediated Dutp-Biotin Nick End Labeling

Introduction

The medical culture of India contains both folk traditions and codified knowledge systems with references in the Atharva Veda, being textual evidence of the traditional use of medicinal plants. In Ayurveda, more than 2,000 plant species are considered to have medicinal value, while the Chinese Pharmacopoeia listed more than 5,700 traditional medicines, most of which are of plant origin [1]. Medicinal plants in different form offer unlimited opportunities for the discovery of new drugs. Increasing interest in drugs of plant origin are due to several reasons, viz., inefficiency of conventional medicine, abusive and/or incorrect use of synthetic drugs results in serious side effects, over and above a large percentage of global population have no access to conventional treatment [2].

India has three major biodiversity hotspots of the world i.e., Himalayan, Western Ghats and Indo-Burma, having vast repository of flora and fauna. It is reported that India is bestowed with over 45,000 species of plants which constitute about 7% of the world's total flora out of which 11% have been known to have medicinal properties [3]. Geographically, though it covers only 2% of the Earth's surface, it is the richest country of the world as far the genetic resources in terms of medicinal plants are concerned. India is rich in traditional folklore healthcare system, use of plant as a source of medicine has been inherited and is an important component of the health care system in India. An estimated 65% of rural Indians use Ayurvedic medicine system and medicinal plants to meet their primary health care needs [4,5]. The Northeast region of India comes under Indo-Burma hotspot, gifted with vast range of medicinal plants. The North eastern states of India comprises of eight sister states viz. Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, harbours more than 130 major tribal communities of the total 427 tribal communities found in India. The native tribes of this region have a rich tradition of using several plants in their own traditional medicine system to cure parasitic infections.

Parasitic helminths are multicellular worms belongs to two phylum namely Platyhelminthes and Nemathelminthes/Aschelminthes. The phylum Platyhelminthes subdivided in to three classes: trematoda, cestoda and turbellaria. They are the common human infectious agents account for half of the WHO designated "Neglected Tropical Diseases," and infect 1-2 billion of the world's poorest and deprived sections of the society, especially in the tropical countries [6,7]. Among helminthes parasites Gastrointestinal (GI) helminths are responsible for significant production loss in livestock and crop production industry globally [8-10]. Epidemiological studies reported that out of the three major classes of helminths, nematode alone constitute more than 1 billion, trematode more than 250 million and cestode about 0.4 million of the global prevalence of helminthiasis leading to high economic losses to both the small- and large-scale farming communities [11-13]. As per as public health is concerned, it is estimated that approximately one-third of the world's population are infected by at least one or more helminth parasites [14,15].

Evidence of the anthelmintic properties of plants and plant extracts is derived primarily from ethnoveterinary sources [16]. A number of plants having potential to cure worm infections have been identified and established their medical potential. Over the past 100 years, the development and mass production of chemically synthesized drugs have revolutionized health care in most parts of the world [17]. Large sections of the population in developing countries still rely on traditional practitioners and herbal medicines for their primary care. According to WHO up to 90%, 70% and 40% population in Africa, India and China, respectively, depends on traditional medicine to meet their regular health care needs [18]. More than 90% of general hospitals in China have units for traditional medicine [18]. In the United States, about 38% of adults and 12% of children were using some form of traditional medicine [19,20]. It has been estimated that in developing countries about 80% of the world's population rely predominantly on indigenous practice of plants and

plant extracts for controlling various diseases affecting both human beings as well as other animals [21,22].

Genus *Carex* Linn., one of the largest genera among angiosperms in the world, which is cosmopolitan in distribution with relatively high species richness in the temperate regions of Northern Hemisphere. All species of *Carex* are perennial with an exception to *C. bebbii* and *C. viridula* which can produce fruit in their first year of growth, and may not survive longer [23]. They typically have rhizomes, stolons or short rootstocks, but some species grow in tufts (caespitose) [24]. *Carex* consists of grasses and sedges, belongs to the family Cyperaceae contains over 2000 species distributed worldwide. In India, *Carex* is one of the largest and widely distributed genera, occurring from tropical to the sub-tropical Jammu through temperate Kashmir valley to the cold-arid Ladakh region [25,26]. Although these plants are abundant, only few species have been studied, revealing the presence of α-viniferin and other resveratrol oligomers as active compounds of the plant [27]. *Carex baccans* (Figure 1), locally known as "Kre" in Meghalaya (India), the root-tuber extract of the plant is traditionally used by the Jaintia tribe of northeast India to get rid of intestinal worm infections [28].

Figure 1: *Carex baccans* with flowers and underground part root – tuber.

Geographical Distribution

The sedge family (Cyperaceae) having 104 genera (with about 5000 species) distributed worldwide except Antartica, making it the 3rd largest family of monocots [29]. It is reported that out of 2000 species of *Carex* available throughout the world 527 species are found in China, 82 species in India out of which 49 species are found in North-Eastern India [30]. *C. baccans* is found growing in wet moist places and in swamps at an altitude of 1,500-2,500 m, in dense moist to semi-evergreen forest. It is a native species to temperate and tropical Asia and is found in China, Malaysia, Sri Lanka, Indonesia, and Philippines [31]. In India it is found in Maharashtra, Madhya Pradesh, Karnataka, Kerala, Tamil Nadu and in Northeast India.

Morphology

C. baccans is a clumping and perennial evergreen herb, having rhizome and a short root stock. The leaves are dark green blade, 1-2 cm wide and 2-3 feet long, which extends away from the stalk [24]. The blade is normally long and channeled. The leaves have parallel veins and a distinct midrib. The flowers are small and combined into spikes, which are arches up and out from the clump and combined into a larger inflorescence carrying greenish flowering seed clusters that grow 6-7 inches long and 3 inches wide. It is monoecious in nature. The fruit of *Carex* is a dry, one-seeded, known for its bright, showy seed heads. As they mature, they turn in to bright orange-red.

Traditional Use

Carex spp. have gained recent attention for their nutraceutical properties as they

produce bioactive compounds. Apart from anthelmintic use, the plant is also in use to treat hypertension, fever, dysmenorrhoea, leucorrhea, chincough, ulcer, measles and gynaecological problems by different ethinic groups in Asia [32-35].

Phytochemistry

Resveratrol (3,5,4'-trihydroxystilbene) is a naturally occurring non-flavanoid phytoalexin molecule found in the root tuber of different species of the genus *Carex* [36-38]. Antiviral, antibacterial and antifungal properties of the compound are established [39-41] and the compound is also known to be well-tolerated by animals at high doses without any adverse effects [42]. *α*-Viniferin, a trimeric form of resveratrol also found in the plant *C. baccans* and exhibits a wide range of biological activities include anti-inflammatory, antioxidant, inhibitory activity of Protein Kinase C (PKC), tyrosinase and prostaglandin H2 synthase [43-48]. Other known chemical constituents from the plants are smiglaside A and smiglaside B [49]. Molecular structure of all the phytochemicals of the plant are depicted in Figure 2. However, the present review discusses in details the anthelmintic activity of *C. baccans* and its active principles (resveratrol and α-viniferin) on the poultry tape worm *R. echinobothrida.*

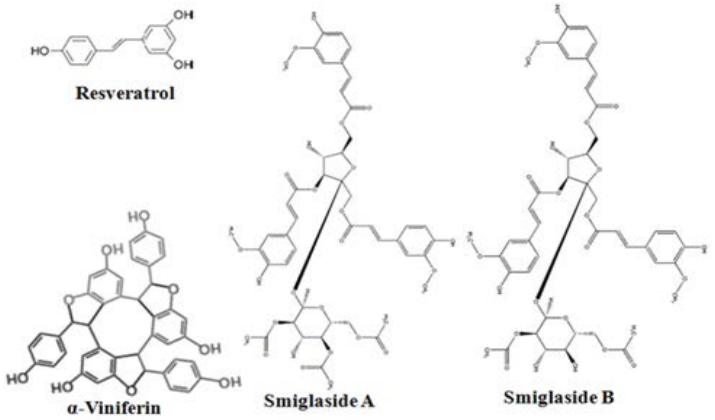

Figure 2: Phytochemicals from *Carex baccans*.

Anthelmintic Properties

In vitro and *in vivo* anthelmintic efficacy

In vitro study showed a dose-dependent significant ($P \leq 0.05$) cestocidal activity at all concentrations of crude extract. The control group of *R. echinobothrida* survived up to 72.01 ± 0.06 h in a medium of PBS with 0.1% DMSO. *In vitro* exposure of parasites to different treatment groups like root-tuber extract, active compounds and PZQ showed a very active movement of parasites at the initial hour of exposure but at later stage slowly moved to a sluggish state with less/no active movement. Crude extract of *C. baccans* at its highest concentration (5 mg), caused paralysis at 6.439 ± 0.047 h and death at 7.254 ± 0.029 h. Similarly, at other lower doses of crude extract at 1 and 2 mg/ml of PBS the time taken for paralysis were 13.67 ± 0.08 and 10.24 ± 0.066 and death 15.38 ± 0.039 and 12.48 ± 0.03 h, respectively. Similarly, highest concentration (1.36 mg/ml of PBS) of resveratrol caused paralysis at 9.37 ± 0.05 and death at 23.65 ± 0.06, whereas α-viniferin (1.35 mg/ml of PBS) caused paralysis at 11.38 ± 0.09 and death at 34.13 ± 0.67 h [50,51]. However, the broad spectrum reference drug PZQ at its highest concentration (0.05 mg/ml of PBS) paralysed the parasite taking 0.35 ± 0.11 h leading to death at 5.32 ± 0.03 h [52].

The *in vivo* study demonstrated a clear dose-dependent cestocidal activity of *C. baccans* root-tuber extract against the rat tapeworm *H. diminuta*. When the infected animals were

administered with 10, 25 and 50 mg crude root-tuber extract of the plant/kg body weight of rat, it showed decrease in the egg counts by 17, 29 and 56%, respectively (Table 1) [53]. Three days single dose treatments comprising of 10, 25 and 50 mg crude root-tuber extract of the plant/kg body weight of rat achieved 6, 24 and 44% reduction in worm burden, respectively (Table 1) [53]. However, when treated with resveratrol at doses of 1.14, 2.28 and 4.56 mg/kg body weight, there was a reduction of 15, 27 and 46% of egg count and 3, 20 and 31% reduction in worm burden, respectively. Animals exposed to 5 mg of praziquantel/ kg body weight showed reduction by 72 and 68% in EPG count and in the worm recovery, respectively [53].

Treatment group	EPG		% reduction in EPG rate /	No. of worm recovered/	% worm recovery
(mg/kg x dose x day)	Days 18-20 (A)	Days 33-35 (B)	A / B worm count	rat	% reduction in
Control	24250±1195	25167±2786	- -	4.833±0.16	- -
		Carex baccans root-tuber extract			
10x1x3	24222±870	19917±870*	17	4.5±0.223	93/6
25x1x3	24235±1221	17083±1221*	29	3.666±0.21*	75/24
50x1x3	24250±1218	10667±881*	56	2.666±0.21*	55/44
		Resveratrol			
1.141 x1x3	24050±495	20416±768	15	4.666±0.21	96/3
2.282 x1x3	24110±381	17583±860*	27	3.833±0.3*	79/20
4.564 x1x3	24550±810	13083±700*	46	3.333±0.21*	69/31
		Praziquantel			
5x1x3	24074±1204	6666±435*	7	1.5±0.223*	31/68

Table 1: Effect of Carex baccans root-tuber extract, resveratrol and praziquantel on mature worms of Hymenolepis diminuta infections in rats as monitored by Eggs Per Gram (EPG) of faeces count and worm recovery rate at autopsy.
*: P≤ 0.05 vs. control value (n=6)
Source: Giri BR, RR Bharti and Roy B. 2015. In vivo anthelmintic activity of Carex baccans and its active principle resveratrol against Hymenolepis diminuta. Parasitology Research 114(2), 785-788.

MTT assay

MTT assay of resveratrol exposed parasites revealed 27, 45, 74 and 93 % reduction in viability compared to control when exposed for 6, 12, 18 and 23 h, respectively [54]. The gradual reduction in the motility of the worms, as observed visually, corresponds to the decreased viability in MTT assay.

Scanning electron microscopy

Scanning electron microscopic observations on control *R. echinobothrida* showed suckers in the scolex typically marked with rows of short but thick pointed hooklets (Figure 3A). Proglottids appear to be normal with regular and continuous distributions of microtriches (Figure 3B). However, cestode treated with root-tuber extract the scolex appeared greatly distorted with suckers extensively shrunken and few proglottids revealing shrunken surface (Figure 3C-D). The cestode treated with resveratrol showed distorted scolex with shrunken

suckers and destructed general body topology (Figure 3E-F) [50]. α-Viniferin exposed cestode showed damaged scolex with shrunken suckers and degenerated proglottids surface with formation of wrinkles (Figure 3G-H) [51]. PZQ treated parasite showed distorted scolex with bulging out of suckers (Figure 3I). It also revealed destruction of tegumental surface with shrunken proglottids (Figure 3J) [55].

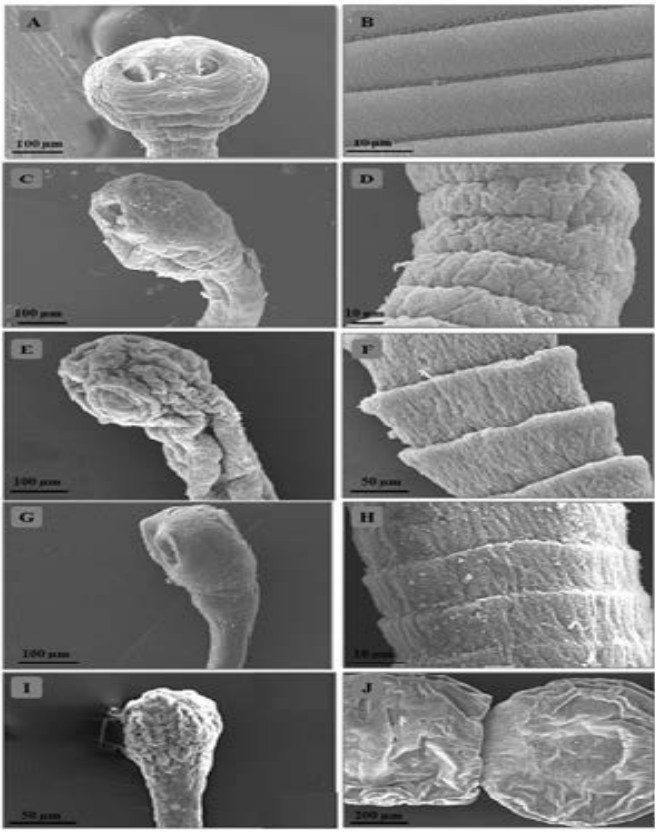

Figure 3: Stereosacn micrographs of control (A, B), *C. baccans* crude extract exposed (C, D), resveratrol exposed (E, F), α-viniferin exposed (G, H) and PZQ exposed *Raillietina echinobothrida* (I, J). A. Control worm showing normal contour of scolex having suckers; B. Enlarged view of a portion of proglottid showing densly packed microtriches gently sloping downwards; C. Shriveled scolex with suckers; D. Proglottids showing shrinkage of the tegumental surface; E. Anterior part of the body showing deformed scolex with suckers; F. Proglottids showing shrunken surface topography and scars; G. Wrinkled scolex; H. Proglottids showing damaged tegumental surface; I. Distorted scolex with suckers; J. Proglottids showing wrinkles and scars on the surface.

Figure 3 (A, B, E) reprinted from parasitology International, 63, B.R. Giri and B. Roy, Resveratol induced structural and biochemical alterations in the tegument of *Raillietina echinobothrida,* 432-37, Copyright (2014), with permission from Elsevier.
Figure 3 (G, H) reprinted from Microscopy and Microanalysis, 21, B. Roy and B.R. Giri α-viniferin induced structural and functional alterations in *Raillietina echinobothrida*, a poultry tapeworm, 377-384, Copyright (2015), with the permission from Cambridge University Press.
Figure 3 (I, J) reprinted from Micron, 50, S. Dasgupta, B.R. Giri and B. Roy, Ultrastructural observations on *Raillietina echinobothrida* exposed to crude extract and active compound of *Securinega virosa*, 62-67, Copyright (2013), with permission from Elsevier.

Transmission electron microscopy

Transmission electron micrographs of control parasite showed typical ultrastructure of tegument with intact microthrix layer followed by distal cytoplasm, secretory bodies with tegumental discs, non-disrupted basal lamina (Figure 4A) [50]. Sub-tegumental cells lying beneath the sub-tegumental muscle blocks contain healthy cell, nucleus in the cytons is

almost round in shape and has regular conspicuous double nuclear membrane, granular nucleolus, chromatin material and normal mitochondria (Figure 4B) [50]. Crude extract of *C. baccans* treated parasite showed ragged tegumental layer with less number of microtriches, disrupted distal cytoplasm, swelling of basal lamina (Figure 4C). Distorted nuclei, nuclear membrane and formation of vacuole were evident in the sub-tegumental cells exposed to the crude extract of *C. baccans* (Figure 4D). Resveratrol exposed parasite showed degradation of both the circular and longitudinal muscle layers (Figure 4E). The nuclei in the tegumental cyton showed vacuolated cyton with granulated cytoplasm, damaged and wavy shaped nuclear membrane and condensed chromatins throughout the nucleus (Figure 4F) [50]. α-Viniferin exposed parasites showed disrupted and dilated basal infolds and ridges were located from the glycocalyx and microtriches up to the sub-tegumental layer (Figure 4G) [51]. Sub-tegumental cyton showing wavy shaped irregular singlet nuclear membranes with disintegrated nucleolus (Figure 4H) [51]. Similarly, worms treated with PZQ also showed destruction of microthrix layer and degeneration of muscle stacks in the distal cytoplasm of tegument (Figure 4I). The sub-tegumental cyton showed damaged cell membrane with blabbed nuclear membrane and condensed nucleolus (Figure 4J) [55].

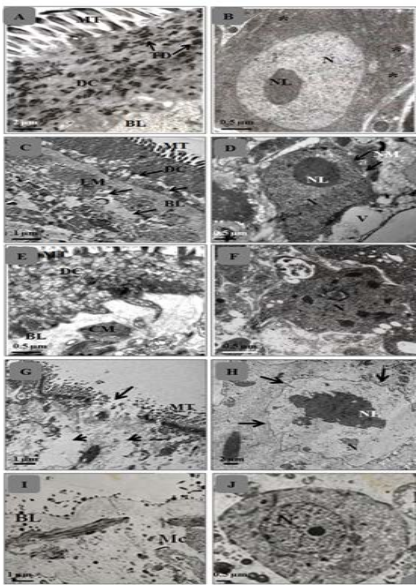

Figure 4: Transmission electron micrographs of control (A, B), crude extract exposed (C, D), resveratrol (E, F), α-viniferin (G, H) and praziquantel exposed *R. echinobothrida* (I, J).

A. Control tegument with intact Microthrix Layer (MT) , Distal Cytoplasm (DC) electron-dense secretory bodies, non-disrupted Basal Lamina (BL); B. Sub-tegumental cyton having Nucleus (N), Nucleolus (NL) with no chromatin clumping, intact nuclear membrane and normal mitochondria (*); C. Deformed Distal Cytoplasm (DC, arrows) and Longitudinal Muscle layer (LM, arrows); D. Sub-tegumental cyton having distorted Nucleus (N), completely disturbed Nuclear Membrane (NM), though nucleolus aws intact (NL) and granulated cytoplasm with Vacuole (V); E. Distorted distal and proximal cytoplasm having disrupted Circular Muscles (CM); F. Deformed Nucleus (N) with chromatin clumping; G. Damaged tegumented with loss of Microthrix Layer (MT) and having remnants of basal lamina and muscle laers (arrows). H. Sub-tegumental cyton showing distorted Nucleus (N), dispersed Nucleolus (NL), and wavy nuclear membrane (arrows). I. Stripped tegument with exposed Basal Lamina (BL), and slightly disorganized Muscle Layers (ML); J. Sub-tegumental cytons having cells damaged cytoplasm, presence of altered Nuclei (N) and nucleolus.

Figure 4 (A, B, E, F) reprinted from Parasitology International, 63, B.R. Giri and B. Roy, Resveratrol induced structural and biochemical alterations in the tegument of *Raillietina echinobothrida,* 432-37, Copyright (2014), with permission from Elsevier.

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Histochemical localization of enzymes

Tegumental enzymes: The AcPase activity in the form of brownish black depositions was observed throughout the whole tissue sections in control parasite (Figure 5A). Similarly, AlkPase and ATPase also showed a similar kind of enzyme staining (Figure 5F and 5K). High activities of enzyme were localized mainly in the tegument, sub-tegument and musculature regions of the control parasites. Exposure of the parasites to crude root-tuber extract of *C. baccans* showed visible reduction in the staining intensities of AcPase, Alkpase and ATPase enzyme activity (Figure 5B, G and L). Resveratrol and α-viniferin exposed *R. echinobothrida* retained mild AcPase, AlkPase and ATPase activity in testes and ovary, and to some extent in the tegument and sub-tegument (Figure 5C-D, H-I and M-N) [50, 51]. Similarly, drug treated parasites also showed a more or less similar extends of reduction in the staining intensities of all the three tegumental enzymes (Figure 5E, J and O).

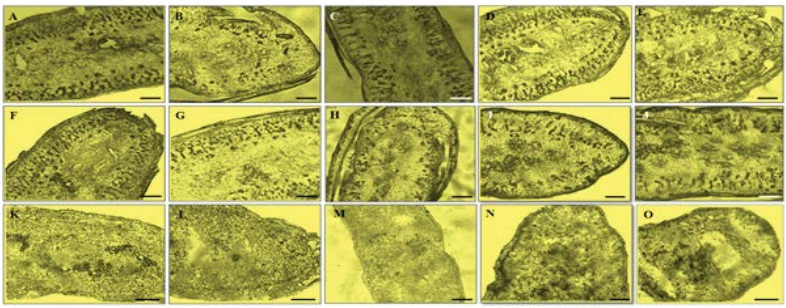

Figure 5: Histochemical localization of acid phosphatase (A-E), alkaline phosphatase (F-J) and adenosine triphosphatase activities (K-O). Control (A, F and K); crude extract of *Carex baccans* treated (B, G and L); resveratrol (C, H and M); α-viniferin (D, I and N) and praziquantel treated (E, J and O). [All scale bar = 100 µm]
Figure 5 (C, H, M) reprinted from Parasitology International, 63, B.R. Giri and B. Roy, Resveratrol induced structural and biochemical alterations in the tegument of *Raillietina echinobothrida*, 432-37, Copyright (2014), with permission from Elsevier.
Figure 5 (D, I, N) reprinted from Microscopy and Microanalysis, 21, B. Roy and B.R. Giri, α-viniferin induced structural and functional alterations in *Raillietina echinobothrida*, a poultry tapeworm, 377-384, Copyright (2015), with permission from Cambridge University Press.

Neurotransmitter related enzymes: In the control parasite a higher staining intensity for AchE was observed which confined to the tegument, sub-tegument as well as somatic musculature of the parasite (Figure 6A). When *R. echinobothrida* exposed to the crude extract of *C. baccans* a reduction in the stain intensities for AchE were noted (Figure 6B). Resveratrol and α-viniferin exposed parasites also showed decreased staining intensities (Figure 6C-D) [56]. Similarly, PZQ exposed parasites showed diminished staining intensities compared to control (Figure 6E).

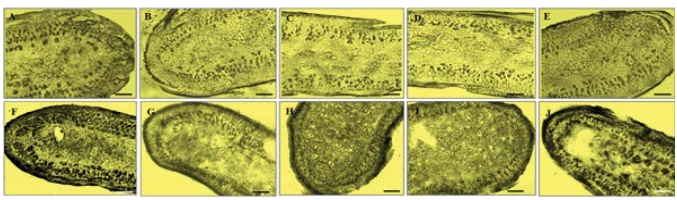

Figure 6: Light microscopiuc photographs of transverse sections of *Raillietina echinobothrida* showing Histochemical localization of acetylcholinesterase activities (A-E) and nitric oxide synthase (F-J). Control (A, F); crude extract of *Carex baccans* treated (B, G); resveratrol (C, H); α-viniferin (D, I) and praziquantel treated (E, J). [All scale bar = 100 µm]
Figure 6 (C, D, H, I) reprinted from Parasitology Research, 114, B.R. Giri and B. Roy, Resveratrol and α-viniferin induced alterations of acetylcholinesterase and nitric oxide synthase in *Raillietina echinobothrida*, 3775-3781, Copyright (3015), with permission from Springer-Verlag Berlin Heidelberg.

Histochemical localization of NOS revealed higher staining intensities in the control parasite section (Figure 6F). The higher staining intensities were observed in the main nerve cords, nerves in association with the musculature especially the cirrus musculature. Histochemical detection of NOS in the crude extract treated parasites showed diminished staining intensities in different confined area of the parasite (Figure 6G). Resveratrol and α-viniferin exposed parasites revealed less staining intensity throughout the tegument and sub-tegument compared to the control (Figure 6H-I) [56]. However, PZQ exposed parasites showed a similar trend of diminished staining intensities compared to the control (Figure 6J).

Energy metabolism related enzymes: High LDH activities were observed throughout the tissue sections of control *R. echinobothrida* (Figure 7A). Similarly, histochemical detection of MDH revealed higher staining intensities in the control parasite (Figure 7F). After exposure of the parasites to *C. baccans* crude extract, its active compounds and PZQ, a reduction in LDH stain intensities was noticed (Figure 7B-E) [57]. A similar trend of decrease in MDH stain intensity were also observed in the parasites exposed to crude extract of *C. baccans,* its active compounds and PZQ (Figure 7G-J) [57].

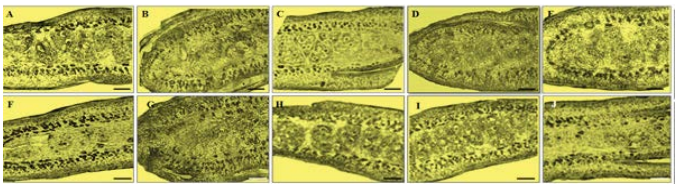

Figure 7: Light microscopiuc photographs of transverse sections of *Raillietina echinobothrida* showing Histochemical localization of lactate dehydrogenase (A-E) and malate dehydrogenase activities (F-J). Control (A, F); crude extract of *Carex baccans* treated (B, G); resveratrol (C, H); α-viniferin (D, I) and praziquantel treated (E, J). [All scale bar = 100 µm]
Figure 7 (C, D, H, I) reprinted from Acta Tropica, 154, B.R. Giri and B. Roy, α-Viniferin Resveratrol and induced alterations in the activities of some energy metabolism related enzymes in the cstode of parasite *Raillietina echinobothrida*, 102-106, Copyright (3016), with permission from Elsevier.

Biochemical studies

Tegumental enzymes: In the control parasites high AcPase activities (5.04 ± 0.11 U/mg tissue protein) were observed. However, on exposure to different test materials highest inhibition in AcPase activity was observed in parasites exposed to α-viniferin (26%) followed by crude extract (4%), PZQ (2%) and resveratrol (2%) [50,51]. Biochemical study on AlkPase showed highest enzyme activity (19.41 ± 0.51 U/mg tissue proteins) in control *R. echinobothrida* (Table 2). When the parasites were treated with different test materials, changes were observed in the AlkPase activity and the maximum inhibition was recorded in crude extract exposed parasites (35%) followed by α-viniferin (16%), PZQ (15%) and resveratrol (7%) [50,51]. Likewise, ATPase showed highest activity at an extent of 29.1 ± 0.54 U/mg tissue protein in control parasite. Crude root-tuber extract was found to be more effective against ATPase activity (21% inhibition) followed by α-viniferin (18%), resveratrol (13%) and PZQ (9%) treated parasites [50,51].

	AcPase	%IN	AlkPase	%IN	ATPase	%IN
Control	5.04±0.16	--	19.41±0.51	--	29.1±0.54	--
C. baccans	4.81±0.17	4	12.56±0.27*	35	22.74±0.48*	21
Resveratrol	4.93±0.11	2	17.96±0.33	7	25.2±0.43*	13
α-Viniferin	3.74±0.14*	26	16.24±0.25*	16	23.66±0.12*	18
PZQ	4.91±0.13	2	16.48±0.53*	15	26.25±0.6*	9

Table 2: Biochemical changes in the tegumental enzymes of *Raillietina echinobothrida* treated with *Carex baccans* crude extract, resveratrol, α-viniferin and praziquantel.

Enzyme activity represented as specific activity = µmole of product/min/mg tissue protein, values are given as mean (±SEM) from five replicates (N = 5); IN = Inhibition, PZQ = Praziquantel, Students t-test *$P \leq 0.05$.

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Neurotransmitter related enzymes acetylcholinesterase and nitric oxide synthase (ache and nos): AchE activity was found to be 1.6 ± 0.01 U/mg tissue protein in control parasites. Highest reduction in AchE activity was observed in parasites treated with α-viniferin (53%) followed by resveratrol (46%), crude extract (26%) and PZQ (9%) [56]. In control *R. echinobothrida* the NOS activity was recorded to be 8.18 ± 0.13 U/mg tissue protein. However, resveratrol exposed parasites showed highest inhibition (61%) followed by α-viniferin (55%), crude extract (28%) and PZQ (14%) as shown in Table 3 [56].

	$AchE_{x10}$	%IN	NOS	%IN
Control	1.6±0.01	--	8.18±0.13	--
C. baccans	1.17±0.01*	26	5.87±0.24*	28
Resveratrol	0.85±0.008*	46	3.17±0.18*	61
α-Viniferin	0.74±0.006*	53	3.67±0.04*	55
PZQ	1.45±0.01*	9	6.96±0.19*	14

Table 3: Biochemical changes in neurotransmitter related enzymes of Raillietina echinobothrida treated with Carex baccans crude extract, resveratrol, α-viniferin and praziquantel.

Enzyme activity represented as specific activity = µmole of product/min/mg tissue protein, Total activity (in NOS) = the total units/wet weight of the sample taken, values are given as mean (±SEM) from five replicates (N = 5); IN = Inhibition, PZQ = Praziquantel, Students t-test *P ≤ 0.05.

Adapted from Parasitology Research, 114, B.R. Giri and B. Roy, Resveratrol and α-viniferin induced alterations of acetylcholinesterase and nitric oxide synthase in Raillietina echinobothrida, 3775-3781, Copyright (2015), with permission from Springer-Verlag Berlin Heidelberg.

Energy metabolism related enzymes

Lactate Dehydrogenase (LDH): Control *R. echinobothrida* showed high LDH activity (4.06 ± 0.02 U/mg tissue protein). However, resveratrol exposed parasite showed significant inhibition (38%) followed by crude extract of *C. baccans* (33%), praziquantel (31%) and α-viniferin (21%) as shown in Table 4 [57].

	LDH_{x10}	%IN	$PEPCK_{x10}$	%IN	FRD_{x10}	%IN	MDH_{x10}					
							CTH	%IN	CYT	%IN	MIT	%IN
CN	4.06±0.02	--	5.6±0.04	--	1.24±0.01	--	2.44±0.02	--	1.61±0.02	--	0.94±0.02	--
C. baccans	2.72±0.01*	33	5.32±0.05	4	0.96±0.02*	22	1.53±00.02*	37	1.04±0.02*	35	0.62±0.02*	34
Resveratrol	2.5±0.01*	38	4.27±0.01	23	0.83±0.02*	33	1.58±0.002*	38	1±0.004*	37	0.57±0.003*	39
α-Viniferin	3.2±0.009*	21	3.25±0.007*	41	0.79±0.011*	36	1.52±0.003*	37	0.98±0.002*	39	0.6±0.002*	36
PZQ	2.78±0.01*	31	5.12±0.02	8	1.04±0.01*	16	2.14±0.02*	12	1.28±0.01*	20	0.9±0.02	4

Table 4: Biochemical changes in the energy metabolism related enzymes of Raillietina echinobothrida treated with Carex baccans crude extract, active components resveratrol, α-viniferin and praziquantel.

Enzyme activity represented as specific activity = µmole of product/min/mg tissue protein, values are given as mean (±SEM) from five replicates (N = 5); CN= control, CTH = Crude Tissue Homogenate, CYT = Cytosolic, MIT = Mitochondrial, IN = Inhibition, PZQ = Praziquantel, Students t-test *P ≤ 0.05.

Adapted from Acta Tropica, 154, B. Roy and B.R. Giri, α-Viniferin and resveratrol induced alteration in the activities of some energy metabolism related enzymes in the cestode parasite Raillietina echinobothrida, 102-106, Copyright (2016), with permission from Elsevier.

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Phosphoenolpyruvate Carboxykinase (PEPCK): The enzyme activity of PEPCK was found to be 5.6 ± 0.04 U/mg tissue proteins in untreated control *R. echinobothrida*. However, on exposure to different treatments showed significant alterations in the PEPCK activity. α-Viniferin exposed parasites showed highest inhibition (41%) followed by resveratrol (23%), PZQ (8%) and crude extract (4%) as shown in Table 4 [57].

Fumarate Reductase (FRD): Control *R. echinobothrida* showed FRD activity to be 1.24 ± 0.01 U/mg tissue protein. However, when parasites were exposed to different treatments, showed significant alterations in the FRD activity. Parasites treated with α-viniferin showed highest inhibition of enzyme activity by 36% followed by resveratrol (33%), crude extract of *C. baccans* (22%) and PZQ (16%) as shown in Table 4 [58].

Malate Dehydrogenase (MDH): The enzyme activity of MDH in control parasites showed to be 2.44 ± 0.05 U/mg tissue protein in the crude tissue homogenate of control parasite. MDH activity was observed to be higher in cytosol (1.61 ± 0.01 U/mg tissue protein) compared to mitochondria (0.94 ± 0.03 U/mg tissue protein). When parasites treated with resveratrol showed highest inhibition (38%) followed by α-viniferin (37%), *C. baccans* crude extract (37%) and PZQ (12%), compared to the control (Table 4) [57].

Chromosome condensation and DNA fragmentation

Transverse sections of resveratrol exposed worm (Figure 8E-H) revealed increased trend of chromatin condensation as the time of exposure increased compared to control *R. echinobothrida* (Figure 8A-D) [54]. DNA fragmentation in the resveratrol exposed *R. echinobothrida* was confirmed through TUNEL assay. Control parasite didn't reveal any apoptotic nuclei (Figure 9A-D), whereas parasites exposed to resveratrol showed an increase in the number of apoptotic nuclei with increasing time of incubation (Figure 9E-H) [54].

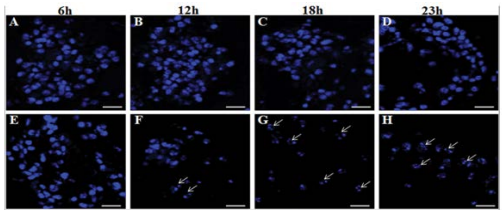

Figure 8: Photographs showing DAPI stained control (A-D) and resveratrol exposed (E-H) *R. echinobothrida*.
Figure 8 reprinted from Research in Veterinary Science, 101, B.R. Giri and B. Roy, Apoptosis like cell death in *Raillietina echinobothrida* induced by resveratrol, 220-225, Copyright (2015), with permission from Elsevier.

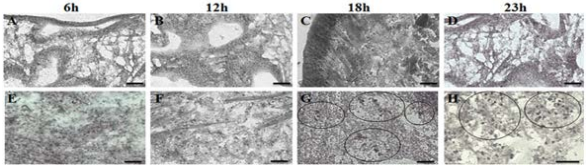

Figure 9: TUNEL-stained light microscopic photographs of control (A-D) and resveratrol exposed (E-H) *R. echinobothrida*.
Figure 8 reprinted from Research in Veterinary Science, 101, B.R. Giri and B. Roy, Apoptosis like cell death in *Raillietina echinobothrida* induced by resveratrol, 220-225, Copyright (2015), with permission from Elsevier.

Mitochondrial membrane potential

Rhodamine123 stained control parasites at different time intervals showed almost similar relative fluorescent intensity at 6, 12, 18 and 23 h of incubation. Whereas, resveratrol

exposed group showed significant decrease in the relative fluorescence intensity at 18 and 23 h of incubation, compared to the respective control [54].

Pro-caspase activity

Control parasites showed a negligible or less activated caspase-3/7 at different time intervals from 12 to 23 h (Figure 10A-D). However, resveratrol exposed parasites showed increased levels of activated caspases 6 to 23 h of incubation (Figure 10E-H) [54].

Discussion

Exposure of *R. echinobothrida* to root-tuber extract of *C. baccans* and its active compounds (resveratrol and α-viniferin) revealed anthelmintic potency of the plant which execute through paralysis followed by death of the parasite in a dose-dependent manner [56]. Thus the finding justifies the traditional use of the plant *C. baccans* in folklore medicine. Similar to the present observations leaves of *Senna occidentalis* had been evaluated for anthelmintic activity against *Nippostrongylus braziliensis* and *Ascaris suum,* and showed promising anthelmintic effects [59,60]. Biffa et al., and Eguale et al., also observed a similar types of *in vitro* anthelmintic potential of the plants *Albizia gumnifera* [61,62]. Roy and Tandon studied the anthelmintic activity of *Alpinia nigra* on intestinal giant fluke *Fasciolopsis buski* and showed that the alcoholic crude extract could paralyze the parasite within 9.5 to 10.5, 6.5 to 6.8 and 4.0 to 4.5 h of incubation at 2.5, 5 and 10 mg/ml of PBS, respectively, which corroborated with the present study [63]. Similarly, Lyndem et al., studied the anthelmintic activity of root tuber peel extract of *Flemingia vestita,* a concoction of rhizome pulp of *Stephania glabra* with aerial roots of *Trichosanthes multiloba* against intestinal helminth *Ancylostoma ceylanicum* and revealed paralysis of the worm in less than half the survival time of control (56.5 ± 0.05 h) at a concentration of 5 mg/ml of PBS [64]. Recent studies showed that paralysis of *R. echinobothrida* occurs at 6.12, 3.92 and 2.93 h when incubated at 5, 10 and 25 mg of *Acacia oxyphylla* extract per ml of PBS [65]. However, the isolated active compound F5-2d of *A. oxyphylla* at 1, 0.1 and 0.05 mg/ml of PBS causes paralysis of *R. echinobothrida* at 0.5, 5.25 and 9.31 h respectively [52]. Similarly, Challam et al., reported that the ethanol extract of *Lysimachia ramosa* and reference drug paralyzed and kill the parasite in a dose dependent manner when tested against *Ascaris suum, F. buski* and *R. echinobothrida* [66].

The results of *in vivo* study showed a noteworthy decrease in EPG counts and worm (*H. diminuta*) burden when exposed to crude extract of *C. baccans* and resveratrol, thus re-confirm anthelmintic potential of the plant [54]. Reduction in EPG count and recovery of worms at necropsy have also been used as criteria to evaluate the anthelmintic efficacy of different traditionally used plants by several workers [67,68]. Hu et al., investigated the *in vivo* anthelmintic activity of *Bacillus thuringensis* derived crystal protein Cry5B against mice chronically infected with *Heligmosomoides bakeri* and *Ancylostoma ceylanicum,* and revealed reduction in EPG and worm burden to an extent of 98% and 70% at a dose 90 and 100 mg/kg body weight, respectively [69]. Similarly, drugs tribendimidine showed a notable decline *Nector americanus* infection better than those achieved by the metabolite dADT [70]. Yadav and Tangpu tested *in vivo* efficacy of *Adhatoda vasica* and found that 800 mg of extract/kg double doses reduced EPG count by 79.57% and worm recovery rate by 16.60%, which showed improved results than 5 mg/kg single dose of PZQ [71]. Similarly, the leaf extract of *Clerodendrum colebrookianum* possesses a dose-dependent efficacy against the larval, immature and adult stages of *H. diminuta* when tested *in vivo.* However, the extract was most effective against the adult stages of the parasite [72]. Sapaat et al., studied the anthelmintic activity of papaya seeds against *H. diminuta* in rats and showed the profound activity at a dose 0.6 and 1.2 gm/kg body weight by reducing the EPG to an extent of 96.8% and 96.2%, and the worm burden 90.77% and 93.85%, respectively [73].

It is well documented that one of the hallmark effects of any anthelmintic is the destruction of the worm's surface topography. This is due to the fact that the tegument is the primary host-parasite interfaces, vital for absorption of nutrients and perception of the surrounding micro-environment provided by the host [74,75]. Stereoscan studies showed that crude extract caused ample distortion and destruction of surface tegument of *R. echinobothrida,* similar to the alteration of surface topography caused by the broad spectrum anthelmintic drug PZQ [28]. Similarly, Roy et al., observed that the crude extract of *M. pachycarpa* and *A. nigra* as well as anthelmintic drug, PZQ caused extensive damage in the surface tegument of *R. echinobothrida* and *F. buski* leading to paralysis and death of the parasites [76,77]. Destruction and disintegration of tegument of cestode parasites was also observed when treated with different phytochemicals from different traditionally used medicinal plants [78,79]. Alcoholic extract of *A. oxyphylla* (Leguminosae) and *L. ramosa* (Primulaceae) caused pronounced deformation and distortion of body surfaces of *F. buski, A. suum* and *R. echinobothrida* [66,80]. Similar extent of damage such as surface lesions and loss of spines have also been observed in *F. hepatica* when treated with deacetylated (amine) metabolite of diamphenethide [81]. Likewise, on exposure to different broad spectrum commercial drugs such as benzimidazole derivatives, triclabendazole, PZQ, oxyclozanide, miltefosine and extract of several plants and their active components causes destruction of absorptive surface as seen in different helminth parasites [65,82-87]. Damaged tegument as observed in the present investigation might have caused severe nutrient deficiency within the parasite. Other than nutrients absorption, spine like microtriches may have a role in holding with its host to maintain its position in the gut. Consequently, alteration of microtriches leads to loss of holding capacity of the parasites to the host.

The ultrastructural characters of cestode tegument revealed to have upper glycolcalyx layer followed by the tegument, the sub-tegument, distal cytoplasm, the basal lamina, the muscle layers and the sub-tegumental cyton. Location of sub-tegumental cyton and important cellular elements away from the outer surface of the parasite is an essential adaptation to avoid immunological attacks by the host. Following *in vitro* incubation with root-tuber extracts, tegument of *R. echinobothrida* showed severe damage as observed by TEM. Damage in the sub-tegumental cyton as observed here is indicative of its adverse effect on the physiology of the parasite. Some other effects noticed like altered nucleus, condensed chromatin, detection of vacuoles and granular cyton, mitochondrial alterations are attributes of a general stress compared to the control group of *R. echinobothrida* [65]. This kind of cellular alterations has already been described in different helminthes under different drug insult corroborated with our present study [82,88,89]. However, tegumental damage, as observed in the phyto-products assaulted *R. echinobothrida* leading to exposure of the cellular components to host immune attack and metabolic stress that ultimately results in to reduction in physical activity of the parasite [80]. Disruption of tegumental surface as observed in the present study may be correlated with osmotic imbalances in the parasite resulting in impaired ion transfer as reported previously in *Opisthorchis viverrini* when exposed to amoscanate [90]. Similar to the severity of destruction and deformation observed in *R. echinobothrida* exposed to the active compounds of *C. baccans,* the phyto-products of *A. oxyphylla, S. virosa* also reported to caused extensive tegumental alteration in the cestode [65,54]. Other than surface topographical alterations, ultrastructural changes were also observed when *H. nana* exposed to PZQ [91]. Similar to the present observations, *H. diminuta* exposed to Cyclosporin-A revealed damaged surface and mitochondria beneath the syncytium layer [92]. Kundu et al., reported the depletion of parenchyma cells and destruction in the connective tissues in *H. diminuta* when treated with *Casia alata* L. [93]. Similarly, extensive distortion and damage of the surface topography of the tegument with eroded microtriches, disruption of muscle layers, vacuolization of tegumental and sub-tegumental layers, swelling and vacuolization of mitochondria has been observed in *R. echinobothrida* when the parasite was exposed to the extracts of *Potentilla fulgens* [64]. Exposure of *C. baccans* derived phytoproducts to flat worm resulted an extensive tegumental

damage as observed in our study indicates that the root-tuber extract of the plant and its active compounds disturb the membrane permeability, disturbance in ion flux across the membrane together with inhibition of neuromuscular activities, finally resulting in paralysis and subsequent death of the parasite. Similar type of ultrastructural changes also observed within the tegumental syncytium and tegumental cells of *F. hepatica* when exposed to triclabendazole and clorsulon [94].

The helminth body surface or tegument is known to be a dynamic, living cellular structure that plays vital role in the physiology of cestodes, being involved in nutrient absorption, defense against enzymatic and immunological attack by the host, in excretion and ionic exchange [95-97]. The tegumental enzymes viz. AcPase, Alkpase and ATPase were observed in the tegument, sub-tegument and somatic musculature region of the control as well as in crude extract, resveratrol, α-viniferin and PZQ exposed worms, and however the enzymes were noted to be diminished in all the treated groups. A similar type of reduced enzymes activities was also reported by different workers in various cestodes and trematodes when treated with different phytoproducts [98-101]. Phosphatases are important tegumental proteins whose association with membrane transport has been implied by their ubiquitous presence in the tissues of secretory or absorptive function [102]. Physiological transport is mediated directly by enzymes located on or within cytomembranes has received much support in recent years [103]. The widespread and impressive amounts of certain tegumental enzymes demonstrated in several cestodes suggest that they might play a highly significant role in digestion and/or absorption [104]. Diminished AcPase activity, as observed in the cestode exposed to *C. baccans* derived phytochemicals indicate that the permeability of the glycocalyx-plasmalemma system is disrupted causing the AcPase to diffuse out to digest the damaged membrane parts leading to a decrease in the tegumental AcPase level. High ATPase activity was observed in the tegument, sub-tegument, muscle layer and intestine of the control parasite compared to the *C. baccans* and its active compounds exposed cestode. A similar type of observation was also recorded in *F. buski* treated with crude extract of *Flemingia vestita* and its active principle, genistein [105]. In case of *R. echinobothrida* the localization of ATPase in somatic musculature strongly suggests that one of the roles of this enzyme to hydrolyze the ATP in this tissue, active transport and lipid synthesis [106]. It has also been hypothesized that the decrease in the tissue ATPase activity disrupts the permeability of the glycocalyx-plasmalemma system causing damage to the plasmalemma parts which in turn causes the AcPase to diffuse out of the cell to digest the damaged membrane parts leading to a decrease in the tegumental AcPase levels. Damage of the parasite membrane also causes an increase inflow of salts from the external media which accumulates in the basal infolds [107]. Recent reports have revealed the potential anthelmintic properties of several traditionally used medicinal plants such as A. oxyphylla, *Artemisia sp., L. ramosa* and *Spilanthes oleraceae* which modulate anthelmintic activity through inhibition of all the three above mentioned tegumental enzymes [64,66,108].

A significant reduction in the activities of AchE in the paralyzed worm as observed in *R. echinobothrida* was corroborated with results reported by Sung et al., [109]. Similar kind of *in vitro* studies in helminths exposed to commercial drugs and phytochemicals revealed to reduce activity of AchE [110,111]. Anthelmintic plants *Allium sativum*, *Punica granatum* and *Flemingia vestita* revealed to have an inhibitory neuromuscular mode of action [98,112,113], as they alter the nerve transmission at neuromuscular junction by inhibiting the AChE [114]. Flaccid paralysis of *R. echinobothrida* due to exposure to *C. baccans* and its active principles as recorded herewith may be a result of neuromuscular blockage and a persistent muscle contraction. Anthelmintic drugs levamisole, pyrantel and morantel are revealed to be nicotinic receptor agonists; elicit spastic muscle paralysis due to prolonged activation of the excitatory nicotinic acetylcholine receptors on the muscles of body wall [115]. However, Ivermectin a commercial drug exerts a persistent anthelmintic activity through paralysis of nematode pharyngeal musculature [116]. Similarly, *Fasciola hepatica* and *F. gigantica* show flaccid paralysis when exposed to carbon tetrachloride, diamphenethide and essential

oils of *Allium sativum* and *Piper longum* [117,118]. The inhibition of acetylcholinesterase as observed in the present study resulting paralysis of the worm, that may leads to quickly loosening of suckers and once rendered immobile, the worms are expelled from host, similar to the mode of action of levamisole, pyrantel, morantel and oxantel [119].

Histochemical localization showed strong NOS stained cell body of nerve in the sub-tegumental nerve plexus of control *R. echinobothrida*. Intensity of stain revealed to be less throughout the tegument and sub-tegument of the parasite exposed to crude extract of the plant, its active compounds and drug, compared to the control. Histochemical studies were corroborated with biochemical assay where a decrease in activity of NOS was observed in the treated parasites compared to control.

In parasitic flatworms a sandwiched between outer syncytial tegumental layer and an inner parenchymal layer is the somatic musculature, which performs the function of movement. According to McKay et al., the somatic musculature of the flat worm is controlled partially by an inhibitory cholinergic and an excitatory serotoninergic system [120]. Nitric oxide produced by NOS of nitrergic nerves reported to stimulates NO-sensitive gunyl cyclase in its effector cells, thereby decreasing the tone of various smooth muscles [121]. Changes in the mitochondrial membrane potential followed by disruption and disintegration of mitochondria in *R. echinobothrida* exposed to crude extract of *C. baccans* as recorded herewith supports the finding of Brown, who observed that a high level of NO under the influence of NOS changes mitochondrial membrane permeability resulting disruption of mitochondrial respiration, inhibition of glycolysis, thus leading to energy depletion [122]. Reduced activities of AChE and NOS as observed in the crude extract and phytochemicals exposed parasites compared to control may be explained by the fact that the normal functions of strong muscular attachment organ in the control worms having higher activities of AChE and NOS are lost due to consumption of crude extract leading to paralysis and detachment from the intestine of host [123].

Characteristically, glycolysis is the major energy-yielding pathway shown to breakdown carbohydrate to reduced organic acids or more rarely alcohols that are then excreted, since the Krebs' cycle and hexose monophosphate pathways are less functional in helminth parasites. Visible changes in the stain intensities were observed for LDH and MDH activity on treatment with the phytoproducts of *C. baccans* and PZQ. Quantitative enzyme assays of key energy metabolism enzymes such as MDH, LDH, PEPCK and FRD also showed reduced activities in the treated parasites compared to control. PZQ showed more or less similar extend of enzyme inhibition as that of crude extract of *C. baccans,* resveratrol, α-viniferin treated parasite. Similar to these observations, Pampori and Srivastava recorded a significant inhibition of different glycolytic enzymes activities like PEPCK, HK, G6PDH and MDH in *Cotugnia digonophora* when treated with different anthelmintics like MBZ, niclosamide and PZQ [124]. Ahmad and Nizami showed that the commercial anthelmintic mebendazole has influenced the activities of some glycolytic enzymes such as phosphorylase, phosphoglucomutase and G6Pase, and also caused glycogen depletion and the inhibition of glucose uptake *in vitro* [125]. PEPCK's main role in helminth parasites is the degradation of glucose rather than its synthesis through the gluconeogenic pathway as in case of mammalian host [104].

Many anthelmintics like benzimidazoles, artemther, isatin act primarily by inhibiting LDH in different helminth parasites, which catalyzes the conversion of pyruvate to lactate [126,127]. Anthelmintic medicinal plants namely *A. sativum* and *F. vestita* reported to inhibit the activity of LDH in *H. contortus* and *R. echinobothrida* when treated *in vitro* [128,129]. Similarly many plants like *Ocimum sanctum, Lawsonia inermis, Calotropis gigantean, Azadirachta indica, A. nigra* and *P. fulgens* revealed to inhibit activity of MDH in nematode and trematode parasites [130,131].

Activity of FRD, a well-known drug target was significantly decreased by 1.29 fold and 1.19 fold, when *R. echinobothrida* were treated with crude root tuber extract and PZQ, respectively. In various helminth groups FRD system has been detected and proved to be an anthelmintic target [132]. During the life cycle of *R. echinobothrida*, the parasite undergoes two different host shifts and also a change in energy metabolism pathway. The larval parasite lives mainly in the cavity of intermediate host, whereas the adult worm resides inside the small intestine of the definite host. The adult worms living in reduced oxygen situation, use the anaerobic PEPCK (phosphoenolpyruvate carboxykinase)-succinate pathway. In this pathway the last step is the NADH-fumarate reductase system, which is composed of complex I and complex II. It is well noted that the variation in the redox potential between NAD+/NADH and fumarate/succinate ample to drive ATP synthesis [133].

This review revealed the *in vitro* and *in vivo* anthelmintic activity of crude root-tuber extract of *C. baccans* and its active principles. Stereoscan and ultrastructural changes brought about by the exposure of *C. baccans*, resveratrol, α-viniferin and PZQ in the tegument of the parasite responsible for the loss of active movement leading to death of the parasite. As tegument is the protective layer of the parasites, so it seems that the tegument faces the first line interaction with the phytochemicals, which exerts the anthelmintic activity. The level of ultrastructural changes observed in *C. baccans* and its active compounds exposed *R. echinobothrida* seems to alter the normal functioning of the tegument. On the other hand, inhibition of some key tegumental enzymes by the plant extract caused alteration in their normal physiological functions related to nutrient absorption and transportation in the parasite. Similarly, inhibition of neurotransmitter related enzymes such as AChE and NOS by the phytochemicals revealed neurotransmitter inhibitory potential of the test materials leading to paralysis and death of the worm. The presence of energy metabolism related enzymes such as PEPCK, LDH, MDH and FRD and their inhibition on exposure to crude extract and its active principles proved the anthelmintic efficacy of *C. baccans*. Further, condensation of chromosomes, DNA fragmentation and decrease in mitochondrial membrane potential together with increase in proapoptotic caspase indicate that the probable mode of action of the phytoproduct/s is via mitochondria mediated apoptosis.

Conclusion

The present review illustrates the anthelmintic properties of *C. baccans*, a traditionally used medicinal medicinal plant of Northeast India. Though the aqueous extract of the plant is regularly consumed by different tribes to cure different ailments, scientific validity of its use is restricted to anthelmintic properties only. Further, toxicological affect, if any, due to consumption of crude extract of the plant is very much limited. Therefore, further studies should be carried out to evaluate the extent of toxic potential of the plant and its active compounds so as to know the safe doses for consumption.

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A Review on *Clitoria ternatea*(Linn.): Chemistry and Pharmacology

Niraj Kumar Singh[1], Jeetendra Kumar Gupta[1], Kamal Shah[1], Pradeep Mishra[1], Atul Tripathi[2], NagendraSingh Chauhan[3], and Neeraj Upmanyu[4]*

[1]Institute of Pharmaceutical Research, GLA University, Mathura, Uttar Pradesh-281406, India

[2]Institute of Pharmacy, Pt. Ravi Shankar Shukla University, Raipur, Chhattisgarh, India

[3]Drugs Testing Laboratory Avam Anusandhan Kendra, Raipur Chhattisgarh, India

[4]School of Pharmacy & Research, People's University, Bhopal, Madhya Pradesh-462037, India

***Corresponding author:** Dr. Neeraj Upmanyu, School of Pharmacy & Research, People's University, Bhopal, Madhya Pradesh-462037, India; E-mail: drneerajupmanyu@gmail.com

Abstract

The value of mankind is inextricably linked with the wellbeing through natural resources specially the plants around him. Medicinal plants are gift of God, to cure infinite number of diseases in human beings and other living organism. These Plant materials have been extensively used in the indigenous system of medicine which is mention in the Ayurveda and other Indian literature. In all ancient scriptures of Ayurveda, Aparajita is mentioned as one of the important herb. It is a good looking twing herb and very common garden flower plant found all over India especially in southern India Aparajita's botanical name is *Clitoria ternatea* and belongs to Fabaceae (Pipilionaceae) family. *C. ternatea* is a garden plant of India, which has been used the traditional and folkloric medicine in the various diseases. It is scientifically evaluated for anti-inflammatory, antipyretic, analgesic, larvicidal, insecticidal, antimicrobial, anxiolytic, antidepressant, hepatoprotective, tranquilizing and sedative property. This paper reviews plant distribution, agronomic characteristics, pharmacognostical description, ornamental value, traditional properties and uses, phyto-contituents, pharmacological activity of butterfly pea. Thus, the present study is an effort to compile a detailed account and literature survey of *Clitoria ternatea* plant.

Keywords: *Clitoria ternatea*; Pharmacological Properties; Phyto-Constituents; Traditional Uses

Introduction

Since long time immemorial nature has been a mere source of medicinal plants. These medicinal plants are gift of God, to cure infinite number of diseases in human beings and other living organism. They have been the major source of drugs in all system of medicine and

other ancient systems in the world. Such exhaustible source of active ingredients invaluable in the management of many intractable diseases which is harbored by plant kingdom. In the various systems of medicine, many plantsandherbs are used to treat various infirmities. In all ancient scriptures of Ayurveda, Aparajita is mentioned as one of the important herb. It is a good looking twing herb. Aparajita's botanical name is *Clitoria ternatea* and belongs to Fabaceae (Pipilionaceae) family (Figure 1). It is probably originated in tropical Asia [1]. It is widely distributed throughout the humid, lowland tropics of Africa, Asia and Central America. It is found in low and medium altitudes of the settled areas. *C. ternatea* is a strongly persistent, sparsely pubescent, legume. It is perennial climber with slender downy stem, found throughout the tropical regions of the country being cultivated in gardens everywhere and often also found growing over hedges and thickets. It is seen that Aparajita is being adapted to clay soils and has been tested as a forage and cover crop, but never developed as a pasture cultivar [2].In various Ayurvedic preparations different parts of this plant have been used as an active ingredient which is used for treatment of several disorders. There are several reported Ayurvedic 'medha' drugs which contain *C. ternatea* along with other plants. This plant has been scientifically studied for various pharmacological activities like antihistaminic, anthelmintic, hypoglycemic, antidepressant, sedative etc. [3].

Figure 1: Plant of *Clitoria ternatea* (Linn).

Vernacular names

The shape of flowers of the Clitoria plant is a reflection of its genus name. The flowers of this plant resemble in shape with human female clitoris, hence the Latin name of the genus "Clitoria" belongs to "clitoris" and "Ternatea", the name of the species, which comes from Ternate, an Eastern Indonesian island. Similarly in different languages various vernacular names of the flowers are based on reference to a woman's genital organ.

In India:

Sanskrit: Ashphota, Aparajita Saukarnika, Ardrakarni, Girikarnika, Supuspi, Mohanasini Vishadoshaghni, Shwetanama , Vishnu-Kranta, Ashwakhura.

Hindi, Beng, and Oriya: Aparajita or Aparajit.

Gug: Bismar, Garani, Koyala

Kan: Billisaiuga, Satugadagida.

Tel: Dintana, Gilarnika, Neela-ghentana, Sankhupuvvu.

Tam: Kakkanam, Kakatan, Kavachi, Kuruvilai.

Punjab: Dhanattar.

Rajasthan: Koyalri, Titlimatar.

Mar.: Gokurna

Mal.: Aral, Shankapuspam, Malai-amukki.

English: Butterfly pea, Blue pea vine, Mussel-shell climber, Pigeon wings.

In other countries: Butterfly-pea (Australia); Blue-pea, Cordofan-pea, honte (French); blaue Klitorie (German); Fula criqua, Clitoriaazul (Portugese); Azulejo, Conchitis, Papito, Zapatico de la reina, Zapotillo, Conchita azul, Campanilla, bandera, Choroque, Lupita, pito de parra, Bejuco de conchitas (Spanish); Cunha (Brazil); Pokindang (Philippines); Zapatillo de la reina (El Salvador); Kordofan pea (Sudan); Nagar hedi (Kannada); Mavi Kelebek Sarmaşığı (Turkish).

Geographic distribution

Clitoria genus is inconsequential, indigenous climber and a common garden flower found throughout the tropical and subtropical regions of the world. Now the genus becomes rare in humid and sub-humid lands of Asia, America, and Africa and also in semi-arid tropical Australia [1]. It grows from sea level to 1800 and also grown as an ornamental in the warmer parts of the world and outspread from about 20°North latitude to the Salta district in Argentina at about 24°South latitude.

In Africa it grows in grasslands, often on seasonally-waterlogged black clays and in old cultivations whereas in Sudan it is grown for fodder or grazing and in Kenya it is grown in a mixture with *Chloris gayana* [2]. In America, the species of this plant is spread from Florida to Texas and from New Jersey to Kentucky & Arkansas. It is commonly found in Jamaica, Puerto Rico, Turks, and Caicos Islands etc. It is found in all over India, especially in southern India up to an altitude of 1,500 m and in the Andaman Islands [4].

Taxonomic hierarchy

Kingdom: Plantae

Phylum: Angiosperms

Order: Fabales

Family: Fabaceae

Genus: *Clitoria*

Species: *C. ternatea*

Other species of Clitoria

Clitoria albiflora Mattei
*Clitoria amazonum*Benth
Clitoria Andrei Fantz
*Clitoria angustifolia*Kunth
Clitoria annua J. Graham
Clitoria arborea Benth.
Clitoria arborescens R. Br.
Clitoria australis Benth.
Clitoria biflora Dalziel
Clitoria brachystegia Benth.
Clitoria bracteata Poir.
Clitoria brasiliana L.
Clitoria cajanifolia (*C. Presl*) Benth.

Clitoria capitata Rich.
Clitoria dendrina Pittier
Clitoria fairchildiana R. A. Howard
Clitoria falcata Lam.
Clitoria fragrans Small
Clitoria glycinoides DC.
Clitoria guianensis (Aubl.) Benth.
Clitoria javitensis subsp. *javitensis*
Clitoria laurifolia Poir.
Clitoria linearis Gagnep.
Clitoria mariana L.
Clitoria mearnsii De Wild.
Clitoria mexicana Link
Clitoria moyobambensis Fantz
Clitoria nana Benth.
Clitoria pedunculata Bojer ex Benth
Clitoria pinnata (Pers.) R. H. Sm. & G. P. Lewis
Clitoria plumieri Turpin ex Pers.
Clitoria polyphylla Poir.
Clitoria racemosa G. Don
Clitoria racemosa Benth.
Clitoria rubiginosa Pers.
Clitoria sagotii Fantz
Clitoria schiedeana Schltdl.
Clitoria stipularis Benth.
Clitoria tanganicensis Micheli
Clitoria ternatea L.
Clitoria virginiana L.
Clitoria woytkowskii Fantz
Clitoria zanzibarensis Vatke
Clitoria zanzibarensis mengkoemieng

Agronomic characteristics

Soil: *Clitoria* is well adapted to grow in wide range of soil types (in between pH range 5.5-8.9) from deep alluvial to sandy including calcareous soils. It extremely well adapted to heavy clay alkaline soils, and especially on clay soils but also grows well in moderate fertile soils [1]. *Clitoria ternatea* likes a rich, moist soil (peat moss: loam: part sand or perlite 2:1:1) therefore the soil should be evenly moist at all times for well growth.

Water: It requires approximately 400 mm of rainfall but also performs well under irrigation areas and grows from drier areas like Kordofan in the Sudan to the fairly drought tolerant in Zambia. Due to the nature of *C. ternetea,* it cannot tolerate prolonged inundation or water logging but can tolerate short term flooding.

Sun light: It is moderately shade-tolerant but can normally grow in full sunlight.

Temperature: It needs moderate temperature down to 25ºC but not suited to locations with frequent or severe frosts, but it stands up well in hot summer temperatures and having low frost tolerance.

Fertilizer: *C. ternetea* is normally grown in soil containing phosphorous (P) and sulphur (S) which may be required as fertilizers if sown in the infertile soils.

Propagation: It contains around 20% of hard seed according to the seasonal conditions in where it is produced and grows rapidly in warm-moist weather. It is harvested manually by hands and is propagated from seed by cuttings [5]. The seeds of *Clitoria ternatea* are covered by hard seed coats therefore do not germinate or imbibe water, but when stored for 6 months 15-20% germination can be obtained. The use of hot water, sulphuric acid (H_2SO_4), potassium hydroxide and soaking in 100 mg/L solution of Sodium cyanide (NaCN) has also improved germination and early plant growth while mechanical scarification increased germination of 6-month-old seed from 30% to 71% [2].

Pharmacognostical description

Different growing conditions can affect its morphology. It is extensively grown in gardens for its flowers as an ornamental plant and it belongs to the sub family papilionaceae and family Fabaceae (Leguminoseae) botanically, butterfly pea (*C. ternatea*) [6].It has various synonyms like *C. purpurea and C. ternatea,* some have potential for foraging use and some are partially domesticated. The plant is a long-lived perennial herb 90 to 162 cm tall with an erect habit. It has two types one has white-flower and other blue flower. *Clitoria* have cleistogamous and chasmogamous flowers i.e., self-pollinating and insect pollinating respectively. Physical properties of flower like color, structure and position vary from species to species they may 60 to 120 mm long like beans and blue scabbards flat and linear [1]. The flowers of this plant are papilionaceous, axillary, solitary, pedicel 0.8 to 1.3 cm long with bright blue or white with yellow or orange center. Calyx 13 to 20 mm long, corolla 38 to 50 mm, oblong, seeds 8 to 11/pod, Pods 50 to 100 mm by 0.8 to 1.3 cm, nearly straight, somewhat flattened, sharply beaked sparsely hairy, 0.3 to 0.4 cm wide, shiny, often mottled, minutely pitted, olive brown to almost black. Pinnate leaves with 5 or 7 leaflets; stipules persistent, narrowly triangular, 1 to 6 mm long, subulate, prominently 3-nerved; rachis 10 to 70 mm long; petioles are 15 to 30 mm long; stipels are filiform, leaflets are elliptic, oblong, ovate or nearly orbicular, 20 to 50 mm long, 3to 30 mm wide, with apex acute or rounded, often notched, and base cuneate or rounded, both surfaces sparsely appressed pubescent [7].

Flattened pods are 40 to 130 mm long, linear to oblong and 8 to 12 mm wide, are style persistent, pale brown, dehiscent when dry, sparsely pubescent when mature and with thickened margins. The bracteoles are persistent and 0.4 to 1.2 cm long, broadly ovate or rounded, calyx is 17 to 22 mm long with a few fine hairs; lobes triangular or oblong; tube campanulate, 8 to 12 mm long 7 to 10 mm long, acute or acuminate [8]. The physiochemical properties of roots are buffy brown in color, with characteristic odor and bitter in taste. *Clitoria ternatea* have both primary and secondary roots are thick, hard with smooth surface and later are thin, fibrous in nature respectively. Its roots fix nitrogen; therefore this plant has been used to improve soil quality. The thick horizontal roots may grow bearing one to several purplish, glaucous, wiry stems with more than 2 m length.

Ornamental values

C. ternatea widely grows in the warm climatic conditions as an ornamental plant, attractive for its blue flowers and requires very little care while cultivation. It has various types of species of *Clitoria* present in the world which improves the quality of soil by fixing the nitrogen through its roots, but out of them only *C. ternatea* has attractive flowers. The physiological characters of flowers are creamy white and dark blue colored papilionaceous flowers which are very attractive and solitary. It is very valued plant for garden lovers as an important ornamental crop due to its attractive nature. New hybrids were developed

between *C. ternatea* and *C. purpurea* which produced somewhat bigger in flower size when compared with parents and intermediate colored (light blue) flowers. In the segregating progenies variation in flower colors were noticed viz., medium blue, cream flower with blue, light pink color, dark blue with velvety appearance, borders, violet, dark violet, besides the parent colors [1]. For ornamental purposes species with less numbers of leaves and medium heighted segregants with attractive flower such as light pink, deep violet, and velvety blue can be exploited.

Traditional properties and uses

Clitoria is pungent in the post digestive effect, has cold potency, bitter in taste, and possesses light dry and sharp attributes. In Ayurveda 'Sankhapushpi' is one of the formulations which consists of the seeds and roots of *C. ternatea*, is used as a 'nerve tonic', alternative and laxative. It has been used for the treatment of various neurological disorders as an active ingredient in 'Medhya Rasayana'. By various group of persons it is considered as medicine which is useful in skin diseases, eye and throat infections also in urinary disorders, ulcers and antidote activity [9].

Root: The roots have a sharp bitter or acrid taste and credited with cooling, laxative, diuretic, anthelmintic, anti-inflammatory properties. In the scientific studies it was found that extracts of *C. ternatea* can raise the acetyl choline content and acetyl choline esterase activity in rat brain in a similar fashion to the standard cerebral drug pyritinol [9]. In other treatments of various ailments like infections, as anthelmintics, antidote to animal stings, urinogenital disorders and body aches *C. ternatea* is also used [10]. Especially the roots of *C. ternatea* are useful in severe asthma, remittent fever and bronchitis. These are used to administer with ghee and honey as a tonic to children for boost up in their mental abilities, muscular strength, complexation, whooping cough, goiter and epilepsy [11]. Roots used by tribal to cause abortion and its paste applied on cattle stomach for curing abdominal swelling [12]. Research suggested that the methanolic extract of *C. ternatea* roots shown nootropic, anxiolytic, anti-depressant, anticonvulsant and anti-stress activity in animals. The decoction or powder of root is given in rheumatism and ear disease. Root and leaves have emetic and antiperiodic [13].

Seed: The use of seeds of *Clitoria ternatea* for medicinal purpose is both for external and internal applications. Fried seeds are recommended in ascites when given orally with hot water in powdered form with ghee and fennel [13]. Seeds are also used in digestive disorders because they have purgative, cathartic and laxative action when used in combination with ginger powder. Seeds are also prescribed in cough, hepatic disorders, spleen and rheumatic infections. The seeds are safe for abdominal viscera, colic, dropsy and also for arthritis.

Leaves: Leaves are used as emetic, diuretic, antiperiodic and laxative. The leaves are also very useful in the inflammation of mastoid lymph nodes when used with salt in paste form. The juice form has the ability to mitigate the toxins [10]. In combination with ginger juice, the fresh leaves are useful in hepatic fever, excessive sweating and also useful in inflammation around the ear and neighboring glands in juice form with common salt.

Flower: Flowers are suggested and used for the treatment of scorpion sting and snake bite. In Cuba decoction of flowers with roots are considered emmenagogue [10]. An infusion of flowers is used to promote menstruation and induce certain contraction. Flowers are also used to treat chlorosis and intestinal problem [13]. In experimentally induced diabetic mice, the ethanolic extract of flowers significantly lowers the serum sugar level.

Stem: Stem is recommended for the treatment of snake bite and scorpion sting. The stem of the plant contains the phytochemicals which are mainly considered as brain tonic and is also useful for eye and throat infections, skin diseases, urinary troubles [13].

Phyto-contituents

Butterfly pea yields up to 30 tons dry matter per hectare per year in favorable conditions. Plant can be exploited as a source of calcium in herbal drink due to its high calcium concentration. It contains antifungal proteins (Figure 2-12).

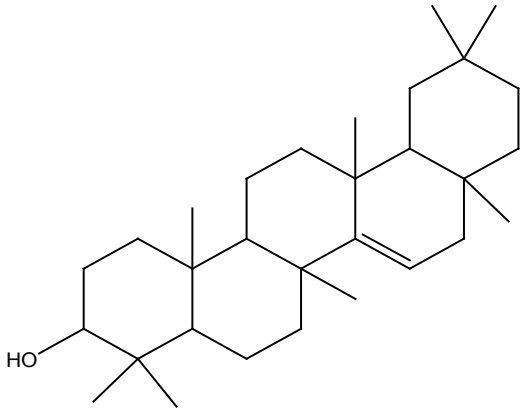

Figure 2: Taraxerol.

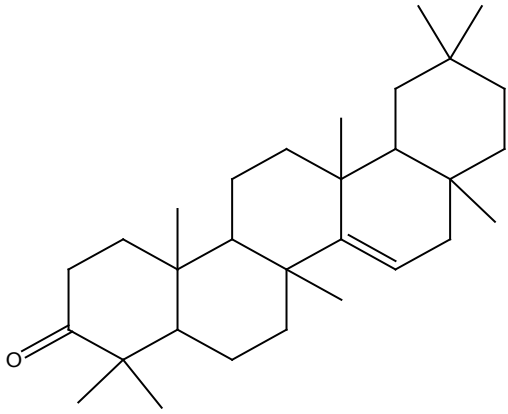

Figure 3: Taraxerone.

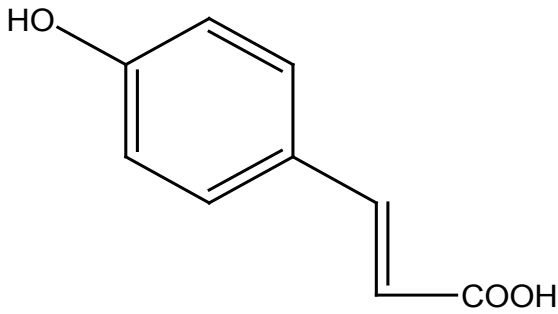

Figure 4: p-Hydroxycinnamic acid.

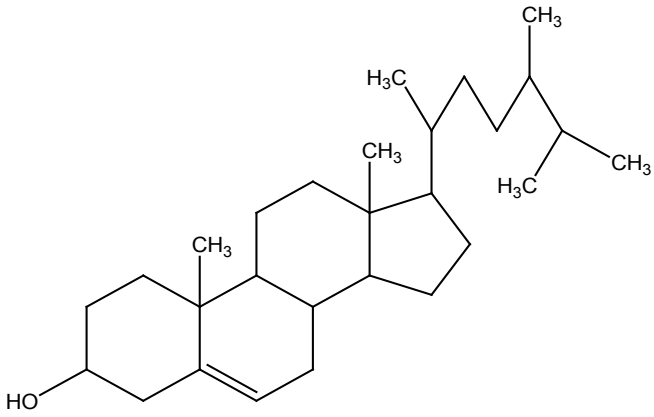

Figure 5: β-sitosterol.

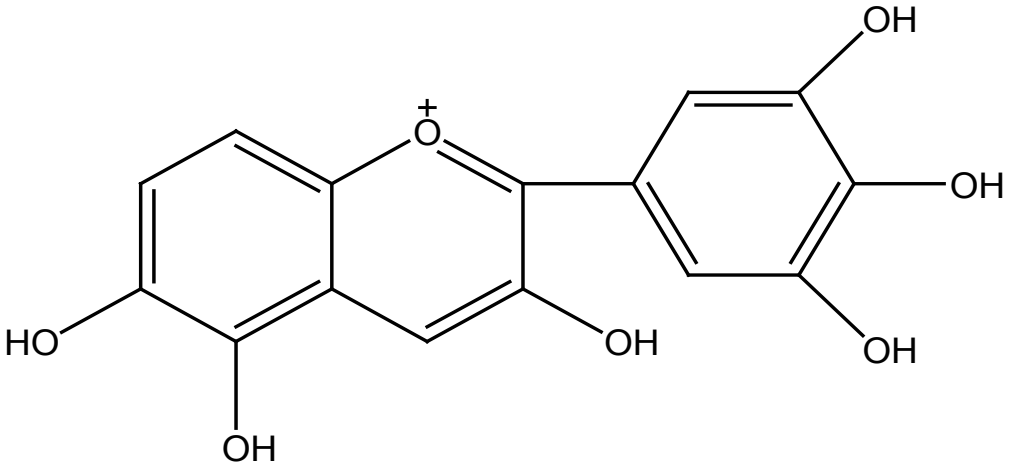

Figure 6: Delphinidin.

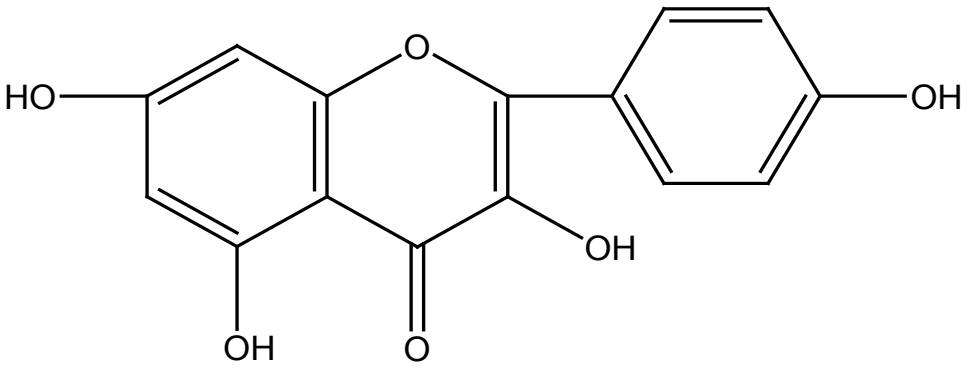

Figure 7: Kaempferol.

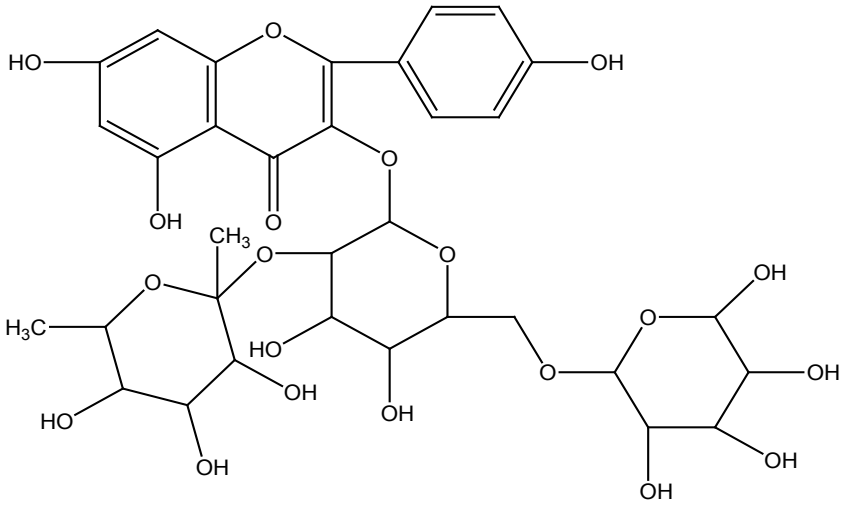

Figure 8: Clitorin.

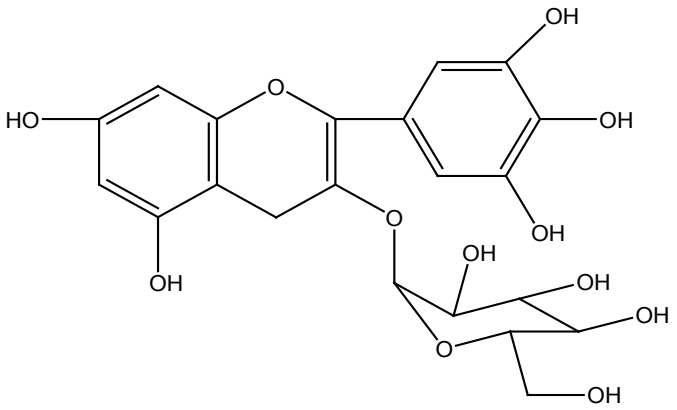

Figure 9: Delphinidin 3-O-β-glycoside (anthocyanins).

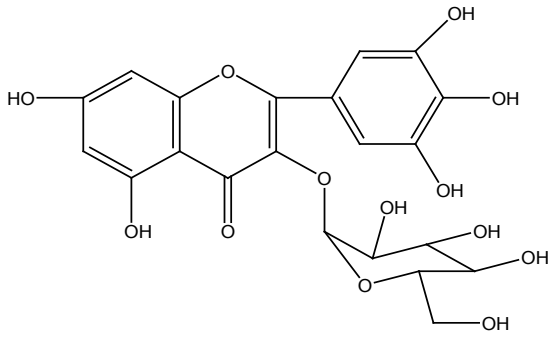

Figure 10: Myricetin 3-glycoside.

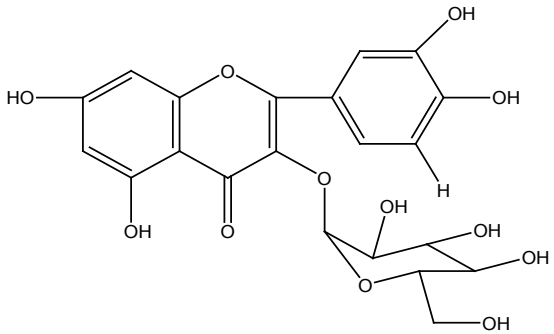

Figure 11: Quercetin 3-glocoside.

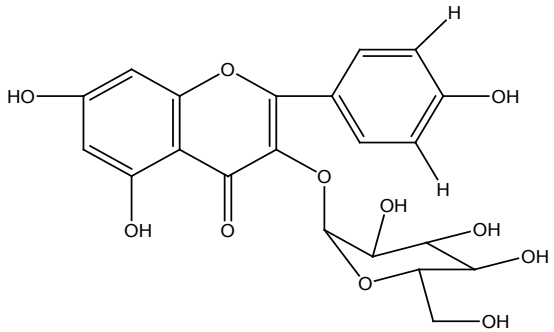

Figure 12: Kaempferol 3-glocoside.

Leaf: The content of crude fiber and protein in the leaves were 21.5% and 21.5-29% respectively. From leaves, clitorin and kaempferol have been isolated [1]. The leaves also contain 3-monoglucoside, 3-rutinoside, 3- neohesperidoside, 3-o-rhamnosyl-glucoside, 3-o-rhamnosylgalactoside of kaemferol, besides kaemferol-3-o-rhamnosylo- rhamnosyl-glucoside. It also contains aparajitin and β- sitosterol [13]. The flowers (blue in color) contain delphinidin-3,5- diglucoside, delphinidin-3β-glucoside, and its 3 methyl derivative, malvidin-3β-glucoside, kaemferol and cynidin chloride. A lactone- aparajitin from leaves [1].

Root: Taxaxerol and taxaxerone are present in the roots of plant. The bark of roots contains sresin, tannin, starchand flavonol glycosides. The root nodule contains glycine, alanine, valine, lecine, α-aminobutyric acid, aspartic acid, glutamic acid, arginine, ornithine, histadine, γ-aminobutyric acid [10,14].

Seed: The seed contains bitter acid resin as an active principle with fixed oil, tannic acid and glucose, also contains a cotyledon, which is full of granular starch and bitter in taste. There are two chemicals which are isolated from seeds viz. Sitosterol and anthoxanthin. Other than that seed-oil yields palmitic, stearic, oleic, linoleic and linolenic acids. Oils from blue and white-flower varieties have been found to have almost similar composition. Seeds also contain cinnamc acid, hexacosanol, nucleoprotein with its amino acid sequence somewhat similar to insulin [12].

The seeds are very high in protein content (15-25%). The seeds contains p-hydroxycinnamic acid, flavonol-3-glycoside, ethyl-α-D-galactopyranoside, adenosine, 3,5,7,4-tetrahydroxyflavone-3-rhamnoglucoside, polypeptide, hand exacosanol. Oligosaccharides or flatulene are also present in seeds. A food dye, delphinidin 3,3',5'-triglucoside also reported in seeds [4]. Lecin represents about 2.8% of the total extractable

protein from seed meal or 30 mg of lectin/30 g of *C. ternatea* seeds in contrast 9 mg fetuin/30 g of seeds. Tryptophan and tyrosine is also reported in the seeds [15].

Flower: Two acyl moieties were determined as E-4-0-β-D-glucopyranosyl-p-coumaric acid and 6—0-malonyl-D-glucopyranose. Other six ternatins A1, A2, B1, B2, D1 and D2 in *C. ternatea* flower ware isolated by reverse phase HPLC [16]. The white flower yield only kaeferol. From the petals of *Clitoria ternatea* L. some flavonol glycosides isolated are kaempferol 3-O-(200-O-a-rhamnosyl-600- O-malonyl)-b-glucoside; quercetin 3-O-(200-O-arhamnosyl- 600 -O- malonyl) -b- glucoside; myricetin 3 -2G -rhamnosylrutinoside; quercetin 3-2G-rhamnosylrutinoside 4. Flower also contains kaempferol 3-2G-rhamnosylrutinoside; kaempferol 3- neohesperidoside; quercetin 3-neohesperidoside; myricetin 3-neohesperidoside; kaempferol 3-rutinoside; quercetin 3-rutinoside; myricetin 3-rutinoside; kaempferol 3- glucoside; quercetin 3- glucoside; myricetin 3-glucoside [13]. Cyanine chloride and kaempferol are isolated and identified from the flowers. Isolation of Six acylated anthocyanins A, B, C, D, E and F from blue flowers has been done with the partial characterization of kaempferol and its 3- glucoside, robinin, quercetin and 3-glucoside and ternatins A and B [17]. Blue flower of butterfly pea also contain lobelinins, which has the 3,5,3',5'-tetraglucoside substituted pattern. Deacylternatin is also reported in the blue flower petals [18].

Various types of *C. ternatea* lines with different petal have been investigated for flavonoids. The newly isolated glucoside from the petals of mauve line is Delphinidin 3-O-(2″-O-α-rhamnosyl-6″-O-malonyl)-β-glucoside. Also, a group of ternatins identified from the entire blue petal lines i.e. 15 (poly) acylated delphinidin. The white petal lines do not contain anthocyanins.While ternatins are identified in all blue petal lines as 3′,5′-disubstituted polyacylanthocyanins, the mauve petal line accumulated delphinidin 3-O-(6″-O-myl)-β-glucoside instead [19]. Researchers found that the difference in flower color from blue to mauve is due to the lack of (polyacylated) glucosyl group substitutions at both the 3′- and 5′-positions of ternatins but not due to a change in the structure of an anthocyanidin from delphinidin.

Pharmacological properties

Anthelmintic activity: Anthelmintic activity was found in ethanolic and aqueous extract of *C. ternatea* leaves at the dose of 100 mg/ml. This was performed at three different concentrations (100, 50, 25 mg/ml) of ethanolic and aqueous extracts respectively by using *Eisenia foetida.* The study was focused at the *in-vitro* comparative study of aqueous and ethanolic extracts of leaves of *C. ternatea* for anthelmintic activity. Thus, the study involved in the determination of time of paralysis (P) and time of death (D) of the worms. While determination for both extracts, the time of paralysis and death time of aqueous extract was observed as 18 ± 1.57 and 53.33 ± 0.33 and in case of ethanolic extracts 12.33 ± 0.80 and 32.33 ± 0.71 respectively. At last, the anthelmintic activity of ethanolic extract of *C. ternatea* was found more potent than aqueous extract of *C. ternatea* [5].

Antihistaminic activity: Antihistaminic activity was found in the ethanolic extract of *C. ternatea* roots in dose dependent manner. Evaluation for antihistaminic activity was done using clonidine and haloperidol induced catalepsy in mice for Ethanol Extract of *C. ternatea* Root (ECTR) at doses 100, 125 and 150 mg/kg IP. Dose dependent catalepsy was induced in mice by Clonidine, a α_2 adrenoreceptor agonist which was inhibited by histamine H1 receptor antagonists but not by H_2 receptor antagonist. Clonidine, which is responsible for the release of histamine from mast cells, is responsible for different asthmatic conditions. A non-selective D_2 dopamine antagonist (Haloperidol) induces catalepsy is primarily due to blockade of dopamine receptors in the straiatum. The agents responsible for increase in dopamine transmission inhibit haloperidol-induced catalepsy. Findings showed that ethanol Extract of *C. ternatea* Root (ECTR) and Chlorpheniramine Maleate (CPM) inhibit clonidine induced catalepsy significantly $P < 0.001$ when compare to control group, while

ECTR and CPM fail to inhibit haloperidol induced catalepsy. So it is concluded that the agents increasing dopamine transmission inhibits haloperidol-induced catalepsy and the present study shows ECTR possesses antihistaminic activity [20].

Antimicrobial activity: The antimicrobial screening was evaluated against Extended Spectrum Beta Lactamase (ESBL) producing *Salmonella enteritidis, Salmonella typhimurium, Klesiella pneumonia,* Enteropathogenic *E.coli,* Uro-pathogenic *E.coli,* and *Pseudomonas aureginosa* isolated from patients with urinary tract infection and acute gastroenteritis. Disc diffusion method was used to test the above mentioned extracts for their activity. Water, methanol and chloroform extracts of *C. ternatea* flowers was exhibited activity against uropathogenic *E.coli,* Enteropathogenic *E.coli*, Enterotoxigenic *E.coli, Salmonella typhimurium*, *Klesiella pneumoniae* and *Pseudomonas aureginosa.* Methanol extract of *C. ternatea* exhibits comparatively high activity as compared with chloroform and aqueous extracts. The inhibitory zone produced by water, methanol and chloroform extracts at a concentration of 4 mg/disc was found 12 mm, 16 to 26 mm and 14 mm to 18 mm respectively while petroleum ether and hexane extracts did not exhibit any activity [21].

Cytotoxic activity: The crude methanol extract of stem-bark, leaves and seeds of *C. ternatea* demonstrated a significant cytotoxic activity in a brine shrimp lethality bioassay test. The LC_{50} values of the crude methanol extract of stem-bark, leaves and seeds were found to be 179.89, 25.82, 110.92 µgm/ml) respectively. Among them crude methanol extract of leaves (25.82 µgm/ml) and methanol fraction of leaves (22.28 µgm/ml) showed a very promising cytotoxic activity [22].

Central cholinergic activity in rats: Researcher has reported the alcoholic extract of roots of *C. ternatea* on spatial memory retention and associated changes in Acetylcholine (ACh) and Acetylcholinesterase (AChE) activity in the brain after electroshock or scopolamine induced amnesia. The preselected trained rats were administered with either alcoholic extract of *C. ternatea* or standard Shankhapushpi syrup for 10 days once a day. The animals of respective groups were subjected to electroshock or scopolamine treatment followed by radial arm maze task performance1 h after the last dose. Thereafter, the brain were immediately isolated and ACh as well as AChE levels were estimated. Study shows significant memory retention against scopolamine and electroshock induced amnesia in root extract treated rats. The extract was found to be more effective in scopolamine induced amnesia model. This action was found to be associated with significant decrease in AChE activity and increase in ACh content of whole brain in different regions of the brain compared to respective controls qualitatively [23].

Hypoglycemic Effect: The effect of orally administered aqueous extracts (400 mg/kg body weight) of *C. ternatea* leaves and flowers were examined in control and test group of rats on insulin, glycosylated hemoglobin and serum glucose. The aqueous extracts of *C. ternatea* leaves and flowers significantly ($P<0.05$) increased the liver and skeletal muscle glycogen, the activity of the glycolytic enzyme and glucokinase serum insulin but able to reduce the serum glucose, glycosylated hemoglobin and the activities of gluconeogenic enzyme, glucose-6- phosphatase. After all the biochemical tests, the group of leaf extract-treated rats indicated essentially the same profile as those treated with the group of flower extract [24].

Previously, the leaves and flowers of *C. ternatea* have been reported for antidiabetic property; hence current study is an attempt to evaluate the antidiabetic potential in seeds of *C. ternatea.* Methods: Preliminary phytochemical investigations of Ethanol extract of seeds of *C. ternatea* Linn. was done. The seed extracts were screened for hypoglycaemic activity in Streptozotocin induced diabetic rats (60 mg/kg, i.p.) at two dose levels like 200 mg and 400 mg/kg body weight. Results: Presence of various phytoconstituents in ethanolic extract viz. alkaloids, glycosides, saponins, tannins, phenolic compounds, carbohydrates, proteins, sterols, and flavonoids. The ethanol extract at 400 mg/kg.b.wt dose showed significant

decreased blood glucose ($p < 0.001$), cholesterol ($p < 0.05$), alkaline phosphatase ($p < 0.001$), aspartate amino transferase ($p < 0.001$) and alanine amino transferase ($p < 0.001$), when compared to diabetic control. Further study is required to isolate active phytoconstituents from ethanolic extract of seeds of *C. ternatea* Linn [25].

Neurogenic potential: In Indian Ayurvedic system of medicine, extracts derived from *C. ternatea* Linn have been used as an ingredient of "Medhya rasayana", intentionally used for improving memory and longevity in humans and also in treatment of various neurological conditions. Our earlier experimental studies with oral intubation of *C. ternatea* aqueous root extract had shown significant increase in learning and memory of postnatal and young adult Wistar rats. In the present study we were designed to elucidate the *in vitro* effects of 200 mg/ml of *C. ternatea* aqueous root extract on proliferation, differentiation and growth of anterior sub ventricular zone neural stem cells derived from prenatal and postnatal rat pups. Results shown significant increase in proliferation and increase in the yield of differentiated neurons of a SVZ neural precursor cells at 7 days *in vitro* and growth of neurospheres when treated with 200 ng/ml of *C. ternatea* aqueous root extract as compared to age matched control. Results indicate that CTR has growth promoting neurogenic effect on a SVZ neural stem cells and their survival similar to neurotrophic factors like Survivin, Neuregulin 1, FGF-2, BDNF possibly the basis for enhanced learning and memory [26].

Proteolytic activities: The activities of endopeptidases (pH of hemoglobin is 3.5 and pH of azocasein is 6.0), carboxypeptidase (pH of CBZ-Phe-Ala is 5.2), and arylamidases (pH of LPA is 7.0 and pH of BAPA is 7.6) were assayed in extracts of cotyledons and axis of resting and germinating seeds of *C. ternatea* L. All the activities were low in resting seeds but the endopeptidases at pH 3.5 and the arylamidase at 7.0 were high in cotyledons. The activities of endopeptidases showed an increase at the day 3 followed by a decrease, while the carboxypeptidase and the arylamidases increased in cotyledons reaching a maximum at the day 9. In the axial tissue the endopeptidases and carboxypeptidase activities showed an increase until the day 9 followed by a decrease and the arylamidases were low. The increase of acidic endopeptidase and carboxypeptidase activities in germinating cotyledons has been suggested as an indication of their participation in the degradation of the storage proteins [27].

Wound healing activity: The effects on wound healing were investigated using excision, incision and dead-space models in rats. Seed and root extracts significantly improved wound healing property when administered orally by gavages as well applied topically as ointment which are comparable to that of cotrimoxazole ointment. The finding of this study suggested that plant possesses effects on all three phases of wound healing: inflammatory, proliferative and remodeling phase [28].

Larvicidal activity: Screening of natural products for mosquito larvicidal activity against three major mosquito vectors *Aedes aegypti, Anopheles stephensi,* and *Culex quinquefasciatus* resulted in the identification of three potential plants extracts viz., *Saraca indica/asoca, Nyctanthes arbortristis,* and *C. ternatea* for mosquito larval control. In the case of *S. indica/asoca*, the chloroform extract of the bark and the petroleum ether extract of the leaves were effective against the larvae of *C. quinquefasciatus* with respective LC_{50} values 227.9 and 290.5 ppm. The LC_{50} values of chloroform extract of *C. ternatea* leaves were 302.2, 517.2, and 422.2 ppm against *A. aegypti, A. stephensi,* and *C. quinquefasciatus*, respectively. The methanol and chloroform extracts of flowers of *C. ternatea* showed larvicidal activity against larvae of *A. stephensi* with the respective LC_{50} values of 245.4 and 748.7 ppm. Among the methanol extracts of *C. ternatea* leaves, roots, flowers, and seeds, the seed extract was effective against the larvae of all the three species with LC_{50} values 66.2, 155.5, and 55.4 ppm, respectively, for *A. stephensi, A. aegypti,* and *C. quinquefasciatus*. Among the three plant species studied for mosquito larvicidal activity, *C. ternatea* was showing the most promising mosquito larvicidal activity [29].

Enhancementof acetylcholine content in rat hippocampus: Significant increase in Acetylcholine (ACh) content in hippocampi as compared to age matched controls after the

treatment with 100 mg/kg of *C. ternatea* aqueous root extract (CTR), for 30 days in neonatal and young adult age groups of rat. Increase in ACh content in their hippocampus may be the neurochemical basis for their improved learning and memory [30].

Antipyretic activity: Evaluation of anti-pyretic potential Of Methanolic Extract of *C. ternatea* L. Root (MECTR) of blue flowered variety (Family: Fabaceae) on normal body temperature and yeast-induced pyrexia in albino rats. Increase in rectal temperature was observed after 19 hours of Yeast suspension (10 ml/kg body wt.) subcutaneous injection. The extract produced significant reduction in normal body temperature at doses of 200, 300 and 400 mg/kg body wt., p.o., and yeast-provoked elevated temperature in a dose-dependent manner. The effect extended up to 5 hours after the drug administration. The anti-pyretic effect of the extract was comparable to that of paracetamol (150 mg/kg body wt., p.o.), a standard anti-pyretic agent [31].

Effects on growth and morphogenesis of *Aspergillus niger:* *The extract showed a favorable antifungal activity against A. niger with a minimum inhibition concentration 0.9 mg/mL and minimum fungicidal concentration 1.7 mg/mL, respectively. The leaf extract exhibited considerable antifungal activity against filamentous fungi in a dose-dependent manner with 0.5 mg/mL IC_{50} value on hyphal growth of A. niger. The main changes observed under scanning electron microscopy after C. ternatea extract treatment were loss of cytoplasm in fungal hyphae and the hyphal wall and its diameter became markedly thinner, distorted, and resulted in cell wall disruption. In addition, conidiophore alterations were also observed when A. niger was treated with C. ternatea leaf extract [32].*

The effect of leaves extracts against the fish pathogens: The extracts of *C. ternatea* was tested against *P. aeruginosa, E. coli, K. pneumonia, B. subtilis, A. formicans, A. hydrophila* and *S. agalactiae* by the agar well diffusion method. Different extracts of *C. ternatea* showed inhibitory effects against *P. aeruginosa, E. coli, K. pneumonia, B. subtilis, A. formicans, A. hydrophila* and *S. agalactiae*. Ethyl acetate extracts of *C. ternatea* showed maximum of zone of inhibition against *A. formicans* (19 mm), *A. hydrophilia* (20 mm), *B. subtilis* (20 mm) and *P. aeruginosa* (22 mm) next to that ethanol extract of *C. ternatea* showed *A. formicans* (19 mm) and *E. coli* (15 mm) followed by Acetone extract showed maximum zone of inhibition *S. agalactiae* (20 mm) and *K. pneumonia* (19 mm) [33].

Hepatoprotective activity: The methanol, chloroform, and petrolium ether extracts of roots of blue and white flowered varieties of *C. ternatea* (CT) were found to have hepatoprotective property. This was assessed by evaluating their hepatoprotective potential against Carbon Tetrachloride (CCl_4) induced hepatotoxicity in rats. Methanolic extracts of roots of blue and white flowered varieties at dose 250 and 500 mg/kg b. w. were showed significant ($P<0.001$) reduction in the serum TB level. The white flowered variety of CT showed much more reduction in TB level as compared to blue flowered variety of CT [10]. Hepatoprotective activity of *C. ternatea* seed and root and *Vigna mungo* seed against acetaminophen- and carbon tetrachloride-intoxicated rats was investigated. *C. ternatea* and *V. mungo* seed extracts significantly ($p<0.05$) decreased SGOT, SGPT, ALP and Total Bilirubin (TB) in both acetaminophen and CCl_4 - intoxicated rats. The *C. ternatea* root extract, showed similar results only in CCl_4 - intoxicated rats. These findings were further supplemented by histopathological studies of liver tissues. Hepatic collagen content as evident from decreased ($p<0.05$) hydroxyproline levels and hepatic mast cell infiltration were significantly decreased in extracts pre-treated animals. In addition, *C. ternatea* and *V. mungo* seed extracts significantly ($p<0.05$) reduced hepatic lipid peroxidation as evident from the decreased MDA, increased antioxidant enzymes activities and GSH levels in the liver tissues. The findings of study suggested that *C. ternatea* and *V. mungo* possess potent hepatoprotective activity. The hepatoprotective activity of *C. ternatea* could be attributed to antioxidant properties and prevention of pre-inflammatory changes [34].

Antioxidant activity: The chemical composition of the flowers of *C. ternatea* suggest that they may have antioxidant activity, ethanopharmacological evidences shows that

the extracts of *C. ternatea* (butterfly pea) flowers are used in Thailand as a component of cosmetics. The aqueous and ethanolic extract of *C. ternatea* was found to have antioxidant potential. Aqueous extracts were shown to have stronger antioxidant activity than ethanol extracts (IC_{50} values were 2 mg/mL and 5 mg/mL, respectively). This was assessed by performing DPPH scavenging activity test. The total phenolic content was 2.0 mg/g extract as gallic acid equivalents. The data from this study support the use of *C. ternatea* extracts as antioxidant inclusions in cosmetic products [35].

***In-vitro* cytotoxic activity:** This study evaluates the *in-vitro* cytotoxic effect of petroleum ether and ethanolic flower extracts of *C. ternatea* Linn by using trypan blue dye exclusion method. Both extracts exhibit significant cell cytotoxic activity. For both the extracts decrease in cell count was observed with increase in concentration of the extract. There was a dose dependent increase in cytotoxic activity for all the concentrations tested [36].

Anti-inflammatory, analgesic and antipyretic Properties: *C. ternatea* roots methanol extract when given by oral route to rats was found to inhibit both the rat paw oedema caused by carrageenin and vascular permeability induced by acetic acid in rats. Moreover, the extract exhibited a significant inhibition in yeast-induced pyrexia in rats. In the acetic acid-induced writhing response, the extract markedly reduced the number of writhings at doses of 200 and 400 mg/kg (p.o.) in mice [3].

Conclusion and Future Perspectives

Nature has been a source of medicinal agents since time immemorial. The plant kingdom harbors an in exhaustible source of active ingredients invaluable in the management of many intractable diseases. They are well known in traditional herbal medicine for their diseases curing property. Aparajita is one of the herbs mentioned in all ancient scriptures of Ayurveda. *C. ternatea* belongs to family 'Fabaceae'; is cultivated throughout India. It is a perennial twing herb; steams are terete, more or less pubescent and persistent legume found in India, China, Philippines and Madagascar etc. It is native to tropical Asia and widely distributed thought the world mainly in tropical countries. It is a very common garden flower plant found all over India especially in southern India. Butterfly pea is recognized as being adapted to clay soils. It is reported to be a good "Medhya" (brain tonic) drug and, therefore, mainly used in the treatment of "Masasika" roga (mental illness). In Ayurveda, the roots, seeds and leaves of *C. ternatea* have long been widely used as a brain tonic and is believed to promote memory and intelligence. *C. ternatea* has been widely screened for its various pharmacological activities especially well documented for neuropharmacological action. The root and root barks are used in ascathartic, diuretics and has laxative effects. Juice of roots is used in the treatment of chronic bronchitis. The leaves are useful in otalgia and hepatopathy, whereas seeds are cathartic. The flowers and leaves are used to make collyrium, leaves are also used to relieve joint pain in arthritis, and hepatic disorder, the seeds have laxative effects, and are cathartic, and it contains antifungal proteins. *C. ternatea* plant has the most promising mosquito larvicidal activity. *C. ternatea* have number of pharmacological activities such as possessing nootropic, anxiolytic, antidepressant, anticonvulsant, sedative, antipyretic, anti-inflammatory and analgesic activities, memory enhancing, acetylcholine content increasing and acetylcholinesterase activity. Future scope of present investigation is isolate active phytoconstituents which is responsible for various pharmacological activities. The detailed chemical natures and structure of the active principles responsible for its activity are not known. Hence, further studies should be carried out to elucidate the active principles of *C. ternatea*.

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Ethnomedicinal Uses, Phytochemistry and Pharmacology of *Cissampelos pareira*: A Review

Kamal Shah[1]*, Shaiba Sana Qureshi[1], Jeetendra Kumar Gupta[1], Neeraj Upmanyu[2] and Nagendra Singh Chauhan[3]

[1]Institute of Pharmaceutical Research, GLA University, Mathura(U.P.), India

[2]School of Pharmacy & Research, People's University, Bhopal(M.P.), India

[3]Drugs Testing Laboratory Avam Anusandhan Kendra, Raipur (CG), India

***Corresponding author:** Dr. Kamal Shah, Asst. Professor, Institute of Pharmaceutical Research, GLA University, Mathura(U.P.), India; E-mail: kamal0603@gmail.com

Abstract

The plant *Cissampelos pareira* is a sub-erect or climbing herb, belongs to the family Menispermaceae. It is commonly known as Bhatindupat in Punjab and laghupatha or ambastha in Indian traditional medicine. There are around 30 plant species summarized under this botanical name "*Cissampelos pareira"*, found in all over the world. Only one species is found in tropical and subtropical parts of India. The plant is commonly found on the hilly tracts along watercourses, orchards, parks, hedges and gardens of moist soils, either twining or creeping around other plants. This plant mainly occurs in Asia, East Africa and America. It is a climbing shrub with green leaves, orange to red drupe berries, horseshoe shaped seeds and brown to yellowish roots. Its aerial parts contain number of secondary plant metabolites like alkaloids, flavonoids, tannins, volatile oils and glycosides. In the last two decades of the century the scientists are trying to evaluate many plant drugs used in traditional system of medicine. The pharmacognostical study is one of the major criteria for identification of plant drugs. The present review on *C. pareira* provides useful information for its correct identity. Studies on pharmacology and phytochemical screening serve as a valuable source of information and provide suitable standards to determine the quality of this plant material in future investigations.

Keywords: Ayurvedic; *Cissampelos pareira*; Extracts; Medicine

Introduction

Cissampelos pareira was first described from Latin America, but actually occurs throughout the tropics [1]. It is a dioecious climbing plant which belongs to the family Menispermaceae of tribe Cocculeae [2]. *Cissampelos* consist of approximately 30 species, spreadall over tropical and subtropical forests of Asia, America, East Africa and India [3,4]. The genus "*Cissampelos*" is derived from the Greek words "kissos" meaning "Ivy" and "ampelos" meaning "vine" [5]. The name refers to the ivy-like resemblance of the growth of this plant in green rambling branches and the grape-like racemes of fruits [6]. The species "*pareira"* is derived from the Portugusename given to the roots of some wild vine [7].

C. pareira is generally known as Patha in Ayurveda in classical texts of (Charaka and Sushruta). The plant has various traditional uses, being applied for its therapeutic as well as toxic effects [8]. It has been used for the treatment of urinary problems, fever and skin infections. In the rainforests of South America, *C. pareira* is known as Abuta, commonly known as the "Midwife'sherb" [9]. The root of this plant has a rich history, being used by resident peoples of South America, for centuries to treat many women's ailments i.e. menstrual cramps, to stop uterine hemorrhages after childbirth, prevents threatened miscarriage, ease childbirth and postpartum, because of its intense relaxant effect on smooth muscle [10,11]. *C. pareira* is frequently prescribed to treat diseases of cough, abdominal pain, heart, kidney stones, asthma, arthritis, diarrhea, dysentery kidney infections and fever according to Ayurvedic Pharmacopeia of India [12,13]. However, at the same time it was traditionally used in the preparation of curares, the famous South American arrow poison used in hunting to cause death by asphyxiation. With greater potency and less toxicity, the root of this plant is used as a promising muscle relaxing agent, neuromuscular blocking agent and a substitute for tubocurarine.

The genus "*Cissampelos"* contain alkaloids mainly bisbenzylisoquinolines, morphines, berberines, and aporphines [14]. Since ancient times, it has been used in Indian Ayurvedic medicine for preparing Pathadi kwath, Mahayograj guggulu, Pusyanug churn and Agnimukh churn. *C. pareira* has been used to treat coughs, delirium, fever-cerrado habitants, madness, epilepsy and convulsions [15]. It is also used as a stimulant, sedative, analgesic, febrifuge, anti-oxidant, tonic and narcotic in various parts of the world. It is used to treat snake bites in Mexico and Central America. *C. pareira*, in combination with *Mimosa pudica L.*, *Piper nigrum L.*, and *Hibiscus rosa-sinensis L.*, is used for birth control in different parts of India [16,17].

Ethnomedical Considerations

The *C. pareira* roots are bitter and pungent and exhibited carminative, astringent, anthminthic, and stomachin, digestive, diuretic, expectorant and anti-inflammatory activity [18]. The plant has been used in cough, leprosy, sensation, asthma, bronchitis, cystitis, dysuria and lactation disorders in various parts of the earth [19]. It is also used in skin disorders, scabies, non-healing ulcers, leprosy, migraine, leucorrhoea and gonorrhea. Its leaves are used in skin ailments, burns, eye trouble, wounds, fever and cold. The root decoction of *C. pareira* is used in malaria and pneumonia in India. The leaves of *C. pareira* are used in Pakistan to treat abscesses and wounds [20]. The tubers of *C. pareira* are used in pseudo-pregnancy in Malawi. The other species of *Cissampelos* such as *C. glaberrima* and *C. ovalifolia* are used for delirium, madness, stimulant, convulsions, coughs, epilepsy, sedative, analgesic and as a tonic and narcotic. Apart from the medicinal uses, this plant is reported for other different properties such as augmenting milk production in dairy cows and food systems for various purposes i.e. thickeners, texture modifiers, gelling agents and stabilizers in Asia [21].

Pharmacognosy

C. pareira is a 2-5 m twinning, perennial and a climbing shrub, supported on trees [22]. The stem is flexible, slender and reaches a maximum diameter of 1 cm. The leaves are simple, alternate, and membranous and palmately 4-8 nerved. Insertion of petiole is slightly away from the margin of the blade. Lamina is dark green outside and grayish underneath with silky-hairy above, hence known as "velvet leaf". Lamina is cordate, apex notched and broadly ovate, 2-12 cm × 4.5-12 cm. The petiole (4-7 cm long) is pulvinate at both the ends; flowers are dioecious, small, unisexual and green in color [23,24]. The fruits are red-orange hairy drupes, partially rounded and covered by a rounded bract. The seeds have horseshoe shape [25].

Microscopic evaluation of leaves

The leaf of *Cissampelos* is microphyll, consisting of an average length of 4.5 cm and width of 5.2 cm. Leaves have no characteristic odor and taste. Histo-anatamical characteristics of leaf have dorsi-ventral differentiation with adaxial and abaxial epidermis. Lamina is flat and reduced in dimension having slender uniseriate clothing trichomes [26]. Midrib region is slightly raised on the adaxial side and composed of epidemics, collenchyma, mesophyll and vascular bundle. Just below the epidermis of the mid rib lies a patch of sub epidermal collenchymas (3-4 cells wide). A chlorenchyma zone consists of 1-2 layers, located beneath the collenchymas. Parenchymatous ground tissues (6-7 layers) occupy the large area. Collateral vascular bundle lies in the middle of the parenchymatous ground tissue with the xylem in the adaxial and phloem on abaxal side. Patches of 3-5 cells of sclerenchyma are distributed around the vascular strand. Epidermis at both surfaces is uniseriate, composed of rectangular cells. Cells of the lower epidermis are very small. Epidermal cell of the midrib are moderately smaller in size than those of the lamina. Starch grains are distributed in epidermal as well as in mesophyll [27].

Microscopic evaluation of stem

In microscopic view, the transverse section of young stem has a circular out line with an undulate and smooth surface. Epidermis is single layered composed of rectangular cells, outer wall of cells are cuticularised (< 3.2 µm) [28]. Some of the epidermal cells have bicellular trichomes (182.1-333.8 µm in length and 13.2–14.5 µm in width). A chollenchyma zone consists of 2 layers, beneath the epidermis, followed by 2-3 layered parenchymatous layers. Cortex is composed of thin-walled parenchyma cells enclosing the secondary phloem. Transverse section of the mature stem has eight vascular bundles arranged in a ring. Adjacent vascular bundles are divided by wide bands of parenchymatous vascular rays [29]. The vascular bundles are dispersed around the parenchymatous ground tissues. Xylem occupies a small portion of the stem. Vessels are mostly circular and solitary in shape. Vessels with a diameter of 40.2-54.3 µm are co-occurred with vessels bearing narrow lumen (19.5-32.5 µm) [30].

Microscopic evaluation of root

Root is slightly curved, long, cylindrical, narrow and highly bitter in taste. Bark is dark grey in color, surface rough, longitudinally striated with furrows and ridges. Different 10-14 radiating vascular stripes with broad medullary rays in the cross section of root resemble a wagon wheel with spokes appearance [31]. The cork zone has a strand of thick walled sclerenchyma, which forms a broken ring on the outside of each vascular strand. Stone cells are pentagonal in shape; walls are striated and pitted with wide lumen. Vascular rays are very prominent which occupy the major portion of the root. Vessels are circular and polygonal in shape [32,33]. The Diameter of lumen ranges from 18.6 µm to 60.3 µm with a mean diameter of 40.2 µm. Xylem vessels contain prismatic crystals of calcium oxalate, ranges from 7.4×11.6 µm to 24.7×42.2 µm. Secondary xylem tissues contain plenty of simple and compound starch grains. The root decoction of *C. pareira* is used in malaria, pneumonia, and dog and snake bite (antidote) in India [34].

Powder microscopy

Leaf powder is dark green in color and has no characteristic taste and odor. Fragments of leaf epidermis showed uniseriate trichomes. Stem powder is light brown, and has no characteristic taste and odor. Root powder is brown colored and highly bitter in taste. Stem and root power contain rich pyramidal calcium [26].

Phytochemistry

Alkaloids are the chief constituents reported from the genus "*Cissampelos*" along with moderate levels of non-alkaloids.

Alkaloid constituents

Wiggers (1840) reported an amorphous bisbenzyliso-quinoline alkaloid, "pelosine" (Figure 1) from the roots of *C. pareira* which was later found to be identical to hayatine [35]. During the 1950s, three bisbenzylisoquinoline alkaloids, hayatine (Figure 2), hayatinine (Figure 3) and hayatidine (Figure 4) were reported from the Indian species and their stereochemistry and chemical structure were described in the 1960s [36]. The stereo-chemistry of this plant was confirmed by its methylation with diazomethane, which afforded O-methylcissampareine and by reduction with sodium borohydride, which yielded dihydrocis-sampareine [37]. Boissier et al., in 1965 reported two bisbenzylisoquinaline alkaloids, hayatine or bebeerine and (þ)-isochondo-dendrine (Figure 5) [38]. Anwer et al., in 1968 isolated cissamine (Figure 6) as chloride from the roots of *C. pareira* [39]. Dwuma-Badu et al., in 1975 reported isochondodendrine, dehydrodicentrine (Figure 7), dicentrine (Figure 8) and insularine (Figure 9) from the roots [40]. Bhakuni et al., in 1987 reported the biosynthetic pathway for Hayatidine, (R,R)-bebeerine, (R,R)-cycleanine, (R,R)-isochondodendrine. He also revealed that hayatidine is biosynthesised by intermolecular oxidative coupling of (R)- and (S)-N-methylcoclaurine, stereo-specifically while (R,R)-cycleanine, (R,R)-bebeerine and (R,R)-isochondodendrine are formed by oxidative dimerisation of (R)-N-methylcoclaurine [41].

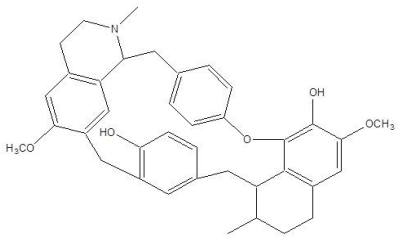

Figure 1: Pelosine.

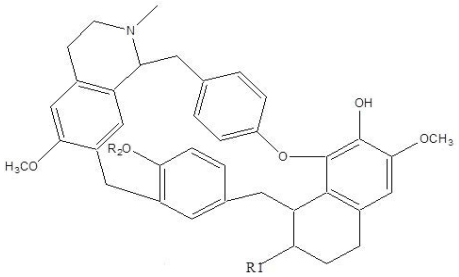

Figure 2: Hayatine: R1=R2=H.
Figure 3: Hayatinine: R1=R2=CH3.
Figure 4: Hayatidin: R1=H, R2=CH3.

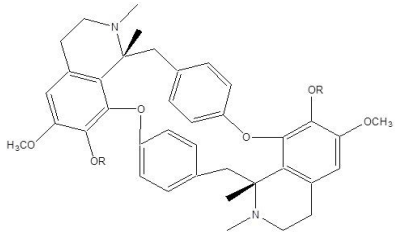

Figure 5: Isochondrodendrine R=H.

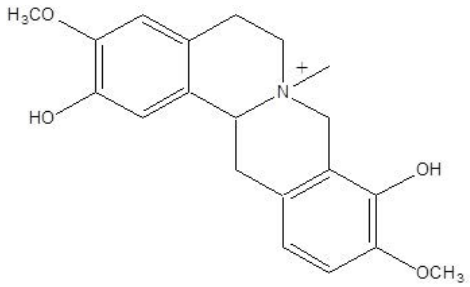

Figure 6: Cissamine.

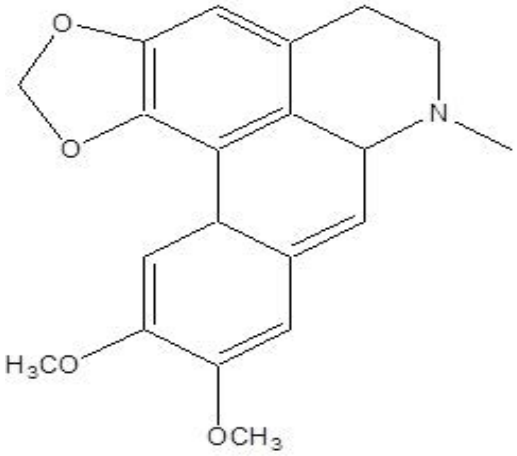

Figure 7: Dehydrodicentrine.

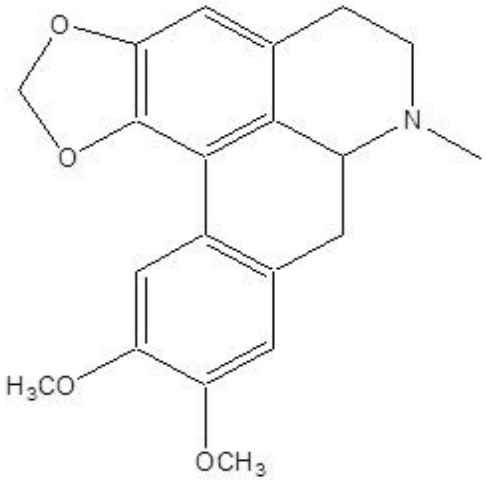

Figure 8: Dicentrine.

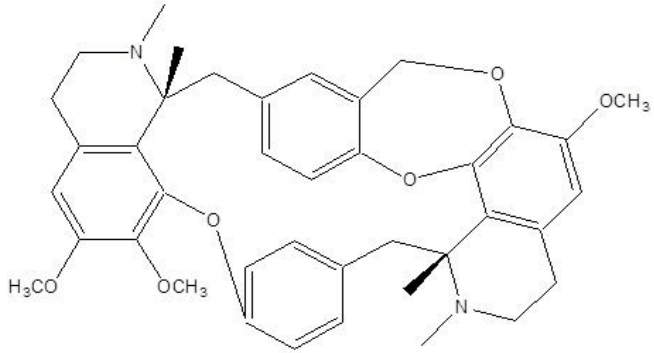

Figure 9: Insularine.

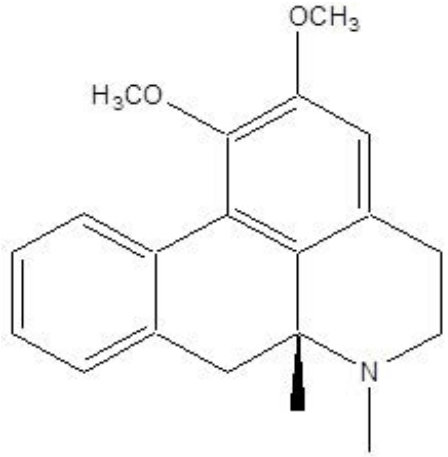

Figure 10: Nuciferine.

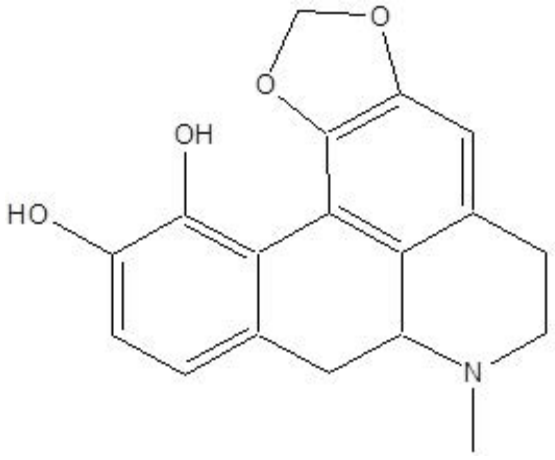

Figure 11: Bulbocarpine.

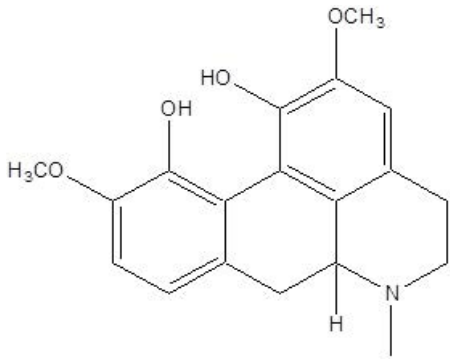

Figure 12: Corytuberine.

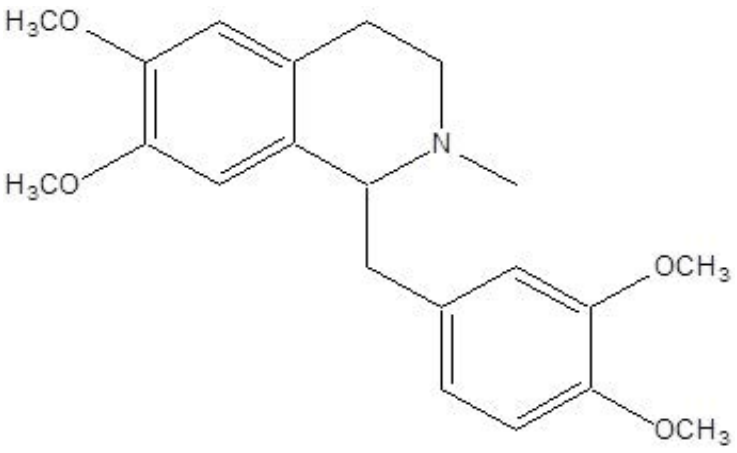

Figure 13: Laudanosine.

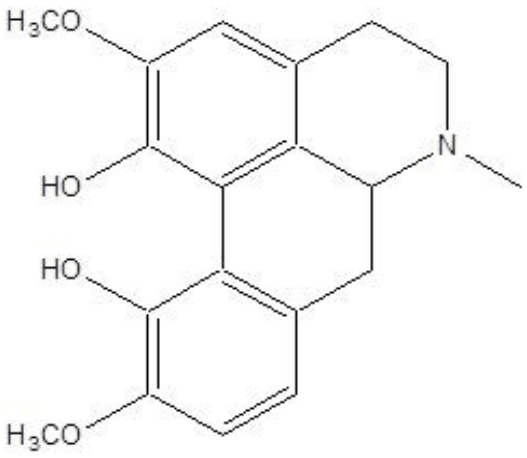

Figure 14: Magniflorine.

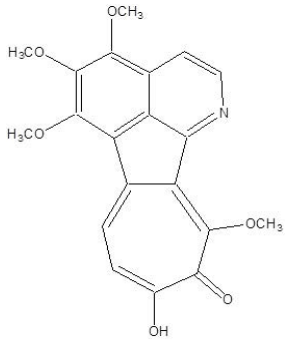

Figure 15: Pareirubrine..

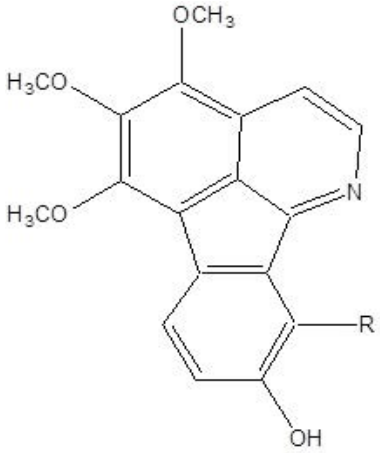

Figure 16: Norimeluteine: R=OCH3.
Figure 17: Norruffscine: R=H.

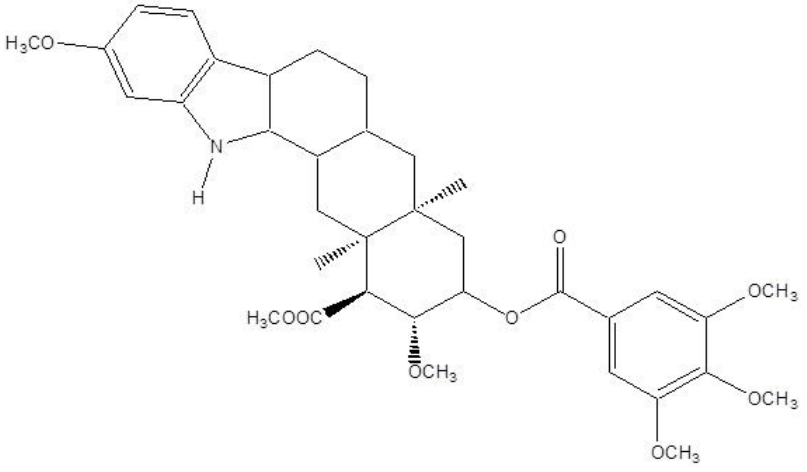

Figure 18: Reserpine.

Ahmad et al., in 1992 observed five alkaloids, nuciferine (Figure 10), bulbo-carpine (Figure 11), corytuberine (Figure 12), laudanosine (Figure 13) and magniflorine (Figure 14) (as hydro-chloride) from the leaves and stems of *C. pareira* [42]. Morita et al., in 1993 determined two tropoloisoquinoline alkaloids, pareirubrines A and B (Figure 15) as antileukemic substances. The conformation of tropolone ring in their structures was confirmed by NMR studies, whereas their solid-state tautomeric forms were illucidated by XRD analysis. In addition an azafluoranthene alkaloid "norimeluteine" (Figure 16), as a cytotoxic substance together with norruffscine (Figure 17) was reported in *C. pareira* [43]. The plant roots contain reserpine (Figure 18) and berberine (Figure 19) similar to that of pelosine (a principle marker compoundl-bebeerine (Sharma et al., 2004) [44].To establish the quality control parameters of *C. pareira* roots, Hullatti et al., in 2010 isolated l-bebeerine in pure form for the authentication of *C. pareira* [45].

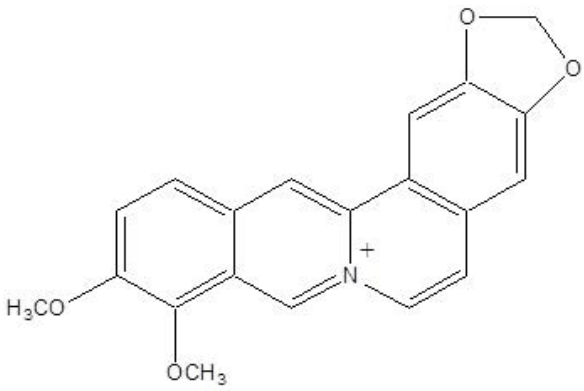

Figure 19: Berberine.

Non-alkaloid constituents

Apart from alkaloids as essential constituents of *Cissampelos* species, some non-alkaloidal constituents were determined. The roots of *C. pareira* contain sterols, fixed oil, d -quercitol (Figure 20) and essential oil, which contains thymol (Figure 21) as a major constituent (Chowdury, 1972) [46]. Rosario et al., 1996 reported a chalcone-flavone dimer, cissampeloflavone (Figure 22) from the aerial parts of *C. pareira* [47].

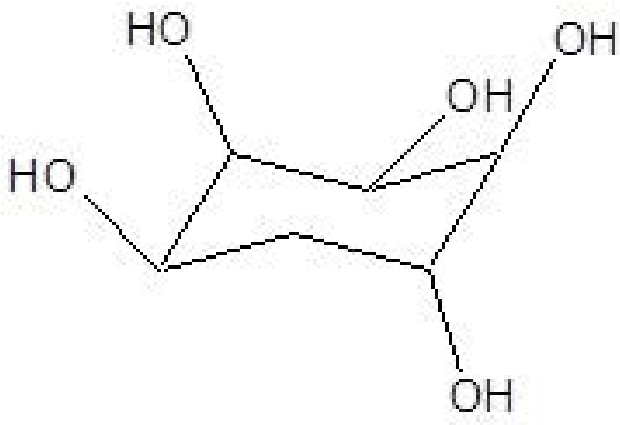

Figure 20: d-Quercitol.

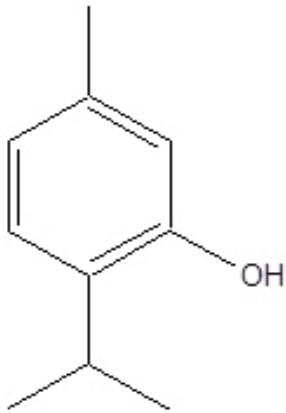

Figure 21: Thymol.

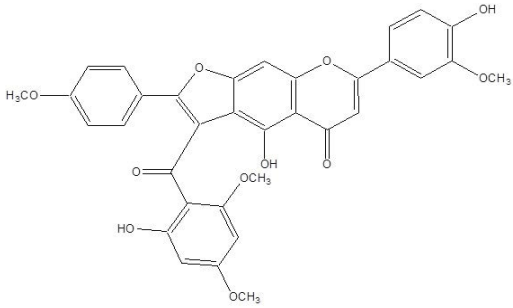

Figure 22: Cissampeloflavone.

Singthong et al., in 2005 extracted pectin from *C. pareira* leaves that consist mainly of 70-75% of uronic (galacturonic) acid (Figure 23) and a very little amount of neutral sugars [48]. This pectin showed shear thinning flow behavior, when studied for its rheological properties. Additionally, a well known flavonoid named 2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxy-4H-chromen-4-one (quercetin) (Figure 24) and a saturated fatty acid, eicosanoicacid (Figure 25) were reported from *C. pareira* [49]. Vardhanabhuti and Ikeda in 2006 reported that the leaves of *C. pareira* produce polysaccharides and pectins mainly composed of galacturonic acid with trace amounts of neutral sugars [50].

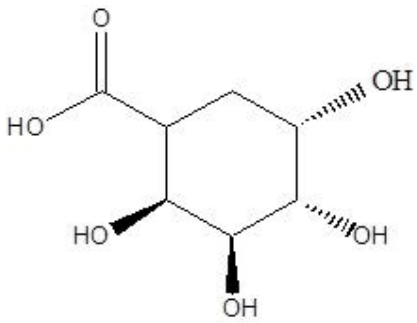

Figure 23: Galacturonic acid.

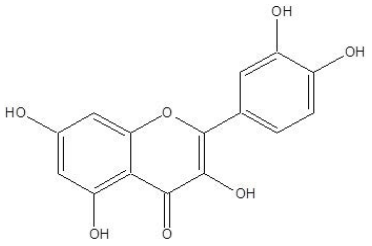

Figure 24: Quercetin.

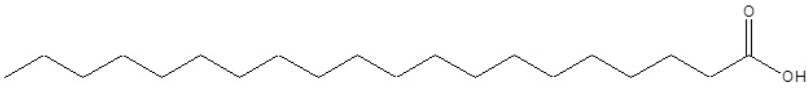

Figure 25: Arachidic acid.

Pharmacology

Anti-inflammatory activity

C. pareira extract and its polyherbal formulation in combination with *Pongamia pinnata (L.) Pierre* and *Vitex negundo L.*, exhibited *in vitro* anti-inflammatory activity at a dose of 600 mg/kg on carrageenan-induced hind paw oedema by 0.16 mL, respectively (Batista-Lima, 2001) [51]. Amresh *e*t al., in 2007 reported that ethanolic extract of the aerial parts of *C. pareira* at a dose of 100 mg/kg, (p.o) showed anti-inflammatory and analgesic activity (abdominal writhes and hot plate) in mice and rat respectively. He also showed that the ethanolic root extract of the same plant exhibited anti-inflammatory activity on acute, subacute and chronic rat models at a dose of 400 mg/kg, p.o [52].

Analgesic and antipyretic activity

Amresh et al., in 2007 reported that the hydroalcoholic root extract from *C. pareira* showed resistance against mechanical pain in analgesiometer-induced pain in mice. The hydroalcoholic root extract reduced the writhing episodes in acetic acid-induced writhing (0.6%; i.p.) by protection of 51.63% at dose of 400 mg/kg, body weight, respectively. The extract also showed protective effects against complete Freund's adjuvant-induced arthritis by 71.52% at similar dose. *C. pareira* in combination with *Pongamia pinnata (L.) Pierre* exhibited 600 mg/kg, respectively [53,54].

Immunomodulatory activity

Moreira et al., in 2003 determined that the hydroalcoholic extract of *Cissampelos sympodialis* leaves showed an immunomodulatory effect on B -lymphocyte function. It has been reported that the methanolic root extract of *C. pareira* at a dose of 200-800 mg/kg hasan immunomodulatory activity in mice. Higher doses of this extract also obtained protection against cyclophosphamide-induced myelosuppression by raising the total WBC count significantly. The berberine-containing alkaloidal fraction of *C. pareira* roots showed an immunosuppressive effect at a dose of 50 mg/kg, (p.o.) [55].

Neuroprotective activity

Hage et al., in 2010 observed that, *C. pareira* in combination with *Anethum graveolens* (1:5) showed protection against age-related cognitive impairment in rats at doses of 10 and 50 mg/kg. He reported that this extract can be used as a food supplement for protection in mild cognitive impairment and Alzheimer's disease [56].

Antivenom activity

The aqueous leaf extract of *C. pareira* has shown toneutralize the proteolytic and haemorrhagic effect of the venom of venomous pit viper (Bothrops asper) [57].

Memory-enhancing activity

Kulkarni et al., 2011 reported that, hydroalcoholic extract of *C. pareira* at 400 mg/kg significantly improved learning and memory of mice and considerably reversed amnesia, induced by scopolamine at a dose of 0.4 mg/kg, (p.o). This extract also lowered whole brain acetylcholinesterase activity when compared to piracetam at a dose of 200 mg/kg [58].

Antifertility activity

Ganguly et al., 2007 reported that the leaf extract of *C. pareira* has antifertility effect. He also observed that it altered the oestrous cycle in female mice and extended the length of the oestrous cycle with significant increase in the duration of dioestrus stage [59].

Antidiarrhoeal activity

The ethanolic root extract of *C. pareira* has got antidiarrhoeal activity ata dose of 25 and 100 mg/kg, (p.o.) [60].

Antidiabetic activity

The hydroalcoholic leaf extract of *C. pareira* at a dose of 200 and 400 mg/kg, (p.o.) has been evaluated to exhibit antidiabetic activity on streptozotocin-induced diabetic rats. It significantly reduced fasting blood glucose and improved the body weight of rats compared to glibenclamide (5 mg/kg).The study also demonstrated decrease in the gluconeogenesis and increase in glucose metabolism as evidenced by increase in serum lipids, liver glycogen and creatinine levels [61].

Hepatoprotective activity

Surendran et al., in 2011 reported that hydroalcoholic root extract of *C. pareira* exhibit significant hepatoprotective effect against CCl_4-induced hepatotoxicity in rats at doses of 100, 200 and 400 mg/kg. The levels for anti-oxidant Superoxide Dismutase (SOD) enzymes were enhanced at doses of 200 and 400 mg/kg. At the same doses, it has shown to decrease cholesterol levels and increased triglyceride levels when compared to silymarin [62].

Muscle-relaxant activity

Kupchan et al., in 1960 reported that hayatin methiodide in combination with hayatinin methochloride from *Cissampelos pareira*, showed muscle-relaxant properties and were recognised as curariform drugs. The aqueous leaf extracts from *Cissampelos mucronata* exhibit anti-abortifacient and uterine relaxant properties. The extract was found to have toxic effects on the blood vessels of the kidneys of wistar rats. The ethanolic root extract of *Cissampelos mucronata* showed significant *in vitro* relaxant activity on isolated non-gravid rat uterine smooth muscles [63].

Anti urolithic activity

Urolithiasis is the third most common disease of the urinary tract. It is defined as the formation of sediment in the urinary tract consisting of poorly soluble crystalloids of urine. Ramesh C in 2010 reported that alcoholic extract of roots of *C. pareira* at (200 mg/kg and 400 mg/kg) doses showed curative effect in urolithiasis induced rats by preventing the formation, reducing number and disruption of calcium oxalate calculi formed in the kidneys. Phytoconstituent like berberine, present in *C. pareira* is responsible for antiurolithic activity. It is therapeutically effective for curative aspect of calcium oxalate urolithiasis [64].

Cardiovascular activity

Singh et al., in 2013 reported that the ethanolic leaf extract from *C. pareira* has cardioprotective activity on isoproterenol-induced cardiac dysfunction in rats. It improved the heart weight/body weight ratio, nitric oxide, lactate dehydrogenase, and serum calcineurin and thiobarbituric acid reactive substance levels. The hydroalcoholic extract of *Cissampelos sympodialis* showed contractions (EC_{50} value of 76.6 µg/mL) in the presence of functional endothelium. Leaves from *Cissampelos sympodialis* has shown to regulate intracellular Ca^{2+} as a mechanism of spasmolytic activity in the rabbit aorta [65].

Anti-oxidant activity

Hussain et al., in 2010 proved that, ethanolic root extract of *C. pareira* (containing polyphenols) exhibited anti-oxidant activity in the 2, 2-Diphenyl-1-Picrylhydrazyl (DPPH) assay at doses ranging between 50 and 300 µg/kg *in vitro*. He also reported that the extract exhibited effective protective effects in an acute oxidative tissue injury on benzo(a)pyrene-induced gastric toxicity in mice at a dose of 100 mg/kg [66]. The alkaloidal fraction from *C. pareira* roots showed strong anti-oxidant activity by scavenging the superoxide ion, stable free radical DPPH and by inhibiting lipid peroxidation in rat liver homogenate induced by iron/ADP/ascorbate complex [67].

Anticancer activity

De Wet et al., 2009 observed that the hydroalcoholic root extract of *C. pareira* exhibited activity against carcinogen metabolising phase I and phase II enzymes along with anti-oxidant enzymes. The extract improved, the mean number of tumor, tumor incidence and the tumor multiplicity on benzo(a)pyrene-induced gastric cancer in mice. The ethanolic extract of *C. pareira* (containing quercetin) exhibited protective property on tumor multiplicity, benzo(a)pyrene induced gastric cancer and micronucleus polychromatic erythrocytes in mice. The other species of *Cissampelos* such as *Cissampelos mucronata*, *Cissampelos hirta* and *Cissampelos torulosa* showed cytotoxicity against TK10 (renal) cancer cell lines, MCF7 (breast) and UACC62 (melanoma) [68]. Gessler et al., 1995 reported that, ethanolic extract of *Cissampelos mucronata* exhibited cytotoxic activity in human carcinoma cell lines *in vitro*, whereas cissampelo flavone had less toxicity to the human KB cell line. When administered orally, the extract mainly polysaccharides and proteins inhibit the tumor growth in a dose dependent fashion. Tumor growth was inhibited by seventy percent at a dose of 200 mg/kg/day. Intraperitoneal or subcutaneous administration at a dose of 50 mg/kg/day also improved the tumor growth [69].

Anti-ulcer activity

Nwafor and Okoye in 2005 observed that ethanolic root extract of C.*mucronata*, showed an anti-ulcer effect on histamine, indomethacin and stress-induced ulcer models in rats. Ethanolic root extract of C.*pareira* and its constituent quercetin, exhibited protective effects against ulceration at doses of 25-100 mg/kg (p.o.) in various acute and chronic ulcers in rats. The extract also improved the ulcer index with decreased perforations in acetic acid-induced chronic ulcers [70].

Antiparasitic activity

The alkaloidal extract from the leaves of *Cissampelos ovalifolia* showed an *in vitro* antiparasitic effect against *Trypanosoma cruzi* and *Leishmania chagasi* parasites with an EC_{50} value of 64.88 µg/mL [71]. The aqueous fraction of the ethanolic leaf extract of *Cissampelos sympodialis* showed anti-inflammatory effects by increased cAMP levels in intact smooth cell cultures and inhibiting cyclic nucleotide phosphodiesterase activity. Cissampelo flavone isolated from *C. pareira* exhibited admirable activity against *Trypanosoma brucei rhodesiense*.

The methanolic extract from *Cissampelos torulosa* exhibited *in vitro* anti amoebic activity against *Entamoeba histolytica* with IC_{90} values of 410 mg/mL [72].

Antimalarial activity

Fischer et al., in 2004 reported that ethanolic extracts of *Cissampelos ovalifolia* exhibited *in vitro* antimalarial activity with IC_{50} values of 165.6 and 34.8 mg/mL against a chloroquine-sensitive strain of *Plasmodium falciparum* and IC_{50} values of 103.1 and 37.4 mg/mL against a chloroquine-resistant strain [73]. Jannu et al., in 2011 showed that ethanolic root extract of *C. pareira* repressed the propagation of the rodent parasite *Plasmodium berghei in vitro* on BALB/c mice [74]. Rukunga et al., in 2009 reported that hydromethanolic extract of *C. pareira* revealed significant anti-plasmodial activity against chloroquine-resistant (ENT30) *Plasmodium falciparum* strains *in vitro*. Singh and Banyal in 2011 reported that an ethanolic root extract of *C. pareira* revealed potent inhibition of *Plasmodium berghei* with an oral dose of 500 mg/kg in mice [75].

Antimicrobial activity

Kumar et al., in 2006 reported that an extract from the whole plant of *C. pareira* showed antifungal activity against *Saccharomyces cerevisiae* and *Aspergillus niger* via complete inhibition at concentrations of 1000 mg/mL in comparison to the positive controls amphotericin B at a concentration of 3 mg/mL. Moreover, Dichloromethane extracts from aerial parts of *Cissampelos mucronata* showed activity against bacteria including *Salmonella typhi*, *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus faecalis* and *Vibrio cholera* [76].

Anti-diuretic activity

Sayan SB et al., in 2014 observed that alcoholic extract of roots of *C. pareira* at a dose of 400 mg/kg has shown a potent diuretic activity by increasing urinary output and increased excretion of sodium, potassium, chloride. This effect was found to be dose dependent, i.e., among the three doses studied, higher dose produced significant effect. He made the comparison with the standard diuretic drug furosemide (10 mg/kg). Earlier Hullatti et al., 2011 reported the diuretic activity with methonolic extract of roots of *C. pareira* [77].

Anti-dengue activity

Dengue is a mosquito borne viral disease that majorly affects global public health risk [78]. In India, dengue outbreaks are correlated to the high prevalence of the mosquito vector, high population density and circulation of all four Dengue Viruses (DENVs). So, potent drugs for dengue are being progressively more needed for public health [79,80].

Pigili RK et al., in 2014 reported anti-dengue activity of extract of aerial parts of *C. pareira* [81]. Sood R et al., in 2015 reported that the alcoholic extract of *C. pariera* (Cipa extract) is an effective inhibitor of all four DENVs in cell-based assays, assessed in terms of viral replication, based on plaque assays and viral NS1 antigen secretion via ELISA. Cipa extract shows virucidal effectin a time and dose-dependent manner in the type-1 assay format. This extract exhibited statistically significant protection against dengue virus infection using the AG129 mouse model. A preliminary evaluation of Cipa extract exhibited no adverse effects on RBC viability and platelet counts. The effect of *C. pariera* extract on virus titers confirmed a >1 log reduction compared to untreated virus, that suggests its potent efficacy in altering the course of major dengue disease to a more favorable outcome [82].

Miscellaneous activities

Kupchan et al., in 1965 revealed that the methiodide of hayatine isolated from *C. pareira*, showed powerful neuromuscular blocking activity when compared to that of d-tubocurarine chloride. The aqueous and alcoholic extract of *C. pareira* exhibited anthelmintic activity against earthworms at doses of 5, 10, 25, 50 and 100 mg/mL. Adesina in 1982 reported that the extract from *C. pareira* has anticonvulsant activity *in vitro*/*in vivo* [83].

Toxicity Studies

Amresh et al., 2008 showed that the hydroalcoholic extract of *C. pareira* has acute and subacute toxicity and produced neither mortality, nor changes in behavior, in animals at a dose of 2 g/kg, (p.o.) for a period of 28 days. The ethanolic extract of the aerial parts of *C. pareira* was reported to be safe up to a dose of 2000 mg/kg (LD_{50}). Ganguly et al., 2007 revealed that the acute toxicity of the leaf extract of *C. pareira* was found at an LD_{50} of 7.3 g/kg, (p.o.) in female mice [84].

Future Perspectives and Conclusions

C. pareira is potential herb belongs to the family Menispermaceae, used to treat a broad range of ailments in folk medicine across many countries, centuries, and continents. It is a rich source of many bioactive alkaloids including aporphines and bisbenzylisoquinolines. This plant is gaining popularity due to their promising antiplatelet, anticancer, vasodilator and antiprotozoal activities. The chemistry and biological activity of some species of this plant, including *C. capensis*, *C. sympodialis*, and *C. glaberrima*, are well known. However, many other species including *C. friesiorum* Diels, *C. andromorpha* DC and *C. nigrescens* Diels have not been pharmacologically and phytochemically explored. Consequently, a large field of future perspective is awaiting the researcher to discover purified fractions and lead molecules, which may have capable biological activity. Thus, there is an urgent need for proper documentation of traditional knowledge to lead to the selection of authentic medicines to provide a solid basis for further research. Some research groups attempted the polyherbal formulation concept with *Cissampelos* plant and found promising analgesic and antipyretic activities. A detailed study is required to clarify the structure-activity relationships and mechanism of action to determine the minimal side-effects and standard dose. This review concludes that *C. pareira* have potential medicinal activity and can be used in the treatment of various diseases. By going through literature review, various pharmacological activities of this plant has been familiarized and it is also found that plant contains a wide range of phytoconstituents which needs to be explored more and more. So that the single constituent related activity can be performed.

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