



An Integrated Approaches of Conversation and Improvement of Medicinal Plants

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Abstract

Medicinal plants have been indispensable to global healthcare systems, offering therapeutic, economic, and cultural benefits. However, biodiversity loss of medicinal plants is caused by factors such as overharvesting, deforestation, climate change, and natural disasters threatening their survival. The importance of sustainable practices while examining integrated approaches for the preservation and enhancement of medicinal plants. Conservation methods include in situ strategies, such as preserving plants in their natural environment, and ex situ techniques, like botanical gardens, seed gene banks, and cryopreservation. Long-term preservation heavily relies on advanced biotechnological techniques, such as synthetic seed technology and plant tissue culture. Effective conservation is hampered by factors like resource scarcity, research limitations, and biopiracy. Public awareness campaigns, strong regulatory frameworks, and sustainable funding mechanisms are all necessary to address these problems. This chapter also explores bioprospecting as a method for finding novel therapeutic chemicals while advancing conservation. In addition to ecological preservation, medicinal plant conservation promotes medication development, cultural heritage preservation, and economic growth. The sustainability of medicinal plants for future generations is the aim of these integrated initiatives, which involve cooperation between governments, researchers, local communities, and industries. This chapter emphasizes the potential of medicinal plants to improve the healthcare sector worldwide and underscores the necessity of balancing conservation

with their sustainable utilization. Combining both traditional knowledge and contemporary scientific discoveries is essential to protect and utilize their full potential for healthcare development.

Keywords

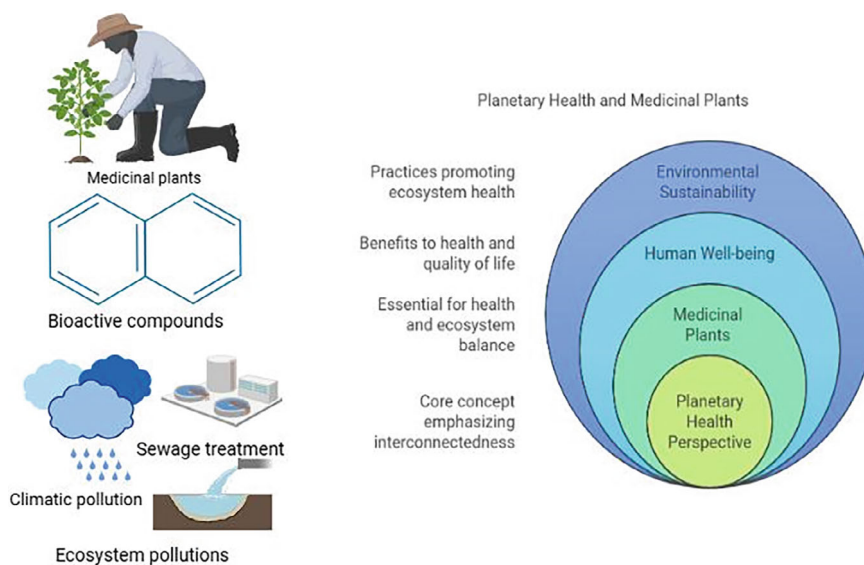
Medicinal plants · Biodiversity · Sustainable use · Conservation · Healthcare

1 Introduction

The term “medical plants” covers an extensive variety of plants that are utilized in herbalism, some of which possess therapeutic properties. In less industrialized nations, medicinal botanicals are the “backbone” of conventional medicine, with over 3.3 billion individuals engaging in their regular use. These therapeutic plants are considered a plethora of components that can be employed in the synthetic and development of novel drugs. Also, these organisms are indispensable to the development of human societies on a global scale. Numerous plant species in a variety of environments may be found in the Indian subcontinent. About 8000 of the roughly 17,000 species of higher plants are thought to be therapeutic and are utilized by village populations, especially tribal tribes, or in traditional medical systems like Ayurveda. UNESCO, 1996, has noted that traditional medicine and medicinal plants are used in the majority of developing nations as a foundation for maintaining good health. Furthermore, the extraction and development of various medications and chemotherapeutics from these plants, as well as from traditionally used herbal treatments in rural areas, have been linked to an increased dependence on the usage of medicinal plants in industrialized countries (Fig. 1). Traditional medical methods have gained international attention in the last ten years. According to current estimates, a sizable section of the populace in many developing nations primarily depends

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Fig. 1 A planetary health perspective of medicinal plants



on traditional healers and medical herbs to cover their basic medical needs. These nations may have access to modern medicine, but historically and culturally, herbal remedies, or phytomedicines, have frequently remained popular. Medicinal plants are commonly utilized as raw materials to extract active chemicals that are then used to make various medications. Plant-based compounds are included in blood thinners, antibiotics, antimalarial drugs, and laxatives. Additionally, the active components of morphine, vincristine, and taxol were separated from opium poppies, yew, periwinkle, and foxglove, respectively. In many developing countries, medicine remains the bedrock of healthcare, which uses the local customs and beliefs. The World Health Organization (WHO) defines health as a comprehensive state of physical, mental, and social well-being, rather than merely the absence of sickness or disability. The World Health Organization's objective of ensuring that all individuals worldwide lead sustainable, socioeconomic, and productive lifestyles by the year 2000 can be significantly furthered by medicinal plants. The growth and commercialization of bioindustries based on medicinal plants in developing nations are contingent upon the availability of facilities and knowledge regarding the industrial potential of medicinal plants, including upstream and downstream bioprocessing, extraction, purification, and marketing. Moreover, the dependence of lower-income urban and rural communities on traditional medicinal plants and herbs as supplemental aids to standard pharmaceutical market products is exacerbated by the absence of updated socioeconomic and public healthcare systems. Approximately 9000 plants have been documented as having therapeutic properties in various cultures and countries, according to recent estimates (Singh et al. 2015).

2 Importance of Medicinal Plants

Plants have been used for healthcare from the earliest days of civilization. Direct use of plants for therapeutic purposes is not just an ancient practice. Across the world, many rural and ethnic communities still employ medicinal plants for their medical needs. Approximately 80% of people worldwide, as the WHO estimates, rely mostly on traditional medicines, many of which are derived from herbs. Available locally and restricted access to modern medicines are the primary causes of the extensive use of plant resources in healthcare (Pattanayak et al. 2021). Alternative medicine is the use of medicinal plants for therapeutic purposes. Almost every culture uses alternative medicine, but Asian and Western cultures use it the most. However, the majority of people still think that the only reliable and efficient medication is one that comes in a dosage form, such as tablets, capsules, etc. Aspirin, digoxin, paclitaxel, and many more plant-based substances are among the numerous pills and capsules that are used on a regular basis. The earliest humans used plants and herbs to flavor and preserve food, soothe pain, cure headaches, and even fend against diseases like epidemics. Throughout the ages, human groups have shared knowledge of their therapeutic qualities with one another (Singh et al. 2015). The biological characteristics of plant species that are employed for a variety of reasons worldwide, including the treatment of infectious diseases, are typically attributed to active chemicals generated during secondary metabolism (Munita et al. 2016). People are currently being cautioned by numerous studies about the dangers of pathogenic germs that have developed resistance to newly discovered antimicrobials. Several studies are required to describe the chemical makeup of these

plant antimicrobials and the mechanisms involved in microbial growth inhibition, either independently or in conjunction with conventional antimicrobials. This is because data on the antimicrobial activity of many plants, which were previously thought to be empirical, have been scientifically confirmed (Ur Rehman et al. 2021).

2.1 Healthcare Importance

According to ethno-medical traditions, India's medicinal plant includes a valuable bioresource of the richest plant. The use of therapeutic plants has been documented in several ancient medical systems, including Ayurveda, Unani, and Siddha, as well as in the Indian pharmaceutical keycodex and the British and American pharmacopoeias. One of the first Himalayan states, Himachal Pradesh, is home to a wealth of therapeutic plants. The Himalayan Significance of Medicinal Plants in Human Life 7 state is home to a wealth of traditional medical knowledge and medicinal plants. The current population of medicinal plants is declining as a result of irresponsible wild harvesting and habitat loss, which has caused plant populations to dwindle and, in some cases, even become extinct. Such a collection of endangered animals is illegal under the law. *Picrorhiza kurroa* and *Aconitum heterophyllum* were highlighted in the technical sessions of a workshop on Himachal Pradesh endangered medicinal plants species because of their elite populations, propagule availability, high-quality production, value addition, and guaranteed markets. Despite being one of the best for high elevations, *Swertia chirata* was not allowed to be grown right away because of its lengthy gestation time and sensitive field management. The Red Data Book has a lengthy list of several endangered medicinal plants which gives the mountain areas and villages a significant source of revenue. The issue of depletion has also escalated due to the huge demand for these plants, since many of them are primarily harvested from the wild (Srivastava et al. 2018).

2.2 Economic Importance

Nations all over the world are currently at risk from the transition of acute to chronic illnesses, which directly affects the supply and demand for pharmaceuticals. The aforementioned circumstance is thought to mostly affect the expanding populations of developing nations. Essential medications are not readily available, and the distribution of medications for both infectious and noncommunicable diseases does not satisfy the needs of a sizable portion of the populace in developing nations. Even though countries have invested a lot of money in the creation of pharmaceutical items, there has been some evidence of a slight impact on

the health of the populace. It was believed that the experience was severe and that a cost-effective methodology was used in the balanced approach to the production, distribution, and use of medication. This strategy has significantly decreased the cost of producing medicines in developing nations and may have helped their circumstances. However, several nations, particularly those in Southeast Asia, were unable to put the strategy into practice and were unable to lower their excessive pharmaceutical spending.

2.3 Cultural Importance

As far back as time began, healing plants have made a big difference in people's health. India has a lot of different kinds of medical plants. Tribal people use these plants to treat a wide range of illnesses, and they play an important role in both healthcare and the local economy. They need these medicinal plants for their religious work, ceremonies, rites, and festivals, but most of them do not know that these plants really help them in their daily lives. In the Indian area, traditional medicine is still an important part of the healthcare system. Researchers have found that medicinal plants from Central India can fix life-threatening illnesses like coronary artery disease, diabetes, cancer, inflammatory conditions, viral diseases, neurological problems, and kidney problems. As a result, the demand for medicinal plants around the world has been slowly growing. Ayurveda, Unani, and Siddha are some of the traditional medicine systems used in India to make most of the dosage forms. A new generation should learn about economic medicinal plants. This will help protect medicinal plants and create jobs, which will improve the health of the indigenous and rural people in India (Neupane et al. 2022; Yadav et al. 2022).

3 Factors Lead to Biodiversity Loss of Medicinal Plants

Since the beginning of time, medicinal and aromatic herbs have been essential in reducing human suffering from illnesses, afflictions, and disorders. Natural and man-made disasters, such as fast climate change, urbanization, industrialization, pollution from overpopulation, declining forest cover, habitat loss, overharvesting, destructive harvesting, and floods, are the main reasons for the reduction of wild medicinal plant species. Like all other living things in the biosphere, medicinal and aromatic plants are susceptible to the effects of climate change. As a result, some medicinal plants that are indigenous to particular ecosystems or geographic locations may eventually be endangered, and they are especially susceptible to the effects of climate change.

As human needs, populations, and economic trade increase, so does the demand for a diverse range of wild species. Several organizations are advocating the introduction of wild species into agriculture systems due to the growing awareness that certain wild species are being overfished.

However, it is important to comprehend that cultivation might likewise have an impact on conservation. For instance, the cultivation of medicinal plants might lessen the amount of wild populations that are harvested, but it can also result in environmental damage, genetic diversity loss, and a reduction in the incentives to preserve wild populations.

4 Medicinal Plant Conservation Techniques

Conservation aims to promote sustainable development by securing and utilizing biological resources in ways that do not deplete the diversity of species and genes found worldwide or devastate significant habitats and ecosystems. Activities including collecting, propagation, characterization, evaluation, identifying and eradicating diseases, storage, and dissemination are generally included. Plant genetic resource conservation has long been seen as a crucial component of biodiversity conservation (Table 1).

4.1 In Situ Conservation

The main goal of the in situ conservation method is to protect wild genetic variety in its natural environment. In India, protected areas like national parks, fauna protected areas, and ecological reserves help to keep forests thriving. This kind of conservation is accomplished by designating certain places as wild nurseries and nature reserves as well as by making sure that the greatest number of wild species can continue to exist in managed environments, such as plantation woods and farms (Kadam et al. 2020). The government ought to evaluate how well the nation's medicinal plants are covered by the protected areas system. Re-introducing species that have been severely reduced by over-collection into their natural habitats is a good idea.

4.2 Ex Situ Conservation

Ex situ preservation is not always clearly different from in situ conservation, but it works well with it when it does. This is especially true for medicinal plants that are being overused and are in danger of going extinct because they grow slowly, are

scarce, and are easily infected when they are planted again. Ex situ conservation tries to grow and reintroduce endangered species into their natural habitats to make sure they stay alive. Sometimes this is done to get a lot of plant material that can be used to make drugs, and it is often done right away to protect medical plant resources. A lot of species of medicinal plants that used to live in the wild can still be grown in gardens that are far from where they normally live. These plants can also have their seeds collected and saved for later planting.

4.3 Bioprospecting and Its Role in Conservation of Medicinal Plant

Medical and pharmacological fields are expanding thanks to medicinal bioprospecting. A person is generally bioprospecting if they are seeking for food or other biological value in their surroundings. The multidisciplinary endeavor of medicinal bioprospecting, which involves a range of researchers and logical subjects, is to search for compounds for medications in the natural environment. Drug bioprospecting could yield fresh leads against pharmaceutical targets like malaria, human immunodeficiency virus (HIV)/acquired immune deficiency syndrome (AIDS), cancer, and Alzheimer's disease, among others. Broad revisions of natural products made from plants (herbal treatments) are currently required, and these items require further research and study of medications that have been approved by the Food and Drug Administration (FDA) (Juan et al. 2017). According to a recent review of the literature, over 70% of medications used to treat anti-infectious disorders and 60% of medications used for oncotherapy come from natural sources. These recommendations date back to 2002. Drug compounds generated from plants increase the likelihood of creating more potent medications through laboratory synthesis and aid in determining the relationship between medications and their target location. To supply the available natural source for treating health concerns, bioprospection is required. It has frequently been discovered that the compounds extracted from medicinal plants may not be used as the finished product, but they may contain lead compounds for the creation of new medications. The aspects of floristic composition, forest stand structure, species distribution, species diversity, soil physicochemical qualities, etc., are all covered in ecological studies on medicinal plants. The management and maintenance of source plant species, as well as the development of new drugs, depend heavily on the findings of species ecology studies. The scientific community's interest in ecological research on medicinal plants for global resource management has grown (Dwivedy et al. 2019).

Table 1 Various medicinal plant conservation techniques

Conservation technique	Description	Method/strategy	Examples/applications	References
In situ conservation (on-site)	Conserving medicinal plants in their natural habitat	<ul style="list-style-type: none"> Protecting natural habitats Sustainable harvesting Habitat restoration 	<ul style="list-style-type: none"> National parks Wildlife sanctuaries Biosphere reserves 	Khan et al. (2019)
Protected areas	Designated regions where plants are protected from human exploitation	<ul style="list-style-type: none"> Establishing conservation areas Banning or regulating resource extraction 	<ul style="list-style-type: none"> Forest reserves National parks 	Das et al. (2016)
Sustainable harvesting	Managing the collection of medicinal plants to ensure long-term survival	<ul style="list-style-type: none"> Harvesting only mature plants Limiting the amount collected Leaving seeds or roots for regeneration 	<ul style="list-style-type: none"> Regulated collection of endangered herbs 	Khasim et al. (2020)
Habitat restoration	Restoring or enhancing the natural environment of medicinal plants	<ul style="list-style-type: none"> Reforestation Soil and water conservation Removing invasive species 	<ul style="list-style-type: none"> Restoring degraded ecosystems 	Gowthami et al. (2021)
Ex situ conservation (off-site)	Preserving plant species outside their natural habitats	<ul style="list-style-type: none"> Gene banks Seed banks Botanical gardens 	<ul style="list-style-type: none"> Seed storage in gene banks Cultivating plants in botanical gardens 	Yadav et al. (2016)
Seed banks	Storing seeds for long-term preservation and future reintroduction	<ul style="list-style-type: none"> Collecting and storing seeds in controlled conditions 	<ul style="list-style-type: none"> Millennium seed bank 	Gupta et al. (2022)
Botanical gardens	Growing medicinal plants in gardens to preserve their species	<ul style="list-style-type: none"> Cultivating plants in protected garden spaces Educating the public 	<ul style="list-style-type: none"> Royal Botanic Gardens, Kew 	Pandey and Savita (2017)
Tissue culture	Propagating plants through tissue culture techniques to ensure genetic diversity	<ul style="list-style-type: none"> Cloning plants in laboratories using tissue culture 	<ul style="list-style-type: none"> Commercial propagation of rare plants 	Yadav et al. (2016)
Gene banks	Storing genetic material of plants for future research and restoration	<ul style="list-style-type: none"> Cryopreservation of plant genetic material 	<ul style="list-style-type: none"> Cryopreserved seeds of medicinal plants 	Rajeswara Rao et al. (2016)
Propagation and cultivation	Growing medicinal plants on farms or controlled environments	<ul style="list-style-type: none"> Cultivation in agroforestry systems Organic farming techniques 	<ul style="list-style-type: none"> Domesticated cultivation of Ginseng 	Gaurav et al., 2018
Agroforestry practices	Integrating medicinal plants within agricultural systems	<ul style="list-style-type: none"> Intercropping medicinal plants with other crops 	<ul style="list-style-type: none"> Medicinal plants grown alongside food crops 	Bijalwan et al. (2019)
Domestication and cultivation	Developing commercial cultivation systems for medicinal plants	<ul style="list-style-type: none"> Selecting plants for cultivation Ensuring optimal growth conditions 	<ul style="list-style-type: none"> Cultivation of Echinacea 	Ramawat et al. (2021)
Research and education	Conducting research and educating the public about medicinal plant conservation	<ul style="list-style-type: none"> Ethnobotanical studies Training and outreach programs 	<ul style="list-style-type: none"> Workshops for communities Botanical research on plant properties 	Samal et al. (2016)
Ethnobotanical research	Studying the traditional uses and significance of medicinal plants	<ul style="list-style-type: none"> Documenting indigenous knowledge Studying plant–medicine relationships 	<ul style="list-style-type: none"> Research into traditional healing practices 	Kichu et al. (2015)
Policy and legal support	Implementing regulations and policies to protect medicinal plants	<ul style="list-style-type: none"> National laws International agreements 	<ul style="list-style-type: none"> Convention on International Trade in Endangered Species (CITES) 	Gowthami et al. (2021)
National regulations	Legal frameworks to protect endangered species of medicinal plants	<ul style="list-style-type: none"> Banning or regulating harvesting of endangered species 	<ul style="list-style-type: none"> Endangered species protection laws 	Kharel et al. (2021)

4.4 Increasing Botanical Gardens for Medicinal Plant Conservation

Nowadays, there are several botanic gardens that focus primarily on the research and cultivation of therapeutic plants. Furthermore, a lot of different botanical parks either have a dedicated medical plant garden or keep unique collections of medicinal plants. Botanic gardens should and can play a larger role in the conservation of plant resources, of which traditional plant conservation is but one example. The majority of gardens and arboreta, particularly in North America, have focused the most of their efforts on their traditional functions, such as display, education, and horticultural research, but many individual botanic gardens have been involved in conservation initiatives for a long period of time. Growing plants successfully in botanic gardens is nothing special!

The fact that many of these gardens now prioritize conservation as an extra activity is a recent trend. In fact, several gardens in North America have included native species conservation in their charters and accessions policies, and comparable initiatives have occurred in other nations to differing degrees. For instance, in collaboration with the Museum National d'Histoire Naturelle, plant conservatoriums have been established in Brest, Porquerolles, and Nancy, France, with the goal of preserving and reviving regionally endangered species. The Conservatoire du Mascarin, which is being built on the Indian Ocean island of Reunion, was listed as a fourth in 1987. Similar to this, the Macaronesian region's endangered species are cultivated and propagated in the Jardín botánico Viera y Clavijo on the Canary Island of Las Palmas. The following succinctly describes the justification for viewing botanic gardens as the "sleeping constituency," or natural collaborators of the conservation movement. It is acknowledged that farmed plant populations and their propagation must become essential components of our worldwide strategy for the preservation of the genetic variety of plant species given the ongoing and growing destruction and change of the world's plant life—the World Conservation Strategy confirms (Dwivedy et al. 2019).

4.5 Medicinal Plant Seed Gene Bank Conservation Techniques

Plant genetic wealth is preserved in a gene bank. Seeds and vegetative plants preserve the rich legacy of plants that provide food and support for people.

DNA, gametes or cells, embryos, tissue culture, propagules, etc. In addition to conventional seeds, refractory species

and vegetatively propagated clonal material are kept in field, cryo, and in vitro settings.

Gene banks have been around for a while in many parts of the world, and their significance has long been acknowledged. Just a few years ago, the biggest and most advanced gene bank in India opened its doors in New Delhi. The main purpose of this bank is to store agricultural species and their wild cousins.

The establishment of a gene bank for forest germplasm has not yet begun, despite the topic having been brought up in recent debates. Given the speed at which forests are being destroyed globally, especially on the Indian subcontinent, it is imperative that the genetic material of Indian forests be preserved.

In order to support in situ conservation activities, the gene bank intends to do the following:

- Plant genetic resources should be kept safe for a long time using methods like *ex situ* protection for seeds, *in vitro* growth, and cryopreservation.
- As a role of the global system, the gene bank serves as a regional depository for identical collections and also as a repository for gathered, threatened, and high-quality material.
- Monitoring and maintaining the current collections, which makes it easier to plan the regeneration program.
- Ensuring that both native and exotic germplasm are available for assessment, use, and conservation by periodically increasing the number of seeds.
- Researching germplasm conservation in the medium and long term.
- Creating and running a forest genetic resource database and information network system.
- Help plan and support graduate programs and short- to medium-term education programs on how to work with forest genetics at the national, regional, and global levels.

With resistant seeds and vegetatively propagated plants, the most popular *ex situ* technique for preserving genetic resources is the field gene bank (FGB). By transferring and preserving samples of a species, subspecies, or variety as live collections, this conservation technique preserves genetic variation away from its natural habitat. By creating a FGB, collections are guaranteed to continue to exist for a long time and to provide authentic materials or propagule for both use and research. A practical benefit of this approach is the availability of the germplasm and ongoing plant growth assessment. The conserved material includes both wild and cultivated species that can be used for research, reintroduction, breeding, and other uses as needed.

4.6 Advanced Techniques for Long-Term Conservation

Around 50,000–80,000 species of therapeutic plants are known to exist, according to the World Wide Fund for Nature (WWF) and International Union for Conservation of Nature (IUCN). From there, overharvesting and habitat loss have already put about 15,000 species in danger. Additionally, an additional 20% of these plant resources are used by the population increase. Many recommendations have been produced based on the thorough study on how to protect medical plants and use them in a way that does not harm them. For their preservation and sustainable usage, only some of the suggestions—such as in situ conservation in botanic gardens and other natural reserves—have been implemented. Progression has been made in plant tissue growth, and sollicitation methods, as well as the vast collection of natural products made possible by biotechnological breakthroughs, are ultimately leading to the effective synthesis of desired bioactive chemicals. Plant cell and genetically edited hairy root culture are a good option to making rare and expensive secondary metabolites that are used in medicine. You can use micropropagation and put tissue or organs inside fake seeds to make them grow. It is now possible to achieve higher in vitro regeneration rates as well as an appropriate technique for the transportation and storage of germplasm.

Furthermore, in the event that normal seed production is insufficient, synthetic seed technology offers a feasible alternative for propagation. However, cryopreservation remains the only technology that can preserve problem species germplasm for an extended period of time (Gantait et al. 2017).

4.6.1 Cryopreservation for Future Use of Medicinal Plants

Some parts of plants, like regular seeds and frost-hardy quiescent buds, do not have much water, so they can be frozen right away without being prepared first. However, most of the things that are frozen for experiments—like cell samples, calli, shoot tips, and embryos—have a lot of water in them, which makes them more likely to get damaged by freezing because they are not naturally freeze-tolerant. Therefore, artificial dehydration is required to shield cells from the harm that results from intracellular water crystallizing into ice. Classical and novel cryopreservation methods differ in the methods used and the physical mechanisms they are based on (Kundu et al. 2018).

Traditional methods use freeze-induced dehydration, but more recent methods rely on vitrification—the direct conversion of liquid water into an amorphous phase or glass without the creation of crystalline ice.

Slow cooling to a predetermined pre-freezing temperature and then quick immersion in liquid nitrogen are the steps

of traditional cryopreservation methods. Due to the need for expensive and sophisticated programmed freezers, they are typically complicated to operate. By using a home or laboratory freezer to complete the freezing stage, their use can occasionally be avoided.

4.6.2 Clonal Germplasm Repositories

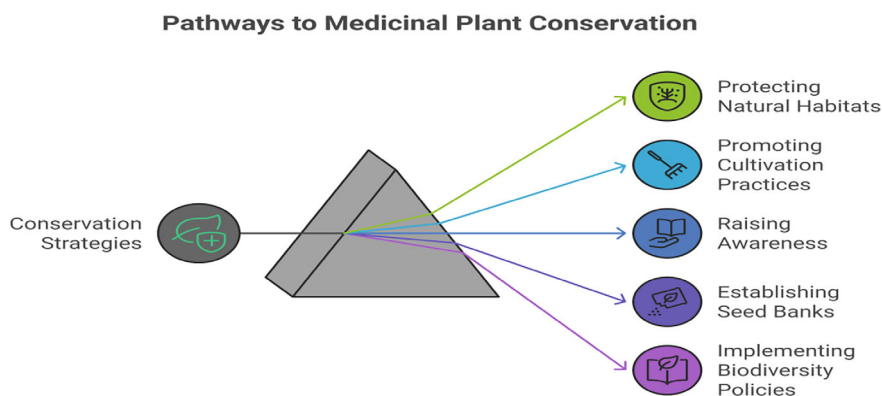
Clonal repositories are similar to field gene banks, but they only contain genetically identical material or clonal material. In contrast, field plantings that emphasize intraspecific variability are referred to as FGB. Clonal repositories were the main focus of nearly all previous horticultural crop research. But there are now more FGBs to protect diversity even in annual gardening crops, like tree crops. The twin function of FGBs is to conserve intraspecific and interspecific variation. The field gene bank's (FGB's) primary goal is to maximize variety while minimizing sample size and quantity. Both random and nonrandom sampling techniques may be used for gathering the samples. Only samples whose shape shows biological stress, like disease protection and other physiological traits, will be chosen by nonrandom selection.

Clonal crops are typically preserved in FGBs as an adjunct to cryo-banks and in vitro conservation methods. Because the germplasm in FGBs is susceptible to disorders, testing, checking in, and management methods are necessary to preserve the accessions. FGBs are the only feasible and economical method of conserving clonal crops, even though it is impossible to claim that they are the most secure type of conservation. Careful preparation and field management are necessary to reduce the dangers (Fig. 2).

5 Challenges for Conservation of Medicinal Plants

Medicinal plant conservation faces several critical challenges that hinder effective efforts to protect and sustain these valuable resources. A major issue is the lack of people don't know enough about the biological, cultural, and economic value of medicinal plants, so protection efforts don't get enough support. To get people to care about and fight for their protection, it is important to make people more aware of them through education programs, public campaigns, and community involvement. Additionally, funding and resource constraints significantly limit progress. Conservation efforts require financial, human, and infrastructural resources for research, habitat restoration, and outreach, but these are often inadequate. Increased investment, public-private partnerships, and sustainable financing mechanisms are crucial for addressing these gaps (Table 2).

As the economy and means of existence of human civilizations in emerging nations rely heavily on forest products,

Fig. 2 Conservation strategies of medicinal plants**Table 2** The challenges for the conservation of medicinal plants, along with descriptions and potential solutions

Challenge	Description	Potential solutions	Reference
Overharvesting	Excessive collection of medicinal plants for commercial use or local consumption can lead to depletion of wild populations	<ul style="list-style-type: none"> • Implement sustainable harvesting methods • Encourage the cultivation of medicinal plants in gardens or farms • Create harvest quotas or licenses to regulate collection 	Pandey et al. (2017)
Habitat loss and degradation	Destruction of natural habitats due to deforestation, urbanization, agriculture, and mining threatens plant populations	<ul style="list-style-type: none"> • Protect critical habitats through conservation laws and policies • Restore degraded ecosystems • Promote land-use practices that are compatible with plant conservation 	Yousaf and Toor (2021)
Climate change	Changes in temperature, rainfall patterns, and extreme weather events can alter the growing conditions of medicinal plants, potentially threatening their survival	<ul style="list-style-type: none"> • Develop climate-resilient cultivation methods • Monitor plant species' responses to climate change and adapt conservation strategies accordingly 	Das et al. (2017)
Invasive species	Invasive plant species can compete with native medicinal plants, affecting their growth and survival	<ul style="list-style-type: none"> • Implement programs to control and remove invasive species • Restore native plant species and ecosystems • Educate communities about the risks posed by invasive species 	Dar et al. (2019)
Genetic erosion	Overharvesting and habitat loss can reduce the genetic diversity of medicinal plants, making them more susceptible to diseases and climate change	<ul style="list-style-type: none"> • Establish seed banks and botanical gardens for ex situ conservation • Promote in situ conservation in protected areas • Support breeding programs to maintain genetic diversity 	Singh (2015)
Unsustainable trade	The global trade in medicinal plants can lead to overexploitation, especially when plant species are not properly regulated	<ul style="list-style-type: none"> • Establish sustainable trade guidelines and certifications (e.g., fair trade and organic certification) • Implement monitoring systems for trade and collection of endangered species 	Raju et al. (2024)
Loss of traditional knowledge	The decline in indigenous knowledge of medicinal plants can lead to the loss of valuable cultural practices and sustainable use techniques	<ul style="list-style-type: none"> • Document traditional knowledge through ethnobotanical research • Involve indigenous communities in conservation and knowledge preservation • Promote intergenerational knowledge transfer 	Juan (2017)

the ongoing growth of the human population is one of the reasons for concern over the ability to meet daily needs for food and medicine. Because of this phenomenon, forests and their products are continuously being eroded, making it more difficult to meet demands and preserve valuable bioresources. The requirements for their purity and accurate identification, however, are not keeping up with the growth. The market pricing for medicinal plants and their derivatives do not give us exact information about supply and demand, profits, or how the market functions.

Another key challenge is there is not enough study and data on medicinal plant types, including their ecology, distribution, and threats, which hampers effective conservation planning. Increased research and collaborations among the researchers, local communities, and traditional physicians are vital to bridging this knowledge gap. Lastly, conservation prioritization and tradeoffs add complexity, as decisions must consider species' conservation status, they have monetary worth, cultural importance, and environmentally friendly roles, and they need to be balanced with tradeoffs like protection and safe use. To make sure that medicinal plants are protected for the foreseeable future, authorities, conservation groups, researchers, communities, and the business sector must all work together to overcome these challenges.

5.1 Biopiracy

“Biopiracy” means using natural resources and traditional knowledge in a way that is inappropriate or against the law, especially that of indigenous groups, without proper acknowledgment or payment. The appropriation of therapeutic plants like neem, turmeric, and basmati rice are notable examples that show how susceptible indigenous knowledge systems are to being exploited by international enterprises.

As part of global endeavors to make sure that gains from using biological assets are shared fairly, the International Convention on Biological Diversity (CBD) and its follow-up, the Nagoya Protocol, have been created. These programs stress that access and benefit-sharing (ABS) processes, terms that are agreed upon by both parties, and informed consent are necessary to stop biopiracy. However, their usefulness has been restricted due to enforcement issues and important nations' lack of engagement.

The intricacy of biopiracy is demonstrated by the neem tree case. Indian groups had been using traditional knowledge for centuries, and Western firms tried to patent it on the grounds of innovation. A significant win against biopiracy was achieved when these patents were eventually revoked as a result of opposition from groups in India and Europe as well as campaigners like Vandana Shiva. The commercialization of the hoodia plant, which the San

people have long used as an appetite suppressant, in South Africa highlights the difficulties and advancements made in combating biopiracy. Despite the exclusion of indigenous groups from early accords, agitation led to a modest profit-sharing arrangement, setting the stage for fair cooperation.

National measures like Brazil's Biodiversity Law, which forbids biopiracy and aims to guarantee equitable benefit-sharing with indigenous communities, have been influenced by the CBD and Nagoya Protocol. Administrative obstacles continue to impede implementation despite legislative progress (Huggan and Tiffin 2015). Biopiracy is getting more acute because pharmaceutical sales are going through unprecedented levels. It has been estimated that the global medicinal plant market, which was discovered by following the advice of local and indigenous tribes, is worth \$43 billion. For this reason, the knowledge of indigenous peoples is so valuable: “Discovering traditional information makes the method of looking for medicinal plants 400% more effective.” When indigenous groups lack official legal protection, biopiracy frequently serves as a quick route to enormous profits without having to fairly compensate the information's original sources.

5.2 Research Restrictions

Restrictions that unintentionally hinder research have resulted from the controversy around bioprospecting and intellectual property rights. After the Convention on Biological Diversity (CBD), strict regulations were put in place to protect indigenous knowledge and biodiversity. These limitations do, however, occasionally impede scientific study that is unconnected to biopiracy. As an example: Access to plant samples is hampered by bureaucratic obstacles, which deters real scientific research. Because of their fear of exploitation, some nations have implemented unduly restrictive laws that prevent or postpone crucial conservation research.

Overly stringent laws designed to stop biopiracy frequently fall short of striking a balance between sustainable research methods and medicinal plant conservation. The issue is made worse by misunderstandings over the extent of bioprospecting and irrational hopes for financial gain. These overreactions limit prospects for cooperation and the creation of solutions to protect medicinal plants. Fragmented conservation efforts are the result of inconsistent research licenses worldwide. Other countries lag behind, enforcing inconsistent prohibitions that sabotage international cooperation, while China and other countries are developing frameworks to standardize medicinal plant research through laws and quotas (Chen et al. 2016).

There are claims that certain nations and territories have overreacted to concerns about intellectual resource theft and biopiracy by imposing harsh limits on research that could have major negative effects to sustainable development and

conservation. It is very likely that these purported overreactions have been mostly caused by problems with medicinal plants in particular. It is likely that there are frequent misunderstandings regarding the scope of bioprospecting, the potential financial rewards, and the relative importance of bioprospecting research in comparison with research with other goals.

5.3 Overharvesting

Growing demands associated with population increase and the corresponding expansion of agricultural land into forests and woods, habitat destruction, and land degradation are all directly linked to the overexploitation of plants for medicinal purposes and other biotic resources.

Destructive harvesting typically leads to resource depletion and potentially species extinction for medicinal plants with sluggish growth and limited availability.

As a result, it is important to think about the sustainable usage of medicinal herbs and develop appropriate harvesting techniques. Medicinal plants (such as herbs, shrubs, and trees) are more harmed by root and whole-plant harvesting than by leaf, flower, or bud collection. Herbal medicines made from whole plants or roots can be safely swapped over to medicines made from plant parts.

Controlled growing conditions can make sure that production stays stable and boost the production levels of active chemicals, which are usually metabolites that are secondary in nature. In order to obtain more of the things that people want, farming methods are designed to give the plants an adequate amount of water, nutrients, supplements that people can choose to add, and natural factors like light, temperature, and humid. Increasing cultivation also helps restore their wild resources, brings down their selling prices, and drops the amount of medicinal plants that can be harvested.

5.4 Deforestation

Overexploitation, careless collection, unchecked deforestation, and habitat damage can all make a species less common, but they cannot tell you by themselves how sensitive or resistant a species is to harvest pressure. The risk of extinction is linked to many biological features, such as ecological specialization, dispersion spread, size of population, species diversity, development rate, and the system of reproduction.

5.5 Natural Threats

In response to destructive gathering, medicinal plants are becoming infrequent and hard to find. Many species have

lost their genetic stock and will never be able to get it back because they were taken from their natural habitats to be used as medicine. Medicinal plants are in danger because their habitats are being lost or broken up. Natural ecosystems are quickly being changed or killed by growing farming, cities, exploitation, and building new roads and bridges. Medicinal plants often need certain types of ecosystems to survive. When these habitats are destroyed or gone, the populations of those plants become more fragile. Fragmentation stops the flow of genes, lowers population numbers, and raises the chance of local mass extinctions. To protect medicinal species of plants and make sure they live on, conservation initiatives ought to concentrate on keeping and restoring good environments. Medicinal plants are in danger when they are harvested without following the rules and in a way that does not support their communities. As the need for herbal remedies grows, people may collect plants in ways that are not viable, which can hurt wild populations and cause overexploitation. Some medical plants grow slowly or cannot reproduce well, which makes them more likely to be harvested too much. Harvesting ways that hurt plants or kill whole individuals without letting them grow back make the problem even worse. Sustainable harvesting methods, like encouraging farming and accreditation initiatives, can help wild species by reducing the amount of pressure on them.

Changes in the Climate and Environmental Factors

The changing climate is a big problem for plants that are used for medicine. Changing trends of rainfall, increasing temperatures, and catastrophic storms can throw off the intricate equilibrium of the environment that they need to survive. Temperature, moisture, and fluctuations in humidity can have an effect on medicinal plants, making them unable to grow, reproduce, or stay healthy in general. Changes in climate can also affect where species live, causing their ranges to grow or shrink. To respond to and lessen the effects of climate change, conservation approaches should include finding species that can survive in changing climates and protecting a variety of habitats that act as ecological barriers (Shackleton et al. 2015).

To deal with these dangers, we need an integrated strategy that includes protecting habitats, using environmentally friendly harvesting methods, and adapting to climate change. Protected areas and nature parks can help keep important places for plants that heal safe. Agroforestry practices or community-based projects that promote the growing of healing plants can help populations of wild plants by easing the stress on them. For long-term preservation, it is also important to teach locals, traditional medicine specialists, and customers about ecological harvesting methods and how important it is to protect medicinal plants (Kharel et al. 2021). To sum up, the problems that medicinal plants face, such as ecosystem loss, overharvesting, and climate change, are big problems that make it hard for them to stay alive. To deal with these dangers, we need to take protection actions that protect

habitats, use sustainable methods, and come up with ways for animals to adapt. By reducing these risks, we can make sure that medical plants will be around for subsequent generations and keep the many health and well-being benefits they offer.

6 Potential Benefits of Medicinal Plant Conservation

The preservation of healing plants can be helped through the integration of traditional medicine into modern healthcare systems. A lot of traditional medicine is based on healing plants. Including them in national healthcare guidelines and procedures can help them stay in use and protect them. Using scientific study and evidence-based methods to backup traditional healing practices can help people accept them more and make it easier for traditional healers and modern healthcare providers to work together. This kind of mixing can lead to the creation of healthcare practices that are respectful of different cultures and last a long time, using the wide range of healing plants (Shukla et al. 2023). The pharmaceutical industry understands that medicinal plants have an enormous amount of potential as an origin of new compounds. Many medications that save lives, such as antibiotics, anticancer drugs, and medicines for heart disease and blood vessels, were made from substances found in plants. It is very important to protect medicinal plants so that there are still a lot of different chemical compounds that can be tested and used in drug research. Medicinal plants are also very important in traditional systems of medicine like Ayurveda, traditional Chinese medicine, and Indian healing techniques. These methods take an in-depth look at healthcare and have been praised for how well they work. It is important to protect medicinal plants so that traditional health practices can continue and be accepted. To sum up, therapeutic plants are important in terms of history, culture, and the economy. They have deep roots in cultural practices, help local economies, and are very important to both conventional medical systems and pharmaceutical firms. Preserving medicinal plants protects cultural history, helps the economy grow in a way that does not harm the environment, and keeps these plants' medical benefits hidden for future use (Chen et al. 2016). Medicinal plants are especially important for protection because of the reverence that people have for them. These values are about how medicinal plants can help with healthcare, making money, preserving national identity, and making sure people can make a living. People think that these effects can sometimes be so big that focusing on medicinal plants can help with a lot more than just protecting endangered communities of medicinal plants or making sure that medicines are made in a way that does not harm the environment (though these are both good goals on their own). It would be helpful to look into the link across where different types of plants grow and how valuable medicinal plants are to

people (if this could be measured). It is thought that medicinal plants often have the best relative values in places with a lot of different kinds of plants. If this link is proven to be real, then projects at many plant variety centers that aim to protect all living things could often gain from relying on medicinal plants.

7 Conclusion

In summary, a multifaceted approach to protecting and improving medical plants is needed to keep ecological diversity high, encourage long-term use, and make healthcare better. With this method, medicinal plants will be around for future generations because it uses many strategies, such as protecting habitats, improving farming methods, using biotechnology, and getting people involved. Nature reserves need to be protected and excessive exploitation stopped, and healthy approaches to harvesting should be pushed at the same time. New farming methods, like selective breeding, genetic editing, and tissue culture, can be used along with traditional knowledge to make medicinal plants better. The quality, yield, and healing qualities of these plants are all improved by this harmonious integration. Keeping plants for medicinal purposes alive is a difficult and multifaceted task that needs people to work together, use long-lasting methods, and combine science and traditional wisdom. We can make sure that medicinal plants will be available and useful for generations to come by dealing with threats, taking advantage of chances, and absorbing information from past successes. It is important to protect these plants because they are part of nature and help people's health and well-being all over the world. It is up to all of us to make sure that medicinal plants continue to grow and help both people and wildlife in the future. Important to the achievement of these activities is cooperation between investigators, neighborhoods, policymakers, and businesses. To make practices that are good for the environment and traditional heritage last, we need to work together. This will also help make medicinal plants more useful for medicine and drugs. When everything is put together, it not only protects and improves medical plants, but it also helps reach bigger goals like protecting the environment along with rendering people healthier.

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