P.E. Rajasekharan
Shabir Hussain Wani *Editors*

Conservation and Utilization of Threatened Medicinal Plants

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Foreword

Wild plant species form the foundation of healthcare practices throughout much of Asia, particularly traditional practices, such as traditional Chinese medicine, Ayurveda, Siddha, Unani and Tibetan medicines. Compounds such as reserpine from snakeroot and paclitaxel from Himalayan yew have important pharmaceutical uses in Europe, North America and elsewhere. Some species are in demand for their aromatic properties too. The use of Jatamansi oil dates back over 1000 years, whilst red sanders is in demand for its timber and as a source of red dye. In India, collection and processing of medicinal plants contributes at least 35 million workdays per year to the poor and underemployed, but rising demand is threatening this vital source of livelihood income in India and elsewhere.

Priority also needs to be given to wild land. There exists medium to high capability for research and use of improved methodologies for ex situ conservation. Nevertheless, strengthening of both technical and infrastructure capabilities is required in most cases. Crucial concerns associated with in situ and on-farm conservation through participatory approaches involving local communities to develop appropriate regeneration systems, maintenance and continuous cultivation in farmers' field, provision of adequate incentives to farmers with enough seed and planting material and promotion of village level nurseries/gardens to perpetuate local diversity need to be addressed. The static (ex situ) conservation strategy seeks to dramatically alter the original evolutionary trajectories of a plant species; a 'genetic snapshot' of sorts is conserved.

At the same time, the current status of technology does not allow many important species to be stored in genebanks, since they are all not propagated through orthodox seeds. In this context, this compilation is a welcome initiative as it discusses the state of the art related to conservation and use of threatened medicinal plants. This book provides a comprehensive overview using broad subject-based reviews about contemporary approaches to conservation and use in the framework of different technologies including biotechnological approaches as practised. The aim was to review the current status of threatened medicinal plants research in light of the surge in the demand for herbal medicine. The current volume brings together chapters on threatened medicinal plants of, and covers both wild (non-cultivated) and domestic

(cultivated) crops with, therapeutic value. The work includes a brief chapter on the singular nature of threatened medicinal plant genetic resources giving rationale for it being distinct from field crop genetic resources. Other chapters give insight on protocols for conservation of selected threatened medicinal plants ex situ and focus on increased need to complement it with in situ conservation approach. Geospacial tools are also briefly described emphasizing on the gene pool in threatened medicinal plants. Legal and biotechnological aspects, namely morphological, genomics, chemical and molecular characterization, are also dealt with. The ways by which these resources are used with sustainable management and replenishment are described. The topics of interest include but are not restricted to research perspectives for sustainable development of various such plant species. The book will be a good reference tool, useful to horticulturists, botanists, policy makers, conservationists, NGOs and researchers in academia and industry.

I am happy to learn that Dr. P. E. Rajasekharan and Dr. Shabir Hussain Wani have edited this book titled *Conservation and Utilization of Threatened Medicinal Plants* to be published by Springer Nature. Both the editors have a rich and long experience in the area of plant genetic resources. I am impressed with their zeal and commitment for science, including research, teaching and dissemination of scientific knowledge. I congratulate both the editors for their timely initiative in bringing out this publication.

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Preface

Medicinal and aromatic plants (MAPs) have been utilized in various forms since the earliest days of mankind. They have maintained their traditional basic curative role even in our modern societies. Apart from their traditional culinary and food industry uses, MAPs are intensively consumed as food supplements (food additives) and in animal husbandry, where feed additives are used to replace synthetic chemicals and production-increasing hormones. Importantly, medicinal plants (MPs) and their chemical ingredients can serve as starting and/or model materials for pharmaceutical research and medicine production. Current areas of utilization constitute powerful drivers for the exploitation of these natural resources. Today's demands, coupled with the already rather limited availability and potential exhaustion of these natural resources, make it necessary to take stock of them and our knowledge regarding research and development, production, trade and utilization, and especially from the viewpoint of sustainability. This book on conservation and utilization of threatened medicinal plants of the world is aimed to look carefully at our present knowledge of this vast interdisciplinary domain. In the era of global climatic change, the series is expected to make an important contribution to the better knowledge and understanding of threatened MPs. The history of medicinal and utilization dates back to the beginnings of mankind. Our forefathers used natural substances, they could find in nature, to ease, cure their sufferings, illnesses, and to heal their wounds. This type of approach has survived in the traditional medicinal (TM) uses, until today, since nearly 80% of the world population still relies on MPs in their medications. The renaissance of MP-use in the high-income countries of the world has brought about a different type of use in the form of herbal medicines complementary and alternative medicines (CAM). MPs have become "industrial products" with new concepts like phytotherapy and veterinary medicinal uses, aromatherapy, nutraceuticals, cosmeceuticals, and animal welfare uses widening the scope of the utilization. New, innovative, value-added applications include their use in functional foods, animal husbandry, as well as plant protection in agriculture. In this regard, the versatile utilization of essential oils is promising. Modern approaches in production and uses have brought about an increased focus on the importance of quality, safety, and efficacy of both MPs and their produce. MPs will also maintain their importance in

the search for new, valuable sources of drugs and lead compounds. In view of the steadily increasing demands on these important natural resources, attention should be paid to the sustainable forms of production and utilization.

Contributors of this volume were selected from a wide range of institutions for introducing a diversity of authors. At the same time, these authors were selected based on their vast expertise in specific areas of their choice to match the diversity of topics. These authors have a deep understanding of their subject to enable them not only to write critical reviews by integrating information from classical to modern literature but also to endure an unending series of editorial suggestions and revisions of their manuscripts. Needless to say, this is as much their book as ours. We hope that this volume will help our fellow researchers and a generation of students enter the fascinating world of threatened medicinal plants resources research and conservation with confidence, as perceived and planned by us. All these aspects are well covered in this volume.

The book is primarily designed for use by the undergraduates and postgraduates studying horticulture, sustainable crop production, agricultural sciences, and plant sciences. Horticulturists, plant and agricultural research scientists, and those in academia will find this book of great use. Libraries in all universities and research establishments where agricultural and horticultural sciences are studied and taught should have multiple copies of this valuable book on their shelves. Editors wish to thank all the contributors and staff of Springer for their cooperation in the completion of this book.

Bengaluru, Karnataka, India — P. E. Rajasekharan
East Lansing, MI, USA — Shabir H. Wani

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About the Editors

P. E. Rajasekharan is a Principal Scientist at the ICAR Indian Institute of Horticultural Research, Bengaluru. He completed his PhD in In Vitro Conservation of Threatened Medicinal Plants in the Department of Botany, Bangalore University. He is known for his contributions to the area of plant genetic resources, i.e. in vitro conservation and cryopreservation of horticultural crops. Also, he holds three post-graduate diplomas: Intellectual Property Rights from the National Law School of India University, Human Resources Management from Indira Gandhi National Open University (New Delhi) and Ecology and Environment from Indian Institute of Ecology, New Delhi. He supervised 20 MPharm students at Rajiv Gandhi University of Health Sciences. He also wrote many review articles and book chapters, participated in various national and international symposia and seminars and presented research results on cryopreservation and in vitro conservation. In addition, he has developed globally applicable cryopreservation protocols for the conservation of nuclear genetic diversity (NGD) in pollen of important vegetable, ornamental and endangered medicinal species. He also worked on conservation of threatened medicinal plants and established Field Gene Bank for the same at ICAR-IIHR, Bengaluru. He developed conservation protocols for several RET medicinal plant species including *Nothapodytes foetida*. Recently, he worked on *Madhuca insignis* which was rediscovered after 120 years and reintroduced in the natural habitats. He currently teaches courses on Plant Genetic Resources

and Intellectual Property Rights in Agriculture. He has more than 200 articles and 2 books to his credit, one coedited with Dr. Ramanatha Rao published by Springer Nature, i.e. *Conservation and Utilization of Horticultural Genetic Resources***.** He is an expert reviewer for several international peer-reviewed journals, and sits on the editorial board of several journals. He is a Fellow of the Indian Society of Plant Genetic Resources and Indian Association for Angiosperm Taxonomy.

Shabir Hussain Wani is Senior Assistant Professor at Mountain Research Centre for Field Crops, Khudwani – 192101, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, J&K, India. He received his PhD degree in Plant Breeding and Genetics on "transgenic rice for abiotic stress tolerance" from the Punjab Agricultural University Ludhiana, India. After obtaining his PhD, he worked as Research Associate in the Biotechnology Laboratory, Central Institute of Temperate Horticulture (ICAR), Srinagar, India. He then joined as Programme Coordinator in Krishi Vigyan Kendra (Farm Science Centre), Senapati, Manipur, India. He teaches courses related to plant breeding, seed science and technology and stress breeding and has published more than 100 papers/chapters in journals and books of international and national repute. He served as Guest Editor and Review Editor for the journal *Frontiers in Plant Science* (2015–2018). He has also edited several books on current topics in crop improvement for abiotic stress tolerance published by Springer Nature and CRC Press, USA. His PhD research won first prize in the North Zone Competition, national level, in India. He was awarded Young Scientist Award from the Society for Promotion of Plant Sciences, Jaipur, India, in 2009. He is a fellow of the Society for Plant Research, India. Recently he also received Young Scientist Award (Agriculture) 2015 from the Society for Plant Research, Meerut, India. He also served as Visiting Scientist in the Department of Plant Soil and Microbial Sciences, Michigan State University, USA, under the UGC Raman Postdoctoral Fellowship programme. Currently, he is in charge of wheat improvement programme at MRCFC Khudwani, SKUAST, Kashmir.

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Part I
Genetic Resources of Threatened Medicinal Plants at Crossroads

Chapter 1
Distribution, Diversity, Conservation and Utilization of Threatened Medicinal Plants

P. E. Rajasekharan and Shabir Hussain Wani

Abstract Rich biodiversity of India is under severe threat owing to habitat destruction, degradation, fragmentation, and overexploitation of resources. According to the Red List of threatened plants, 44 plant species are critically endangered, 113 endangered, and 87 vulnerable (IUCN, 2000). Widespread losses of plant species and varieties are eroding the foundation of agricultural productivity and threatening other plant-based products used by billions of people worldwide, as reported in a new study by the World Watch Institute, Washington, and worldwide some 3.5 billion people in developing countries rely on plant-based medicine for primary health care. Loss of habitat, pressure from nonactive species, and over harvesting have put one out of every eight plant species at risk of extinction, according to the world conservation union. Many medicinal plants are also in trouble from over harvesting and destruction of habitat. Since less than 1 percent of all species have been screened for bioactive compounds, every loss of a unique habitat and its species is potentially a loss of future drugs and medicines.

Keywords Threatened medicinal plants · Conservation · Red list · CAMP

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1.1 Introduction

In India, of the 17,000 species of higher plants, 7500 are known for medicinal uses (Shiva 1996). *Ayurveda*, the oldest medical system in Indian subcontinent, has alone reported approximately 2000 medicinal plant species, followed by Siddha and Unani. The Charaka Samhita, an age-old written document on herbal therapy, reports on the production of 340 herbal drugs and their indigenous uses. Approximately 25 percent of drugs are derived from plants, and many others are synthetic analogues built on prototype compounds isolated from plant species in modern pharmacopoeia (Rao et al. 2004). Further, the demand for medicinal plant-based raw materials is growing at the rate of 15 to 25 percent annually, and according to an estimate of WHO, the demand for medicinal plants is likely to increase more than US $5 trillion in 2050. In India, the medicinal plant-related trade is estimated to be approximately US $1 billion per year (Table 1.1).

1.2 Distribution

Macro analysis of the distribution of medicinal plants shows that they are distributed across diverse habitats and landscape elements. Around 70% of India's medicinal plants are found in tropical areas mostly in the various forest types spread across the Western and Eastern Ghats, Vindhyas, Chota Nagpur Plateau, Aravalis, and Himalayas. Although less than 30% of the medicinal plants are found in the temperate and alpine areas and higher altitudes, they include species of high medicinal value. Studies show that a larger percentage of the known medicinal plant occur in the dry and moist deciduous vegetation as compared to the evergreen or temperate with habitats.

Analysis of habitat of medicinal plants indicates that they are distributed across various habitats. One third are trees and an equal portion shrub and the remaining one third herbs, grasses, and climbers. A very small proportion of the medicinal

Table 1.1 List of medicinal plants traded in large volume internationally

Actaea racemosa	*Centella asiatica*	*Hydrastis perforatum*	*Silybum marianum*
Allium sativum	*Echinacea purpurea*	*Matricaria chamomilla*	*Silybum chirayita*
Aloe ferox	*Echinacea angustifolia*	*Melissa nettle*	*Tanacetum parthenium*
Aloe vera	*Echinacea sinica*	*Oenothera biennis*	*Taxus wallichiana*
Aloe Montana	*Ginkgo biloba*	*Papaver somniferum*	*Taxus brevifolia*
Atropa belladonna	*Glycyrrhiza glabra*	*Pelargonium sidoides*	*Taxus chinensis*
Carapichea ipecacuanha	*Hippophae rhamnoides*	*Sabal serrulata*	*Ulmus rubra*
Cassia senna	*Hydrastis Canadensis*	*Serenoa repens*	*Vaccinium macrocarpon*

plants are lower plants like lichens, ferns algae, etc. Majority of the medicinal plant are higher flowering plants.

1.3 Medicinal Plant Wealth of India

India is rich in medicinal plant diversity. All known types of agroclimatic, ecologic, and edaphis conditions are met within India. The biogeographic position of India is so unique that all known types of ecosystems range from coldest place like the Nubra Valley with 57 °C, dry cold deserts of Ladakh, temperate and alpine and subtropical regions of the North-West and trans-Himalayas, rain forests with the world's highest rainfall in Cherrapunji in Meghalaya, wet evergreen humid tropics of Western Ghats, arid and semi-arid conditions of Peninsular India, dry desert conditions of Rajasthan and Gujarat to the tidal mangroves of the Sunderban. India is rich in all the three levels of biodiversity, such as species diversity, genetic diversity, and habitat diversity. There are about 426 biomes representing different habitat diversity that gave rise to one of the richest centers in the world for plant genetic resources. Although the total number of flowering plant species is only 17,000, the intraspecific variability found in them make it one of the highest in the world. Out of 17,000 plants, the classic systems of medicines like Ayurveda, Siddha, and Unani make use of only about 2000 plants in various formulations (Table 1.2). The classical traditions were prevalent in the past particularly in the urban elite society. The rural people who constitute 70–75% of the Indian populations live in about 576,000 villages located in different agroclimatic conditions. The village people have their own diverse systems of health management. While most of the common ailments were managed in the house by home remedies which included many species and condiments like pepper, ginger, turmeric, coriander, cumins, tamarind, fenugreek, and tulsi more complicated cases were attended by the traditional physicians who use a large number of plants from the ambient vegetations and some products of animal or mineral origin to deal with the local diseases and ailments. These are indeed community-managed systems independent of official or government system and are generally known as Local Health Tradition (LHT). The traditional village

Table 1.2 Distribution of medicinal plants by parts used (based on analysis of 1079 South Indian species)

Parts	Percentage (%)
Roots	26.6
Leaves	5.8
Flowers	5.2
Fruits	10.3
Seeds	6.6
Stem	5.5
Wood	2.8
Whole plant	16.3
Rhizome	4.4

physicians of India are using about 4500–5000 species of plants for medicinal purpose. However, there is no systematic inventory and documentation about the folk remedies of India. There is urgent need to document this fast disappearing precious knowledge system. The oral traditions of the villagers use about 5000 plant for medicinal purposes. India is also inhabited by a large number of tribal communities who also possess a precious and unique knowledge about the use of wild plants for treating human ailments. A survey conducted by the All India Coordinated Research Project on Ethnobiology (AICRPE) during the last decade recorded over 8000 species of wild plants used by the tribals and other traditional communities in India for treating various health problems. Some interesting observations made in the study are the use of the same species found in different regions for the same ailments, while some other species are used differentially.

Species Available in Phytoclimatic Zones in India

Our country is divided into tropical, subtropical, temperate, and alpine zones. The following medicinal plants are found in different phytoclimatic zones:

1. Tropical zone: *Acorus calamus*, *adhatoda vasica*, *aristolochia indica*, *azadirachta indica*, *cassia fistula*, *commiphora mukul*, *datura metel*, *evolvulus alsinoides*, *gloriosa superba*, *mucuna pruriens*, *psoralea corylifolia*, *pueraria tuberosa*, *tinospora cordifolia*, *tylophora indica*, *withania somnifera*, *chlorophytum arundinaceum*, *strychnos nux-vomica*.
2. Subtropical zone: *Acorus calamus*, *alpinia galanga*, *asparagus adscendens*, *curcuma zedoaria*, *holarrhena antidysenterica*, *urginea indica*.
3. Temperate zone: *Aconitum chasmanthum*, *artemisia maritima*, *berberis aristata*, *bergenia ciliata*, *colchicum luteum*, *daphne papyracea*, *datura stramonium*, *dioscorea deltoidea*, *fagopyrum esculentum*, *heracleum candicans*, *podophyllum hexandrum*, *rheum emodi*, *swertia chirata*, *urginea indica*, *viola odorata*, etc.
4. Alpine zone: *Nardostachys jatamansi*, *picrorhiza kurroa*, *dactylorhiza hatagirea*, *hyssopus officinalis*, *aconitum heterophyllum*, *a. balfourii*, *dictamnus albus*, *ephedra gerardiana*, *gentiana kurroo*, *jurinea dolomiaea*, etc.

1.4 Threatened and Endemic Plants of Indian Region

India with its varied climate, high mountains in the north, and sea on the other three sides supports a rich flora of tropical, subtropical, temperate, and alpine vegetation. It is estimated that over 17,000 species of higher plants occur in India, of which approximately one-third are woody species and another one-third endemic. It is also common knowledge that our forests with all this vegetation are gradually decreasing. Whereas we should have at least 33% of forest cover in order to have harmonious ecosystems, we are at present left with a mere less than 20%. Activities such as conservation of flora and afforestation should, therefore, go hand in hand and must be given top priority. The Indian efforts toward conservation of threatened biota through the Ministry of Environment and Forests are praiseworthy. India is one of

Table 1.3 National organizations working on medicinal plants

Sl. no	Organization	Headquarter	Area of work
1	CSIR-Central Institute of *Medicinal* and Aromatic *Plants*	Lucknow, Uttar Pradesh	Extending technologies and services to the farmers and entrepreneurs of medicinal and aromatic plants
2	ICAR-Directorate of Medicinal and Aromatic Plants Research	Anand, Gujarat	Quality production of medicinal and aromatic plants
3	JN-The Tropical Botanical Garden and Research Institute	Palode, Kerala	Conserving tropical plant genetic resource develops strategies for their sustainable utilization
4	CSIR-Indian Institute of Integrative Medicine	Jammu	Primary focus of research on drug discovery from medicinal plants
5	National Medicinal Plant Board	New Delhi	Development of medicinal plant sector through developing a strong coordination between various ministries/departments/organizations for implementation of policies/programs on medicinal plants

the signatories of the convention on the International Trade in Endangered Species of Wild Fauna and Flora. The National Committee on Environmental Planning and Coordination (NCEPC) and the National Committee on Man and Biosphere (MAB) have also been concerned with the protection of habitat having natural vegetation. Several natural areas have been identified for conservation as biosphere reserves throughout the country. Setting up of gene banks and gene sanctuaries are other major efforts of the government toward conservation (Table 1.3). The real challenge is to conserve the threatened endemic medicinal plants.

1.4.1 Distribution of Medicinal Plants by Habitats

Of the 386 families and 2200 genera in which medicinal plants are recorded, the families Asteraceae, Euphorbiaceae, Lamiaceae, Fabaceae, Rubiaceae, Poaceae, Acanthaceae, Rosaceae, and Apiaceae share the larger proportion of medicinal plant species with the highest number of species (419) falling under Asteraceae.

About 90% of medicinal plant used by the industries is collected from the wild. While over 800 species are used in production by industry, less than 20 species of plants are under commercial cultivation. Over 70% of the plant collections involve destructive harvesting because of the use of parts like roots, bark, wood, and stem and the whole plant in case of herbs. This poses a definite threat to the genetic stocks and to the diversity of medicinal plants if biodiversity is not sustainably used.

Medicinal plants have always been a basic resource for human health. Appreciation for the preventative and therapeutic value of herbal remedies and the

additional benefits of their low cost, wide accessibility, and cultural relevance remain strong in many traditional cultures. Interest in and demand for traditional remedies and other plant-based health products (the so-called botanicals) are increasing worldwide, particularly in rapidly expanding urban societies. Increased consumption of medicinal plants, through expansion of local, regional, and global markets, has increased pressure on a resource that is largely harvested from depleted wild populations in shrinking wild habitats.

Research on the conservation and sustainable use of medicinal plants and their habitats has fallen far behind the demand for this globally important resource. More than 20,000 species of plants are used medicinally somewhere on earth. Nearly half of these species are potentially threatened by over-harvest or loss of habitat. Capacity to assess and monitor the conservation status of medicinal plants, to manage harvest within the limits of sustainability, and to devise cost-effective alternatives for the production of medicinal plants as a resource is extremely limited worldwide. The scale of consumption of this resource has overwhelmed knowledge and tools to effectively implement conservation activities.

The current and potential value of medicinal plants – their value to local community health, to regional markets, and to global health security and trade – is widely recognized as a reason to conserve tropical forest ecosystems. However, many other ecosystems worldwide support a medicinal flora that is important to local health and economy, as well as to regional and global supplies of plant-based medicines. The wide range of habitats, taxonomic groups, and the variety of cultural, social, and economic conditions affecting their use present substantial challenges to conservation and management efforts for these resources. At the same time, the capacity, experience, and expertise developed in meeting these challenges for medicinal plant resource management will contribute more broadly to biodiversity resource management capability in any natural and social environment where plants are used as medicines (Table 1.4).

1.4.2 Distribution of Threatened Medicinal Plants

Macro analysis of the distribution of medicinal plants shows that they are distributed across diverse habitats and landscape elements. Around 70% of India's medicinal plants are found in tropical areas mostly in the various forest types spread across the Western and Eastern Ghats, Vindhyas, Chota Nagpur Plateau, Aravalis, and Himalayas. Although less than 30% of the medicinal plants are found in the temperate and alpine areas and higher altitudes, they include species of high medicinal value. Macro studies show that a larger percentage of the known medicinal plant occurs in the dry and moist deciduous vegetation as compared to the evergreen or temperate habitats.

Analysis of habits of medicinal plants indicates that they are distributed across various habitats. One-third are tress and equal portion shrubs and the remaining one-third herbs, grasses, and climbers. A very small proportion of the medicinal

Table 1.4 Genetic diversity of some important medicinal plants

Sl. no	Species	Country	Genetic diversity	Reference
1	*Artemisia annua*	India	Eight individuals of a population showed chemotypic and genetic variation	Sangwan et al. (1999)
2	*Asparagus racemosus*	India	Accessions of A. racemosus and ornamental species showed 48.3%	Lal et al. (2012)
3	*Butea monosperma*	India	16 accessions from five provinces showed genetic divergence	Khan et al. (2008)
4	*Catharanthus roseus*	India	14 cultivars displayed 82% polymorphism	Shaw et al. (2009)
5	*Coleus forskohlii Coleus aromaticus*	India	Three species exhibited genetic diversity	Govarthanan et al. (2014)
6	*Dioscorea opposita*	China	28 cultivars exhibited 83% polymorphism	Zhou et al. (2008)
7	*Gymnema sylvestre*	India	Plants collected from 12 geographical regions recorded 85% polymorphism	Mouna et al. (2014)
8	*Ginkgo biloba*	China	Nine populations recorded 97.9% polymorphism	Fan et al. (2004)
9	*Hippophae* spp.	Different countries	Genetic diversity is high among populations, origins and subspecies	Cheng et al. (2007)
10	*Justicia adhatoda*	Pakistan	Genetic diversity was high (90%) within populations due to absence of genetic drift	Gilani et al. (2011)
11	*Morinda citrifolia M. tinctoria*, *M. pubescens*	India	22 accessions collected from four regions showed polymorphism	Singh et al. (2011)
12	*Ocimum basilicum*	India	All markers recorded 100% polymorphism	Lal et al. (2012)
13	*Oroxylum indicum*	India	Accessions collected from eight locations indicated high similarity with 49.6% polymorphism	Jayaram and Prasad (2008)
14	*Phyllanthus emblica*	India	Four populations exhibited genetic diversity	Shaanker and Ganeshaiah (1997)
15	*Rauvolfia tetraphylla*	India	Plants from five populations recorded 98% polymorphism	Saidi et al. (2013)
16	*Commiphora wightii*	India	Accessions collected from different locations recorded 83.5% polymorphism with 0.55–0.79 similarity coefficients	Suthar et al. (2008)
17	*Crocus sativus*	Iran	Observed and expected heterozygosities varied from 0.07 to 0.92 and 0.10 to 0.58, with 2.6 alleles/locus	Nemati et al. (2012)

(continued)

Table 1.4 (continued)

Sl. no	Species	Country	Genetic diversity	Reference
18	*Cephaelis ipecacuanha*	Brazil	50 wild clusters with 291 aerial stems showed no genetic differentiation at the cluster level	de Oliveira et al. (2010)
19	*Cassia occidentalis*	India	10 accessions from different districts had 71.2% polymorphism	Arya et al. (2011)
20	*Gardenia jasminoides*	China	Eight wild or cultivated populations registered 67.6% polymorphism	Han et al. (2007)
22	*Melissa officinalis*	Iran, Germany, Japan	Nine populations from Iran and each one from Germany and Japan revealed significant variation in morphoagronomic traits	Aharizad et al. (2012)
23	*Podophyllum hexandrum*	India	12 accessions displayed high degree of genetic diversity	Sultan et al. (2010)
24	*Mucuna monosperma*	India	25 accessions of five species collected from seven provinces displayed high polymorphism	Sathyanarayana et al. (2011)

plants are lower plants like lichens, ferns algae, etc. Majority of the medicinal plant are higher flowering plants.

Of the 386 families and 2200 genera in which medicinal plants are recorded, the families Asteraceae, Euphorbiaceae, Lamiaceae, Fabaceae, Rubiaceae, Poaceae, Acanthaceae, Rosaceae, and Apiaceae share the larger proportion of medicinal plant species with the highest number of species (419) falling under Asteraceae.

About 90% of medicinal plant used by the industries is collected from the wild. While over 800 species are used in production by industry, less than 20 species of plants are under commercial cultivation. Over 70% of the plant collections involve destructive harvesting because of the use of parts like roots, bark, wood, and stem and the whole plant in case of herbs. This poses a definite threat to the genetic stocks and to the diversity of medicinal plants, if biodiversity is not sustainably used (Table 1.5).

1.4.3 Threatened Medicinal Plant Resource Base

Medicinal plants are living resource, exhaustible if overused and sustainable if used with care and wisdom. At present 95% collection of medicinal plant is from wild. Current practices of harvesting are unsustainable, and many studies have highlighted depletion of resource base. Medicinal plant-based industries although old and vast are still being managed on traditional ethos and practices and lack a proactive and socially responsible image. Many studies have confirmed that pharmaceutical companies are also responsible for inefficient, imperfect, informal, and opportunistic marketing of medicinal plants. As a result, the raw-material supply

Table 1.5 International organizations working on medicinal plants

Sl. no	Organization	Headquarter	Area of work
1	Asia Pacific Information Network on Medicinal and Aromatic Plants	Philippines	To share databases of medicinal plants among its members
2	Botanic Gardens Conservation International	Kew, London	Forms the world's largest plant conservation network
3	Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)	Washington, D.C.	Treaty to protect endangered plants
4	Fair-trade labeling organizations	Bonn, Germany	Product certification of medicinal plants
5	International organic trade association	North America	Focuses on the organic trade of medicinal plants
6	International Trade Center	Geneva, Switzerland	Providing trade technical assistance in countries all over the world
7	Medicinal Plants Specialist Group of the Species Survival Commission of IUCN	Gland, Switzerland	Conservation and sustainable use of medicinal plants
8	Trade Record Analysis of Fauna and Flora in Commerce (TRAFFIC)	Cambridge, United kingdom	Trade of wild plants and animal species
9	United Nations Environment Program (UNEP)	Nairobi, Kenya	Assists developing countries in implementing environmentally sound policies and practices
10	United Nations Industrial Development Organization (UNIDO)	Vienna, Austria	Promotion of international industrial cooperation
11	World Fair Trade organization	Culemborg, The Netherlands	Improving the livelihoods of economically marginalized producers
12	World Health Organization (WHO)	Geneva, Switzerland	Shaping the research agenda and stimulating the generation, translation, and dissemination of valuable knowledge
13	World Wide Fund for Nature (WWF)	Gland, Switzerland	Wilderness preservation

situation is shaky, unsustainable, and exploitative. There is a vast, secretive, and largely unregulated trade in medicinal plants, mainly form the wild that continues to grow dramatically in the absence of serious policy attention with environmental planning. Confusion also exists in the identification of plant materials where the original of a particular drug is assigned to more than one plant, sometimes having vastly different morphological and taxonomical characters. There are few others, where the identity of plant sources is doubtful or still unknown; therefore, adulteration is common in such cases.

The other main source of medicinal plant is form cultivation. Cultivated material is infinitely more appropriate for use in the production of drugs. Indeed,

standardization whether for pure products, extracts, or crude drugs is critical, increasingly so, as quality requirements continue to become more stringent.

Given the higher cost of cultivated material, cultivation is often done under contract. In the majority of cases, companies would cultivate only those plant species which they use in large quantity or in the production of derivatives and isolates, for which standardization is essential and quality is critical. More recently, growers have set up cooperatives or collaborative ventures in an attempt to improve their negotiating power and achieve higher price.

Of the 270, 000 plant species in existence, 1 in 8 are considered endangered. One-quarter of plant species are at the risk of extinction within the next generation.

Special aspects of endangered species are as follows:

1. Limited amount of plant material available
2. Ability to test protocols severely limited
3. Plants located in remote areas
4. Resources available are also limited

Most biologists consider a species endangered if they expect it would die off completely in less than 20 years if no special efforts were made to protect it, or if the rate of decline far exceeds the rate of increase. Until the last few centuries, species became rare or died out as a result of natural causes. These causes included changes in climate, catastrophic movements in the earth's crust, and volcanic eruptions. Today, species become endangered primarily because of human activities. Species mainly become endangered because of (1) loss of habitat and (2) wildlife trade.

Many wild species are protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This treaty, originally signed by 10 nations in July 1975, aims to control trade in wildlife, plants, and their products. By the late 1990s, over 140 countries had ratified it.

The International Union for the Conservation of Nature and Natural Resources (IUCN) and the World Conservation Union compile lists of endangered plants. Their lists include 34,000 species of plants that are threatened or endangered.

The IUCN Red Lists of Threatened Species are a compilation of plant or animal species categorized as critically endangered, endangered, or vulnerable according to the IUCN categories of threat. For the most part, the Species Survival Commission (SSC) Specialist Group covering the taxa in question makes categorizations with the newer 1994 IUCN criteria.

Many wild species are protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This treaty, originally signed by 10 nations in July 1975, aims to control trade in wildlife, plants, and their products. By the late 1990s, over 140 countries had ratified it (Table 1.2).

The IUCN (International Union for the Conservation of Nature and Natural Resources) and the World Conservation Union compile lists of endangered plants and animals. Their lists include about 34,000 species of plants that are threatened or endangered. Protecting habitat is the key method of preserving endangered species. Many governments and organizations have set aside nature preserves.

Table 1.6 Wild collections used as medicinal plants in different countries

Country	Wild plants used as medicinal (%)
India	77
Europe	90
China	60–80
United States	90
Germany	70–90
Hungary	30–35
Spain	50
Ecuador	90
Albania	90–100
Romania	11,300

Since 1997, an extensive consultation has been carried out to review the IUCN Red List assessment system, and some changes to the categories and criteria have now been agreed on. Taking the data from the Red List analysis book, certain "hotspots" appear. The main areas where mammals, birds, and plants (trees) seem to require the most conservation effort are in the Neotropics (Brazil, Colombia, Ecuador, and Mexico), East Africa (Tanzania), and Southeast Asia (China, India, Indonesia, and Malaysia) (Table 1.6).

The goals of the IUCN Red List Program are to:

- Provide a global index of the state of degeneration of biodiversity.
- Identify and document those species most in need of conservation attention if global extinction rates are to be reduced.

The first of these goals refers to the traditional role of the *IUCN Red List*, which is to identify particular species at risk of extinction. The role of the *IUCN Red List* in underpinning priority setting processes for single species remains of critical importance. However, the second goal represents a radical new departure for the SSC and for the Red List Program, for it focuses on using the data in the Red List for multispecies analyses in order to understand what is happening to biodiversity more generally (Table 1.7).

To achieve these goals, the following objectives are proposed:

- To assess, in the long term, the status of a selected set of species.
- To establish a baseline from which to monitor the status of species.
- To provide a global context for the establishment of conservation priorities at the local level.
- To monitor, on a continuing basis, the status of a representative selection of species (as biodiversity indicators) that cover all the major ecosystems of the world.

Listing criteria are now as follows:
Listing in Appendix I (Table 1.8):

Table 1.7 Genetic erosion in medicinal plants

Country	Number of plants eroded	Plant species
China	3000	*Scutellaria baicalensis*, *Panax notoginseng*, *Acanthopanax senticosus*, *Asarum heterotropoides var. mandshuricum*, *A. lancea*, *Bupleurum chinense*, *Cistanche deserticola*, *Dioscorea zingiberensis*, *Ephedra sinica*, *Eucommia ulmoides*, *Magnolia officinalis*
Africa	59,000–90,000	*Warburgia ugandensis*
Chile		*Haplopappus taeda*
India	265	*Gnidia glauca* var. *sisparensi*, *Phyllanthus emblica*, *Calligonum polygonoides*, *Justicia adhatoda*
Brazil		*Carapichea ipecacuanha*
Nepal		*Swertia chirayita*
Europe	150	–
Croatia	17	–
Ukraine	202	–
Estonia	16	–
Finland	20	–

Table 1.8 Medicinal plant species listed in CITES (Appendix I)

	Source
Aloe barbadensis	(Korean Government) (Roberson 2008) (Hawkins 2008) (AHPAAmerican 2014)
Rauvolfia serpentina	(Schippmann 2001)
Saussurea costus	(BGCI) (R&D center of Flower Valley Agrotech 2005) (Hawkins 2008) (AHPAAmerican 2014)
Cyathea dregei	(Schippmann 2001)
Dioscorea deltoidea	(Schippmann 2001) (BGCI) (R&D center of Flower Valley Agrotech 2005)
Diospyros borneensis	(Department of Agriculture of Brunei Darussalam Government 2000)
Euphorbia spp.	(AHPAAmerican 2014)
Gnetum montanum	(Schippmann 2001)
Pterocarpus erinaceus	(Useful Tropical Plants 2017)
Swietenia humilis	(Useful Tropical Plants 2017)
Fraxinus mandshurica	(Korean Government)
Podocarpus neriifolius	(Schippmann 2001)
Picrorhiza kurrooa	(Schippmann 2001)
Nardostachys grandiflora	(Schippmann 2001)
Siphonochilus aethiopicus	(Schweinf and Burtt 2017)
Guaiacum officinale	(Schippmann 2001)

Source: Convention on international trade in endangered species of wild fauna and flora