Review Article
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Bio-diversity and conservation of medicinal and aromatic plants

Abstract

The emerging field of herbal products industry holds a great potential to the economic development of the Indian region. Usage of herbs as a source of food, medicine, fragrance, flavour, dyes and other items in Indian systems of medicine is in increasing trend. It is estimated that, 95% of the medicinal plants used in Indian herbal industry today are collected from wild. Although there are around 8,000 medicinal plant species used by different communities in India across different ecosystems, only around 10% of them are in active trade. There is need to encourage multiplication and cultivation of these plants. The three basic scientific techniques of conservation of genetic diversity of these plants are legislation, in-situ conservations and ex-situ conservations.

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Introduction

India, with its diverse agro-climatic conditions and regional topography, has been considered as the treasure house or botanical garden of plant genetic resources. Hence, India is recognized as one of the world's top 12mega diversity nations. Our herbal wealth constitutes more than 8,000 species and accounts for around 50% of all higher flowering plant species of India; around 70% of the medicinal plants in the country are spread across the tropical forests of Western Ghats. However, available information shows that 1,800 species are used in Classical Indian systems of medicines. Ayurveda uses 1,200, Siddha -900, Unani -700, Amchi -600, Tibetan-450. The emerging field of herbal products industry holds a great potential to the economic development of the Indian region. Usage of herbs as a source of food, medicine, fragrance, flavour, dyes and other items in Indian systems of medicine is in increasing trend. It is estimated that, 95% of the medicinal plants used in Indian herbal industry today are collected from wild. About half a million tonnes of dry material is collected through destructive means indiscriminately and 1.65 lakh ha. of forest is cleaned and felled each year. With the increase in population, rapid expansion of area under food and commercial crops, deforestation, extension of urban area, establishment of industries in rural areas, etc., there is considerable depletion of plant genetic resources wealth, many of them being in the process of extinction day by day.[1,2]

Biodiversity – overview

Although there are around 8,000 medicinal plant species used by different communities in India across different ecosystems, only around 10% of them (880species) are in active trade. Among these, around 48 species are exported in the form of raw drugs and extracts, while around 42species are imported. The wild populations of about 100 of the traded species are known to have declined, thereby making them to be considered threatened. This is the situation of raw drug trade in India that unfolds. Before ascertaining the reasons for this, let us try to understand the "what", "where" and "how much" of these raw drugs.

How many herbs?

Habit wise analysis of these 880 medicinal plants, indicates that these are well distributed across different life forms with the majority belonging to the herbaceous category. The highest proportion of herbs (41%), including grasses, is followed by trees (26%), shrubs (17%) and climbers (16%).

Botanical base

It is interesting to note that these 880 traded plants are distributed across 151 families. Of these 79% belong to the Dicots while the Monocots constitutes 11% followed by Pteridophytes 5% and Gymnosperms 3% and one percent each from Fungi and Lichens. This indicates that a very small proportion of raw drugs belong to the category of lower classes in the plant kingdom (Table 1).

Table 1 Botanical representation of traded medicinal plants (Class wise)

Class	Number of Families
Dicots	119
Monocots	17
Pteridophytes	8
Gymnosperms	5
Fungi	1
Lichens	1

Geographic distribution

India is one of the world's top 12 mega diversity countries with 10 bio geographic regions. India alone includes two among the world's eight biodiversity hotspots. The climatic and altitudinal variations, coupled with varied ecological habitats of this country, have contributed to the development of immensely rich vegetation with a unique diversity in medicinal plants which provides an important source of medicinal raw materials for traditional medicine systems, as well as for pharmaceutical industries in the country and abroad. World Health Organization has listed over 21000 plant species used around the world for medicinal purpose. In India, about 2500 plant species are being used in indigenous system of medicine. The red data book lists 427 Indian Medicinal plant entries on endangered species, of which 28 are considered extinct, 124 endangered, 81 rare and 34 insufficiently known (Table 2).

The natural occurrence of traded species is another element of interest here. It is found that these species are distributed across

different bio-geographic zones, diverse habitats and landscape elements. About 18% of these species are confined to Himalayan and Trans Himalayan zone including North East India while around 4% is restricted to Western Ghats and 0.5% is found only in the Desert zone. The rest of the species (around 77%) have a wide range of distribution across the other bio-geographic zones of the country (Table 3).

Table 2 Botanical representations of traded medicinal plants (Family wise)

Family	Species
Fabaceae	67
Asteraceae	54
Euphorbiaceae	48
Caesalpiniaceae	41
Apiaceae	37
Lamiaceae	37
Solanaceae	35
Cucurbitaceae	32
Rubiaceae	29
Malvaceae	28

Endangered medicinal plants

Plant parts like leaves, bark, roots, fruits, seeds or even whole plant is indiscriminately collected from wild sources without taking care of saving the plants. Many of the important useful species are on the verge of extinction due to over-exploitation and habitat destruction. More than 95% of the medicinal plants are collected from the wild; a number of them have become endangered in their natural habitats. There is need to encourage multiplication and cultivation of these plants. Collection of the following species from wild sources should be prohibited.

Aconitum sp. (Monk's Hood, Bachang), *Acorus* spp.(Sweet Flag, Vekhand), *Anchusa strigosa* (Gaozaban), *Aristolochia bracteata* (Kiramar), *Artemisia annua* (Worm wood), *Atropa acuminata* (Indian belladonna), *Berberis aristata* (Indian Berbery, Daru Haridra), *Brunium persicum* (Kala Zeera), *Chlorophytum* spp (Safed Musli), *Colchicum luteum* (Tara-Tutiya, Suranjan-1- Talah, Golden Collyrium), *Commiophora wightii* (Guggul), *Concinum fariestatum* (Jeevanti), *Coptis teeta* (Halad-Vachnag, Gold Thread, Mamira), *Curculigo orchioides* (Kali Musli), *Didymocarpus pedicellata* (Shila-Pushpa), *Dorsera* sp. (Sundew), *Ephedra gerardiana* (Somlata), *Eulophia campestris* (Saleb Misri), *Ferula jaeskaena* (Indian Hing), *Gentiana kurroa* (Indian Gentian Pashanbheda), *Gloriosa superba* (Glory Lily, Agnisikha), *Gynocardia odorata* (Kadu Bonsha), *Holostemma annualare* (Peet Chandan, Kasturi Mazil*), Hydrocarpus* sp., *Hyoscyamus niger* (Henbane), *Inula racemosa* (Pshkar Mool*), Iphigenia indica* (Nirpani), *Lilium polyphyllum* (Kshira Kankoli), *Microstylis nicifera* (Jeevaka), *Microstylis wallichii* (Rishvake), *Nardostachys grandiflora* (Jata mansi), *Onosma bracteatum* (Ratnajyot), *Orchis latifolia* (Salam Panja), *Panax pseudo-ginseng* var. *himalicus* (Indian Ginseng), *Physochlaena praelta* (Scholar, Lalthang), *Picrorhiza kurroa* (Kutki), *Piper cubeba* (Kababchini), *Podophyllum hexandrum* (Bankari), *Rauwolfia serpentina* (sarpagandha), *Rheum astrata* (Rewadchini), *Rheum emodi* (Indian Rhubarb, Gandhini), *Saussurea sacra* (Yogispada), *Swertia chirayata* (Chirayata), *Taxus baccata* (Talispatra), *Taxus wallichiana* (Indian Yew).

Table 3 Bio-geographical distribution of traded medicinal plants

Bio-geographic Zones	No of Medicinal Plants Identified	Example Species
Trans – Himalayan	700	*Ephedra gerardiana, Hippophae rhamnoides, Physochlania praalta, Arnebia euchroma, Ferula jaeschkeana*
Himalayan	2900	*Aconitum heterophyllum, Arnebia benthamii, Dactylorhiza hatagirea, Podophyllum hexandrum, Picrohiza kurroa, Pistacia chinensis, Nardostachys grandiflora, Rubia sikkimensis, Coptis teeta, Polygonatum cirrhifolium, Swertia chirayata, Valeriana jatamansi, Rhododendron anthopogon, Taxus wallichiana.*
Desert areas	500	*Tecomella undulata, Tribulus rajasthanensis, Citrullus colocynthis, Commiphora wightii, Acacia nilotica*
Semi-arid areas	1000	*Balanites aegyptiaca, Withania coagulens, Tribulus alatus, Commiphora wightii, Boswellia serrata, Canscora, Acacia nilotica.*
Western ghats	2000	*Myristica malabarcia, Garcinia indica, Coscinium fenestratum, Hydnocarpus pentatandra, Garcinia gummigutta, Vateria indica, Nilgirianthus ciliatus.*
North East India	2000	*Aquilaria malacensis, Smilax glabra, Ambroma augusta, Hydnocarpus kurzii, Vetivaria zizaniodes.*
Deccan peninsula	3000	*Embelia tsjeriam-cottam, Caesalpinia digyna, Screbera sweitenoides, Decalepis hamiltonii, Pterocarpus santalinus.*
Gangetic plains	1000	*Holarrhenaq pubescens , Mallotus philippensis , Pluchea lanceolata, Peganum harmala.*
Andaman & Nicobar islands	1000	*Claophyllum inophyllum , Adnanthera pavonina , Barringtonia asiatica, Aisandra butyrace.*
Coastal islands	500	*Rhizophora mucronata Lam., Acanthus ilicifolius, Avicennia marina, Sonneratia caseolaris.*

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Loss of biodiversity of medicinal plants

Environmental factors

Rainfall: For the past few years the annual rainfall has decreased resulting in the health of many herbaceous species during summer months.

Deforestations: Deforestations have been reported over the last two decades. The spread of agriculture, logging, fire wood collection, heavy wood collection, heavy grazing, etc., are the main reasons for reduction in area under valuable forests. Many valuable wild medicinal plant species are eradicated or minimized every year due to the deforestation activities.

Siltation of water bodies: Siltation of water bodies in the forests has resulted in the reduction of water holding capacity heading to depletion of underground water.

Lack of pollinators: Honey bee colonies have declined in numbers to the extent of 50-60%, in forests and other areas. Loss of pollinators has resulted in reduced seed set and dispersal of seeds.

Developmental activities

Submersion: Loss of many species of medicinal plants has been noticed in forests due to submersion, eg., the Maradavally forest is the catchments of Linganamakki Dam, the main reservoir of Karnataka for irrigation and power generation. Submersion of nearly 10sq. km of forest area during monsoons has resulted in loss of valuable medicinal plant species.

Infrastructure: Expansion of roads, installation of power lines and construction of buildings has caused extensive damage to forests and medicinal plants, eg., Devanarayandurga forest in Karnataka.

Agriculture and forestry methods

Monoculture: There has been a progressive increase in monoculture plantations of economically important indigenous as well as exotic species in forest. Monoculture plantation totally affects the organic productivity and reduces the natural stability and complexity resulting in loss of medicinal plants. eg., *Eucalyptus* and *Acacia* species in many forests.

Encroachments: Encroachments over forestlands have assumed alarming levels. Apart from felling of trees and clearing vegetation, the cultivation practices followed on high sloppy lands has caused soil erosion, and decline of medicinal plant wealth.

Over-exploitation: Gathering of medicinal plants from the forests are rampant. The collection was by unorganized forest collectors, who, in turn sold the product to a contractor at the price fixed by the latter. But now, due to the awareness created by the members of the 'Local Traditional Medicinal Practitioners Association', illegal gathering has been controlled to a certain extent.

Conservation of medicinal and aromatic plants

Conservation strategy (IUCW, UNEP & WWF, 1980) defines conservation as "the management of human use of the biodiversity so that it may yield the greatest sustainable benefit to present generation while maintaining its potential to meet the needs and aspirations of future generations".

Strategies & priorities: The primary goals of biodiversity conservation as envisaged in the World Conservation Strategy can be summarized as follows:

i. Maintenance of essential ecological processes and life support systems on which human survival and economic activities depend.

ii. Preservation of species and genetic diversity and sustainable use of species and ecosystems which support millions of rural communities as well as major industries.

Strategies for conservation of medicinal plants

The conservation of the wild medicinal plants or any other such threatened species can be tackled by scientific techniques as well as social actions.

There are basically three scientific techniques of conservation of genetic diversity of these plants.

i. Legislation

ii. *In-situ*conservation

iii. *Ex-situ*conservation

Legislation: There are no separate policies or regulations for conserving medicinal plants growing in forests in India. There conservation is covered under existing laws pertaining to forestry. Following are the laws formulated by government of India for conservation of forests which directly or indirectly protects the wild herbal flora.

i. Forest Act, 1927

ii. Wildlife (Protection) Act 1972 and Wildlife (Protection) Amendment Act 1991

iii. Forest (Conservation) Act, 1980

iv. Environment Protection Act, 1986

v. National forest policy, 1988

vi. National biodiversity act, 2002

The scheduled tribes and other traditional forest dwellers act, 2006

In-situconservation

i. Conservation of a given species in its natural habitat or in the area where it grows naturally is known as *in-situ* conservation.

ii. It includes Gene bank/Gene sanction, Biosphere reserves, national parks, sacred sites, Sacred grooves etc.

iii. It is only in nature that plant diversity at the genetic, species and eco-system level can be conserved on long-term basis

iv. It is necessary to conserve in distinct, representative biogeographic zones inter and intra-specific genetic variation.

It is cost-effective way of protecting the existing biological and genetic diversity is the 'in-situ' or on the site conservation wherein a wild species or stock of a biological community is protected and preserved in its natural habitat. The prospect of such a 'ecocentric', rather than a species centred approach is that it should prevent species from becoming endangered by human activities and reduce the need for human intervention to prevent premature extinctions. Establishment of biosphere reserves (Table 4), national parks, wild life sanctuaries, sacred groves and other protected areas forms examples of *'in-situ'*

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methods of conservation. The idea of establishing protected area network has taken a central place in all policy decision process related to biodiversity conservation at national, international and global level.

The most commonly referred *in situ* conservation methods are highlighted below:

Biosphere reserves: The Ministry of Environment and Forest, Government of India, had identified 14 biosphere reserves based on survey data and 7 of them have already been made operational by now (Table 4).

Table 4 Biosphere reserves in India

Sl.No.	Biosphere reserve	Area (sq. km	State
1.	Nokrek	80	Meghalaya
2.	Nilgiri	5520	Karnataka, Kerala, Tamil Nadu
3.	Namdapha	4500	Arunachal Pradesh
4.	Nanda Devi	1560	Uttar Pradesh
5.	Sunderbans	9630	West Bengals
6.	Great Nicobar	885	Andaman & Nicobar Islands
7.	Gulf of Manner	555	Tamil Nadu
8.	Manas	2837	Assam
9.	Valley of Flowers	2000	Uttaranchal
10.	Kaziranga	760	Assam
11.	Thar Desert	760	Rajasthan
12	Kanha	760	Madhya Pradesh
13	Rann of Kutch	2000	Gujarat

National parks: Out of a total of 91 National Parks in the country, 2 have been established in Himachal Pradesh, that is, Pin Valley National Park and Great Himalayan Park in the districts of Lahaul-Spiti and Kulu, respectively.

In addition to the above wildlife sanctuaries (448), there are World Heritage sites (5), Wetlands (19, including 6 Ramsagar sites), Mangroves (15), Coral Reefs (4) and other areas such as sacred groves, natural monuments, ethno-biological reserves, etc. These will definitely serve in conserving biodiversity in their respective regions However, experiences have amply demonstrated that in a densely populated developing country like India, where a sizeable population are living in close proximity to forests, declaring protected areas will not entirely be sufficient to ensure conservation on the fast eroding biological diversity. The success of any conservation programme vests solely on the efficient management of protected areas. The involvement of local communities in conservation activities has now been increasingly realised. A people nature-oriented approach thus becomes highly imperative. This will help to generate a sense of responsibility among the local people about the values of biodiversity and the need to use it sustainably for their own prosperity and the maintenance of ecosystem resilience. *In-situ* conservation of medicinal plants in India can be accomplished through the active support and participation of people who dwell in or near and around the protected forest areas.

Sacred groves

Sacred groves are small or large patches of vegetation protected on the basis of cultural and traditional practices on the religious background (Table 5).

Table 5 Sacred groves in India

States	Number of documented groves
Andhra Pradesh	750
Arunachal Pradesh	58
Assam	40
Chhattisgarh	600
Gujarat	29
Haryana	248
Himachal Pradesh	5000
Jharkhand	21
Karnataka	1424
Kerala	2000
Maharashtra	1600
Manipur	365
Meghalaya	79
Orissa	322
Rajasthan	9
Sikkim	56
Tamil Nadu	448
Uttaranchal	1
West Bengal	670
Total	13720

The other complementary methods of *in-situ* conservation are:

i. **On-farm conservation**: On-Farm Conservation involves the maintenance of traditional crop cultivars (land races) or farming systems by farmers within the traditional agricultural system. Traditional farmers use land races, which are developed by the farmer and well adapted to the local environment. This method of conservation has been gaining importance in recent years, though farmers have used it for centuries. In case of agro biodiversity, the effects of growers practices are of paramount importance. Systemic documentation of farmers' knowledge of diversity and usages is needed.

ii. **Home gardens**: Home garden conservation is very similar to on-farm conservation, however scale is much smaller. In rural situations, home gardens tend to contain a wide spectrum of species such as vegetables, fruits, medicinal and spice plants.

iii. **Zero energy input based** concept of parafrost conservation in the Himalayan region which remains covered with snow.

Outlines for in-situ management

A. The Parks Department should prepare a policy at national level on the conservation and utilization of medicinal plants in protected areas.

B. The policy should include:

C. Identifying which of the protected areas are most important for medicinal plants;

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D. Targets and techniques for recording and monitoring medicinal plants in protected areas;

E. Techniques and procedures for collection of medicinal plants within protected areas.

F. The Parks Department should assess the extent to which the protected areas system covers the medicinal plants of the country. It should then create new protected areas and extend existing ones to ensure that all the medicinal plants of the country are conserved. The Parks Department should devise economic and social incentives for maintaining natural habitats and wild species.

G. Park managers should ensure that the conservation and exploitation of medicinal plants are incorporated into site management plans.

H. Species that are heavily depleted by over-collection should be re-introduced into areas where they once grew wild.

Ex-situ conservation

Conservation of medicinal plants can be accomplished by the ex-situ i.e. outside natural habitat by cultivating and maintaining plants in botanic gardens, parks, other suitable sites, and through long term preservation of plant propagules in gene banks (seed bank, pollen bank, DNA libraries, etc.) and in plant tissue culture repositories and by cryopreservation).

Field gene bank (field repository/clonal repository)

i. (Gene Bank: Storage in the form of seed (Base collection at -20°C; Active collection at +4°C to l0°C). The three national gene banks have been established in India for *ex situ* conservation of medicinal and aromatic plants.

ii. National Bureau of Plants Genetic Resources (NBPGR), New Delhi, under ICAR.

iii. Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow, Uttar Pradesh, under the Council of Scientific Industrial Research (CSIR), Ministry of Science and Technology, Government of India.

iv. (Tropical Botanical Gardens Research Institute, (TBGRI), Palode, Thiruvananthapuram (Kerala).

v. The conservation of genetic variability of cultivated plants and their wild relatives is the sole responsibility of the National Bureau of Plant Genetic Resources (NBPGR) that operates under the Indian Council of Agricultural Research (ICAR), Department of Agricultural Research and Education (DARE).

Seed gene bank

Germplasm conservation in Seed Gene Bank is more economical. The NBPGR, New Delhi, houses National Gene Bank (NGB) which is primarily responsible for conservation of germplasm of agri-horticultural crops and their wild relatives for long-term seed storage for posterity. These are referred to as "Base Collection" stored in modules maintained at -20°C. The seeds are dried to attain 4-6 per cent moisture content and hermetically sealed in moisture proof aluminium foil packets. These stored seeds remain viable for 50 to 100years. In most crops, seeds samples with more than 85 per cent seed viability are only processed. The seeds in gene bank are stored preferably as per the gene bank standards recommended by FAO/IPGRI.

National active germplasm sites

The national active germplasm sites (NAGS) are the integral component of the network. There are presently 40 NAGS, which are based at ICAR institutes, (crop-based institutes for a specific crop or a group of crops) and SAUs. These are integral part of national plant biodiversity conservation network. The NAGS are entrusted with the responsibility of multiplication, evaluation, maintenance and the conservation of active collection and their distribution to bonafide users both at the national and international levels. These active/ working collections are stored in modules maintained at +4°C and 35-40 per cent relative humidity (RH). Under these temperatures, seeds are expected to remain viable for 15 to 50years. For medium term storage, seed moisture content is brought down to 8 to 10 per cent. The NBPGR has a network of II regional stations located in different agroclimatic zones of the country to support the active germplasm conservation activities of the regions.

Cryopreservation (in liquid nitrogen at-165°C to-196°C)

Cyropreservation or freeze preservation under liquid nitrogen.

i. **Seed preservation**: The seeds have been grouped broadly into two categories, based on their response to dehydration.[3] A majority of them are desiccation tolerant, called 'Orthodox' and hence can be stored for longer durations. The second group of plant species are called 'Recalcitrant', whose seeds suffer injury on their drying and therefore cannot be stored at subzero temperatures.

ii. **Pollen preservation**: Pollen storage was mainly developed as a tool for controlled pollination of synchronous flowering in plants, especially in fruit tree species. In addition, pollen storage has also been considered as an emerging technology for genetic conservation.[4–6] Pollen can easily be collected and cryo-preserved in large quantities in relatively small spaces.

iii. Exchange of germplasm through pollen poses fewer plant quarantine problems. In recent years, cryo-preservation techniques have been developed for pollen in a large number of species[7] and cryo-bank of pollen has been established for fruit-tree species in several countries.[8]

In vitro (on tissue culture) conservation

The essential prerequisites for an *in vitro* conservation programme are creation of special. facilities (culture rooms with controlled environment, artificial lights, laminar airflow cabinets, autoclave, etc.) and trained scientists and technicians. Information on the *in vitro* multiplication and/or conservation protocols of those plant species is also desirable. Any *in vitro* conservation programme primarily comprises two stages:

i. *in-vitro* multiplication to build up a large number of plants, and

ii. *in vitro* storage. The material stored *in vitro* may be in the form of meristems, shoot tips, axillary buds, embryos, and even callus and cell suspension. *In vitro* gene banks are easy to maintain and often inexpensive provided effective storage systems are developed.

DNA storage (Conservation at -20°C)

Storage of DNA is, in principle, simple to carry out and widely applicable. The storage of DNA seems to be relatively easy and cheap.

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In recent years genetic engineering has resulted in breaking down the species and genus barriers for transferring genes. Transgenic plants have been produced with genes transferred from viruses, bacteria and fungi and even mice. These efforts have led to the establishment of DNA Libraries. Necessary strategies and procedures have to be developed on how to use the material stored in the form of DNA.

Botanical gardens/arboreta

A botanical garden is an institution holding documented collection of living plants for the ' purpose of scientific research, conservation, display and education.[9] They serve as repositories of germplasm collections, specially rare and endangered ones of indigenous and exotic origin.[10] Botanic Garden Conservation International (BGCI), an international organisation with its headquarters in London (UK) was established in 1987 for global co-operation and monitoring the conservation programmes of the botanical gardens. The BGCI has 500 member botanical gardens in III countries all over the world.[9] There are about 1,846 botanical gardens worldwide as per the BGCI database. India has a network of about 140 botanical gardens which include 33 botanical gardens attached to 33 universities botany departments. But hardly 30 botanical gardens have any active programme on conservation. Tropical Botanical Gardens & Research Institute (TGBRI), located in a degraded forest region of Western Ghat Mountains in Kerala has an excellent example in ex-situ conservation of plant diversity in India.

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Conflict of interest

The author declares no conflict of interest.

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