Chapter 13
Conservation and Utilization of High-Altitude Threatened Medicinal Plants

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Abstract The Himalayan region is bestowed with unique flora found nowhere on the earth. The Indian Himalayas are complex and dynamic ecosystems nurturing approximately 8644 plant species. Among these, medicinal plants are predominant floral wealth of Himalayas with almost 1748 of species being utilized for curing diseases since time immemorial. These medicinal plants have enormous national and international demand as raw material leading to their illegal and unscientific harvesting at large scale from the wild in the absence of regulated cultivation practices. Almost 90% of the raw material of these herbs used in the pharmaceutical industries is collected from the wild, out of which 70% is destructively harvested. The demand for these high-value Himalayan medicinal and aromatic Plants (MAPs) is increasing every year despite of their low availability because of the multiple medicinal value of these herbs. These medicinal plants form part of Indian economy, are source of livelihood for local inhabitants, and also form part of local healthcare. Presently, most of the medicinal plants of Himalaya are in peril owing to large-scale illegal and unscientific harvesting, habitat destruction, lack of sufficient knowledge of their ecology and biology, and limited research and development initiatives. About 120 species of Himalayan medicinal plants are under various threat categories, according to International Union for Conservation of Nature (IUCN). Preventing extinction and sustainable utilization of these medicinal plants needs collaborative efforts by both government and researchers by restricting their harvest, reintroduction of species in their natural habitat, for development of in situ and ex situ conservation strategies, and developing techniques for scientific harvesting of these species. At national and international level, efforts made for conservation of Himalayan herbs by various government agencies, and nongovernmental organizations are also gearing up slowly, but immediate attention and serious efforts are

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needed to preserve these therapeutic agents for future use and for sustenance of the Himalayan ecosystem.

Keywords Himalayas · High altitude · Medicinal plants · Endangerment · Trade · Conservation · Sustainable utilization

Global use of medicinal plants in health care is increasing rapidly owing to the claims of efficacy of these plants, interest of public in herbal therapies and herbal medicines, strong belief that herbal products are superior to manufactured products, due to many side effects and high cost of modern drugs, and the growing self-medication movement (Bandaranayake 2006). It is estimated that 80% of the world's population living in the developing world depends on medicinal plants as a primary source of health care, and many people residing in the vicinity of the forests and villages use these herbs to ward off diseases traditionally (Mukherjee 2002; Bodeker et al. 2005; Bandaranayake 2006).

Nowadays developed countries are also focusing on medicinal herbs by practising complementary and alternative medicines (Calapai 2008; Braun et al. 2010; Anquez-Traxler 2011). Medicinal plants are viewed as a safe and balanced approach in healing, and people are ready to pay huge amount of money on herbal products resulting in rising demand for herbal medicines (Roberts and Tyler 1997; Blumenthal et al. 1998; WHO 2002; Kong et al. 2003; Pal and Shukla 2003; WHO 2005; Bandaranayake 2006).

As the global use of herbal medicinal products continue to grow and with the introduction of new herbal medicinal products into the market, public health issues, and concerns associated with their safety are also increasingly recognized by people. Although some of the herbal medicines have good potential in curing disease and are widely used, many herbs remain invalidated. Over 422,000 plant species worldwide possess medicinal value (Iqbal 1993) of which 52,885 species are traded globally (Schippmann et al. 2006). Wild resources serve as a main source (80–90%) of the medicinal plant species. The Indian *Ayurvedic* system alone uses around 1250–1400 medicinal plants species of which almost 80% are wild weeds (Hamilton and Radford 2007). This ever-growing global botanical market is affecting plant resources. The botanical plant market is US$ 20–40 billion worth and is increasing at an annual rate of 10–20% (Larson and Olsen 2007). A large proportion of Himalayan flora possesses medicinal value, and the region is becoming the global centre for medicinal plants (Hamilton and Radford 2007). These medicinal plants not only play an important role by directly contributing to healthcare system but also serve as primary source of income to local people (Rasul et al. 2012).

13.1 Diversity of Himalayan Medicinal Plants

The Himalayas is a rich store house of biodiversity and is known for its biodiversity hotspot in the world. The variations in its altitude, topographic, soil type, and climate factors are the reasons for sustaining such huge biodiversity (Mani 1978). The

Table 13.1 Distribution of medicinal plants

Country or region	Total number of native species in Flora	No. of medicinal plant species reported	% of medicinal plants in the region
World	297,000	52,885	10
India	17,000	7500	44
Indian Himalayas	8000	1748	22

Source: Kala (2006)

Himalayas cover 12.84% of the total geographical area of India (Negi 2009) and nearly 8000 species of flowering plants flourish there, out of which 25.30% are endemic to Indian Himalayas (Singh and Hajra 1996). Indian Himalayas being a complex and dynamic ecosystem harbours approximately 8644 plant species (Khan et al. 2012; Kumar and Maharaj 2018). The Himalayan ranges are spread into eight countries, that is, Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. Indian Himalayas lie between 27°50′N to 37°06′N and 72°30′E to 97°25′E and sustain a great diversity of plant species (Singh and Singh 1992). The Indian part of Himalayas cover an area of about 5 lakh km^2 (about 16.2% of country's total geographical area) and forms the northern boundary of the country. Indian Himalayas constitute about 8000 species of angiosperms, 44 species of gymnosperms, and 600 species of pteridophytes; 1748 of these species are of medicinal value. Out of the 1748 (32.2% of India) species of medicinal plants, 1685 are angiosperms, 12 are gymnosperms, and 51 are pteridophytes. Among these medicinal plants, 1071 are herbs, 335 are shrubs, and 330 are trees (Samant et al. 1998a, b) with the maximum medicinal plants (1717 species) being reported around the 1800 m elevation range (Samant et al. 1998a, b). A total of 62 out of total 1748 species of medicinal plants are endemic to the Indian Himalayas and 208 species are near endemic (Samant et al. 1998a, b). Due to the presence of these unique miraculous medicinal plant species, the Himalayas is globally renowned as a storehouse of medicinal plants (Table 13.1).

13.2 Trade of Himalayan Medicinal Plants

Himalayan Medicinal and aromatic plants (MAPs) are much in demand due their unique therapeutic properties, endemism and small populations. During 2014–15, the export demand of Indian medicinal plants was approximately 134,500 MT with export value of US$3211 crore, whereas the domestic demand was approximately 195,000 MT (http://www.nmpb.nic.in/content/medicinal-plants-fact-sheet retrieved on seventh May 2018). India consumed 512,000 MT of herbal raw drug during the period 2014–15. According to studies, 1178 species were traded, out of which 242 species were traded in excess of 100 MT/year (http://www.nmpb.nic.in/content/medicinal-plants-fact-sheet retrieved on seventh May 2018).

A total of 18.00% of the MAP material traded in India, and out of the 960 species, 350 (mostly demanded MAPs) are demanded in pharmaceutical industries, which are Himalayan MAPs (Export-Import Bank of India, 2003). The demand for these high-value Himalayan MAPs is increasing every year despite of their low availability as upward price trend of most of the Himalayan species is an indicator of this demand. Himalayan medicinal plants have been traded since time immemorial (Jacob and Jacob 1993). However, scientific attention has been given to it recently as a potential drug to cure many rare diseases and for their role in rural livelihoods. Himalayan medicinal plants are important part of local traditional as well as national and foreign traditional system of medicine; therefore, these herbs have high local and global demand. This high demand had led to trade of huge amount of raw material from Himalayas, most of which are illegal. For almost all Himalayan MAPs data on annual quantities traded is scanty or nonexistent despite their use and trade since antiquity (Olsen 2005). Most of this trade is done locally and illegally; thus, it is a Herculean task to estimate exact amount of raw material and species traded. Moreover, the collection and trade of Himalayan medicinal herb is scattered among different Himalayan states in India and is done locally without any regulation and intervention of government, thereby is unreported. Another major reason for lack of accurate and up-to-date data on demand and supply of these Himalayan herbs is that most of the trade goes unrecorded and unclassified. Domestic as well as foreign trade is also poorly recorded. Therefore, it is impossible to assess domestic as well as global trade in Himalayan medicinal plants. Out of all the medicinal plants occurring in the Himalayas, few are in high commercial demand because of their unique property to cure rare diseases; multiple use and the active ingredients present in them have no synthetic substitute (Table 13.2).

The huge demand for raw material of the Himalayan medicinal plants is met by large-scale illegal harvesting from the wild. Almost 90% of the plant material used in the pharmaceutical industries is collected from the wild, and out of which 70% is destructively harvested (Planning Commission, Govt. of India 2000). Commercial cultivation and production of Himalayan medicinal plants is very low than actual demand for raw material. Major factor for overharvesting of these plants is easy access or absence of restriction on harvesting for medicinal plants. Another reason for overharvesting is that collectors are illiterate local people, and due to lack of knowledge of actual worth of these species, they agree to sell raw material at cheap prices to pharmaceutical companies. Therefore, pharmaceutical companies are at a win–win situation as they don't have to grow medicinal plants for raw material and they can easily get it at cheap prices, thereby they opt for harvesting from wild stock. Earlier traditional use of MAPs ensured sustainable use of medicinal plants but now forest laws has been implemented by state and central governments, but still their implementation and enforcement is weak in remote areas of the Himalayas (Planning Commission, Govt. of India 2000). A study carried out on the Himalayan MAPs indicates that 41% of the primary traders source their material through collection in wild solely and 45% from both wild collection and cultivated (Planning Commission, Govt. of India 2000). One important factor that also contributes toward overharvesting and destruction is that mostly these medicinal plants are traded for roots and rhizomes, thereby require destructive harvesting (63% of the

Table 13.2 Medicinal plant species in high trade sourced from temperate forests (Ved and Goraya 2007)

S.No	Species	Estimated annual trade (MT)	Price range of official part (Rs)
1.	*Abies spectabilis*	500–1000	30–50
2.	*Aconitum ferox*	100–200	150–250
3.	*Aconitum heterophyllum*	200–500	2000–4000
4.	*Berberis aristata*	500–1000	15–35
5.	*Bergenia ciliata*	200–500	15–20
6.	*Cedrus deodara*	500–1000	25–35
7.	*Cinnamomum tamala*	500–1000	15–35
8.	*Ephedra gerardiana*	200–500	25–35
9.	*Juniperus communis*	500–1000	35–45
10.	*Jurinea macrocephala*	1000–2000	60–150
11.	*Nardostachys grandiflora*	200–500	110–150
12.	*Onosma hispidum*	500–1000	50–60
13.	*Parmelia perlata*	1000–2000	80–90
14.	*Picrorhiza kurroa*	200–500	220–230
15.	*Pistacia integerrima*	150–200	90–110
16.	*Rheum australe*	500–1000	25–30
17.	*Rhododendron anthopogon*	100–200	15–30
18.	*Swertia chirayita*	500–1000	200–225
19.	*Taxus wallichiana*	100–200	75–90
20.	*Valeriana jatamansi*	100–200	95–100
21.	*Viola pilosa*	200–500	300–350

Source (http://www.nmpb.nic.in/sites/default/files/Projects/Chapter-10.pdf retrieved on 22/03/2018)

raw material in trade comprises roots and 5% comprise whole plants) (Planning Commission, Govt. of India 2000). Out of the total traded species, less than 20 are cultivated commercially on large scale for generating raw material for pharmaceutical companies/herbal drug companies (Planning Commission, Govt. of India 2000). A factor that discourages farmers from commercial cultivation of medicinal plants, especially in the high-altitude zones, is the long gestation period of these species (Planning Commission, Govt. of India 2000).

13.3 Issues and Challenges of Himalayan Medicinal Plants

13.3.1 Endemism and Restricted Distribution

The Himalayan medicinal plants are unique to this region and found nowhere on the earth. The unique climate of Himalayas is reason for these unique species of medicinal plants. Among various altitudinal ranges, temperate Himalayas have high

endemism especially in northwest and west Himalayas compared to the entire Himalayan range (Dhar and Samant 1993; Dhar et al. 1996, 1998). Endemism is coupled with restricted distribution, as these plants require unique microclimates which lead to restriction of these medicinal species in unique microclimate including particular soil type, plant associates, and topography. For instance, *Nardostachys grandiflora* a high-altitude critically endangered Himalayan medicinal plant requires a typical habitat and grows on moist moss-laden rocky and boulder surfaces in crevices with sandy loam acidic soil consisting of residue from metamorphic crystalline rocks and high organic carbon content (7.23–8.96%) (Weberling 1975; Amatya and Sthapit 1994; Nautiyal et al. 2003; Ghimire et al. 2005). Likewise all the species of medicinal plants growing in Himalayas requires its own microclimate which has led to the restricted distribution of these species.

13.3.2 Endangerment of Himalayan Herbs

Increasing demand for medicinal plants globally has increased the annual turnover of Indian herbal medicine to 177,000 MT, which includes trade of 960 species from India (Ved and Goraya 2008). Many medicinal plants are being used in treatment of more than one disease, which has increased the demand for these species and ultimately overexploitation of the Himalayan herbs. This overexploitation resulted in endangerment of these miraculous healing herbs pushing them to the verge of extinction. Currently, about 120 species of Himalayan medicinal plants comes under the categories critically endangered, endangered, vulnerable, near threatened, and data deficient as per IUCN criteria (Samant et al. 1998a, b, 2007; Ved et al. 2003). Concerned with the loss of Himalayan biodiversity, Government of India had regulated collection of these herbs and banned endangered medicinal plants from natural habitats through Wild Life Act and Forest Conservation Act, but this ban has only promoted illegal trade as these species have long gestation period and collectors as well as pharmaceutical industries need profits in shortest time frame. Furthermore, the unscientific harvesting of these medicinal plants prevails due to lack of awareness of proper time, age, and exact growth stage for harvesting these valuable medicinal plants. Therapeutic value of these herbs is due to the presence of rare chemical content in them, and proper stage at which percentage of this content is high is the right stage to harvest for good quality raw material. Also in the Himalayas in absence of any other means of livelihood, owing to hostile climatic condition, local people depend on collection and trade of medicinal plants for livelihood (Larsen et al. 2000; Olsen and Larsen 2003; Bista and Webb 2006). This trade adds to economy of Himalayan nations (Olsen 2005), but now with this lack of alternative livelihood sources coupled with high demand by pharmaceutical companies has pushed these herbs into peril (Bista and Webb 2006). The collection of herbs traditionally for medicinal use is not a problem, until it is in harmony with the natural ecosystem (Cunningham 1993; Ghimire et al. 2005).

13.3.3 Reproductive Bottlenecks

Himalayan medicinal plants have several inherent unique features that contribute to their endangerment besides illegal trade, unscientific harvesting, and overexploitation. One among such inherent features is reproductive bottle neck. Successful reproduction is required for survival of any species, especially reproduction as it creates variability and healthy progeny that can maintain the genetic diversity of the species. These bottlenecks include self-incompatibility, pollen sterility, meiotic irregularities, low seed set, low seed viability, protracted seed germination, seed dormancy, male sterility, and exclusive dependency on pollinators. *Nardostachys grandiflora* is a critically endangered medicinal plant of the Himalayas with inherent infrequent flowering character, with only 8–10% plants in a population bearing flowers in a season impacting its multiplication (Gautam and Raina 2016). Being self-incompatible, *Aconitum heterophyllum, Sausurrea costus,* and *Inula racemosa* have to depend exclusively on pollinators or human interventions for reproduction (Nautiyal et al. 2009; Wafai et al. 2005; Wani et al. 2006). Presence of pollen sterility owing to meiotic irregularities in *Inula racemosa* makes reproduction impossible (Shabir et al. 2013). Low pollen longevity in *Gentiana kurrooa* impacts its reproduction (Raina et al. 2003). Thus, reproductive bottlenecks are other challenges faced by these herbs.

13.3.4 Lack of R&D

Research and development in Himalayan medicinal plants have not been carried out extensively although studies on their uses, cultivation practices, morphology, distribution pattern photochemistry have been carried out, but studies on their genetic system, breeding system, and reproductive biology are lacking in most of the species which hinder development of conservation plan for these species, as these studies are crucial for developing conservation protocol. The inherent features of reproduction of these species needs to be unraveled to assist successful seed set for sustaining its progeny and maximum variability in future generation. Furthermore, no empirical database on research is available regarding trade, demand, supply, and illegal trade of these medicinal plants. Because of this lacuna, a clear picture of existing situation cannot be synthesized. These studies are of utmost importance to assess the exact demand, to develop conservation programmes, and to draft policies on sustainable utilization and harvesting of these medicinal plants from wild.

13.3.5 Lack of Cultivation

Out of the total highly traded temperate medicinal plants, demand of only two or three species is met from cultivation, rest are wild harvested. Cultivation of these medicinal plants is very crucial for sustaining their supplies and conservation of endangered species. Cultivation of these medicinal plants has not received any attention despite initiatives taken by the Government of India (National Medicinal Plant Board); for example, many of these species have been prioritized for intensive cultivation and have been enlisted in negative trade practices. Package of practice on the cultivation of these medicinal plants has already been developed by researchers and scientists. In the absence of any blanket ban on the harvesting of the medicinal plants, pharmaceutical companies are exploiting wild stocks to produce herbal drugs and products, which are major cause for depletion of these natural resources.

Due to these challenges and issues of Himalayan medicinal plants, there is a need to start concerted efforts to conserve these medicinal plants for future generation as they not only act as therapeutic agents but also as integral part of our Himalayan ecosystem, and to maintain stability and integrity of any ecosystem, each and every flora and fauna (both macro and micro) needs to be protected. The need of the hour is to conserve, restore, and sustainably utilize these medicinal species without posing further threat on their survival.

13.4 Conservation of Himalayan Medicinal Plants

Conservation of Himalayan medicinal plants is of utmost importance for future generation. Conservation of these MAPs should focus on preserving the entire genetic diversity of targeted species by conserving its vast population that is adequate enough to represent all its rare and general alleles. For conservation, various conventional and nonconventional methods can be deployed along with taking concerted efforts for cultivation and reintroduction of these species into their natural habitat. Following strategies can be exploited effectively for conservation of Himalayan medicinal plants.

13.4.1 In Situ and Ex Situ Conservation

Conservation of medicinal plants in natural habitat (in situ) is a viable option as it will ensure natural regeneration; evolution of these plants, as each species is intertwined, and on-site conservation focuses on conservation of entire biodiversity/ecosystem thus maintain natural competing and evolving behavior of species. In situ conservation can be practices in national parks, biosphere reserves, wildlife sanctuaries, conservation reserves, etc. In situ conservation cannot survive on its own and

must be supplemented with ex situ conservation. Ex situ conservation can be done similar to conserving these species in home gardens, sacred grooves, establishment of herbal gardens, botanical gardens, arboretum, field gene banks, etc. But in case of ex situ conservation, the species competitive ability to survive and further evolution cannot be sustained. For conservation, there must be a minimum viable population (smallest number of individuals required by any species to persist for long period, usually more than 100 years) present for the successful conservation.

13.4.2 Biotechnological Tools

Biotechnology is another important tool that can be exploited well in conservation of medicinal plants. Ex situ conservation of rare and endangered medicinal plant species through in vitro plant tissue culture techniques can be applied. Conservation of seeds, pollen, gene, and tissue culture, maintaining slow growth cultures can be done which are major biotechnological approaches for conservation of rare and endangered plant species (Paunescu 2009). These biotechnological tools allow of faster mass multiplication of endangered medicinal plant species for conservation of genotypes and can be harnessed to enhance active contents in medicinal plants (Nalawade et al. 2003).

13.4.3 Conservation by Cultivation

Conservation by cultivation of medicinal plants is also important because it will ensure production and availability of organic raw material of uniform quality without any sort of adulteration. Cultivation will also ensure continuous supply of raw material for pharmaceutical industries and high economic returns to the farmers. Moreover, cultivated products can easily be certified. It is reported that if cultivated, these species provide high potential returns to the farmer as most of these plants command high price in market. One study suggested that the cultivation of high-altitude Himalayan herbs could yield products priced anywhere between Rs. 7150 and 55,000 per hectare (Nautiyal 1994), indicating the worth of medicinal plants. Rao and Saxena (1994) reported average annual (per hectare) income of Rs. 120,000 through mixed cropping of high-altitude medicinal herbs. These medicinal can be successfully incorporated with other food crops and in any agroforestry systems of temperate regions.

National Medicinal Plant Board of India has already prioritized medicinal plants for cultivation in Himalayan states (www.nmpb.nic.in.). Although cultivation practices have been developed, but cultivation of medicinal plants in the temperate region has failed because of lack of availability of certified quality planting material, proper information on agro-techniques, exploitative market practices, minimum support price from the government and availability of package of practices in scientific languages not meant for farmers, etc.

Most of these medicinal herbs cannot be grown as a sole crop, therefore, they can be easily introduced as intercrop with other agricultural crops of the region, in agroforestry systems, fruit orchards, pastureland, and wastelands.

Moreover, this cultivation requires improved strains with the following characteristics:

- Synchronous flowering and maturity.
- Resistant to abiotic stress (drought, temperature, salinity, etc.)
- Resistant to biotic stress (disease and insect).
- Higher biomass of official part.
- High active content yield.
- Short gestation period.
- Less dependency on inorganic fertilization for higher productivity.

Understanding the reproductive biology of the species is a must for its conservation and development of improved strains. Pollination behavior (self or cross) of plant plays a significant role for the application of appropriate breeding systems. Concerted efforts have already been made by the researchers in determining the breeding system of some of the commercially important temperate/subtemperate medicinal plants (Table 13.4b). This information can be deployed for developing improved strains.

The studies conducted have been helpful in enhancing seed production in *Gloriosa superba* and developing selection of a high valepotriate yielding strain in *Valeriana jatamansi* and selection of different strains in *Hypericum perforatum* for higher biomass and active content (hyperin yield).

13.4.4 Sustainable Harvest from Wild

Escalating wild harvest is leading to overexploitation, and this practice has exposed many high-value medicinal plant species to the risk of extinction. Sustainable harvesting means that annual harvest must not exceed the annual renewal of the stock of plants.

For establishing sustainable/regulated harvesting methods, existing stocks of the medicinal species needs to be assessed. Furthermore, annual renewal rate of these medicinal species need to be studied to decide annual yield. Regulation of harvesting needs to address issues related to rights of the people over forest products, and local inhabitants should be included in regulated harvesting. There is need to generate alternate income sources for those who are entirely dependent on these resources for livelihood. If these species are sustainably harvested, they have high potential of income generation to harvesters and traders. Steps for regulating harvesting should include the following:

- Define area for regulating harvests and addressing the rights of indigenous people.

Table 13.3 List of endangered Himalayan medicinal plants

	Species	Conservation status	Trade status
1.	*Aconitum chasmanthum*	Critically endangered	Traded
2.	*Aconitum deinorrhizum*	Endangered	Traded
3.	*Aconitum ferox*	Endangered	Highly traded
4.	*Aconitum heterophyllum*	Endangered	Highly traded
5.	*Angelica glauca*	Endangered	Traded
6.	*Arnebia benthami*	Critically endangered	Traded
7.	*Arnebia euchroma*	Critically endangered	Traded
8.	*Atropa acuminate*	Critically endangered	Highly traded
9.	*Betulautilis*	Endangered	Traded
10.	*Dactylorhiza hatagirea*	Endangered	Traded
11.	*Dioscorea deltoidea*	Endangered	Traded
12.	*Epherda gerardiana*	Critically endangered	Highly traded
13.	*Ferula jaeschkeana*	Vulnerable	Traded
14.	*Fritillaria cirrhosa*	Endangered	Traded
15.	*Gentiana kurroo*	Critically endangered	Traded
16.	*Habenaria intermedia*	Endangered	Not recorded
17.	*Hyoscyamus niger*	Endangered	Traded
18.	*Jurinea dolomiaea*	Endangered	Highly traded
19.	*Lilium polyphyllum*	Critically endangered	Not recorded
20.	*Malaxis musifera*	Critically endangered	Not recorded
21.	*Meconopis aculeate*	Endangered	Not recorded
22.	*Nardostachys grandiflora*	Critically endangered	Highly traded
23.	*Panaxpseudo ginseng*	Endangered	Not recorded
24.	*Paris polyphylla*	Endangered	Traded
25.	*Picrorhizakurroa*	Endangered	Highly traded
26.	*Podophyllum hexandrum*	Endangered	Traded
27.	*Polygonatum cirrhifolium*	Endangered	Traded
28.	*Rheum emodi*	Endangered	Highly traded
29.	*Rheum moorcroftianum*	Endangered	Highly traded
30.	*Saussurea obvallata*	Critically endangered	Not recorded
31.	*Saussurea costus*	Critically endangered	Highly traded
32.	*Swertia chirayita*	Critically endangered	Highly traded
33.	*Taxus wallichiana*	Endangered	Highly traded
34.	*Zanthoxylum armatum*	Endangered	Not recorded

(*Source*: Siwach et al. 2013) high traded >100 Metric Ton/year

- Local community should be involved in management and sustainable harvesting, and thus joint forest management could be a best approach. Furthermore, local harvester must be registered legally.
- Involve nongovernmental organizations to sensitize people and implement this system along with generation of alternative income sources to people who are completely dependent on these medicinal herbs for livelihood.

Table 13.4a Medicinal plant species suitable for cultivation in temperate regions

S. No	Species	S. No	Species
1.	*Aconitum heterophyllum*	10.	*Crocus sativus*
2.	*Aconitum ferox/Aconitum balfouri*	11.	*Saussurea costus*
3.	*Hedychium spicatum*	12.	*Picrorhiza kurroa*
4.	*Swertia chirayita*	13.	*Valeriana jatamansi*
5.	*Bunium persicum*	14.	*Boerhaavia diffusa*
6.	*Berberis aristata*	15.	*Dactylozhiza hategria*
7.	*Ferula foetida*	16.	*Hippophae rhamnoides*
8.	*Nardostachys grandiflora*	17.	*Asparagus racemosus*
9.	*Podophyllum hexandrum*	18.	*Taxus wallichiana*

- Involve people in evaluation and monitoring of sustainable harvesting practices.
- Capacity building and skill development programs must be arranged for local people involved in sustainable harvesting.

Moreover, sustainable harvesting means harvesting of plant parts at proper time, that is, at maturity stage and when active content is highest; further harvesting of plant parts must be done only after seed shedding by plants to ensure natural regeneration of species. In many species, harvesting schedule have already been developed, Table 13.4c summarizes information on the harvesting schedule of some important medicinal plants. This information can be used for optimizing wild harvests, if required in accordance to biodiversity concerns.

13.4.5 Conservation by Reintroduction of Species into Nature

Conservation and reintroduction of species into wild/nature must go hand-in-hand to enhance the stock of these medicinal plants. Furthermore, bringing new species into cultivation takes lot of time as plants need to adjust to the new environment. Only those species having high commercial value can be cultivated by farmers as it is profitable. To introduce these species into the existing cropping pattern, research needs to be conducted which is a long-term effort requiring financial assistance and support.

Therefore, steps should be taken to reintroduce endangered Himalayan medicinal plants species in nature/wild for conservation and sustaining their regular supply. Thus, cultivation/reintroduction will pose minimum difficulties with minimum efforts as the environment will be natural and no problems related to establishment, growth, and yield will be encountered. Reintroduction should focus on the following steps:

- Identify endangered and prioritized medicinal plant species of Himalayan regions.

Table 13.4b Breeding system attributes of some medicinal plants

Species	Breeding system	Diploid chromosome no.	Ploidy status	Reproduction	Flower	References
Picrorhiza kurroa	Xenogamy	34	Genomic allotetraploid	Vegetative; Seeds	Bisexual	Raina et al. (2010b)
Gentiana kurroo	Xenogamy	26	Genomic allotetraploid	Vegetative; Seeds	Bisexual	Raina et al. (2003)
Swertia chirayita	Autogamy Xenogamy; Gnetenogamy	26	Genomic allotetraploid	Seeds only	Bisexual	Raina et al. (2013)
Hypericum perforatum	Autogamy	32	Genomic allotetraploid	Seeds only	Bisexual	Mustafa (2006)
Valeriana jatamansi	Autogamy Xenogamy; Gnetenogamy	32	Genomic allotetraploid	Vegetative; Seeds	Pistillate; Bisexual	Raina et al. (2010a)
Podophyllum hexandrum	Autogamy Xenogamy;	12	Diploid	Vegetative; Seeds	Bisexual; Solitary on a plant	Kamini (2016)
Nardostachys grandiflora	Xenogamy	78	Hexaploid	Vegetative; Seeds	Bisexual	Gautam and Raina (2016)
Angelica glauca	Xenogamy	22	Diploid	Vegetative; Seeds	Bisexual	Kamini (2016)

Table 13.4c Harvesting schedule of some medicinal plants based on active content

S. No	Species	Plant part to be harvested	Harvesting stage	%age content	References
1.	*Hypericum perforatum*	One-third of the plant from top	Full flowering	0.075% Hypericin	Mustafa (2006)
2.	*Swertia chirayita*	Whole plant	Full flowering	0.227% amarogentin; 0.071% amaroswerin	Raina et al. (2013)
3.	*Solanum laciniatum*	Berries	Dark green colored	≥4.0% *solasodine*	Rastogi (1990)
		Leaves	Mature	~1.0% *solasodine*	
4.	*Andrographis paniculata*	Aerial biomass	Flowering stage	~2.0% andrographolide	Bhandari (2000)
5.	*Valeriana jatamansi*	Rhizome	>Two-years old in autumn season	~4% Valepotriates;	Sharma (1993)
		Roots	>Two-years old in autumn season	~4% Valepotriates ~2.0% E. Oil	
6.	*Gloriosa superba*	Seeds	Ripened	0.70% colchicine	Gupta (1997)
		Tubers	Dormant stage	0.25% colchicine	
7.	*Mucuna sp (white seeded)*	Seeds	Ripened	5.5% L-Dopa	
	Mucuna pruriens (black seeded)	Seeds	Ripened	6.0–7.0% L-Dopa	Chandra (2001)
8.	*Picrorhiza kurroa*	Rootstock	> 3-yr old in autumn season	Picroside-I: 0.26–3.7% (rhizomes) & 0.10–1.12% (roots). Picroside-II: 2.60–7.08% (rhizomes) and 2.34–6.71% (roots)	Mehra (2006)
9.	*Podophyllum hexandrum*	Rhizome	Three-leaved plants in autumn season	4.3% podophyllotoxin	Mahajan (2004)

- Identify the best-suited forest area for reincorporation, replanting, and mass multiplication.
- Initially, selection and enclosing of a small area (say approximately 10 ha) in a reserved forest can be carried out. This area should be seeded by propagules of the selected species and focus should be given on use of superior genotypes, if available to enhance yield.
- Outside interference for at least not less than three growing cycles of the selected species should be avoided so that these introduced plants are able to produce, set, and disperse seed. Once that is achieved, then natural regeneration process will start along with its spreading to nearby areas and spread beyond the restricted areas.

- No extraction activity should be permitted till the stock of plants reach a point; it can be called as abundant.

13.5 Government's Initiative for Conservation of Medicinal Plants

At international level, organizations like IUCN (International Union for Conservation of Nature), CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora), and Traffic (Trade Record Analysis of Flora and Fauna in Commerce) are working on the conservation of threatened plants. In India, Forest Conservation Act, 1980 and National Wildlife Act of 1972 regulates the trade and any kind of damaging activities to such plants must be punished. Various agencies like National Medicinal Plant Board of India (NMPB), Botanical Survey of India, National Biodiversity Action Plan by Ministry of Environment and Forests (MoEF) indicate that government is also concerned about our biodiversity and is taking necessary steps in this regard. All India Coordinated Research Project on Medicinal Plants and Beetle Wine (AICRP on MP&B) run by Indian Council of Agricultural Research (ICAR) in various agroclimatic zones of India including Himalayan region is also taking necessary steps for conservation of medicinal plant biodiversity. CSIR (Council for Scientific and Industrial Research) is also focusing on conservation of medicinal plants.

13.6 Way Forward

To conserve biodiversity, Himalayan medicinal plant's sustainable utilization should be targeted at various levels with particular focus on enhancing stock of these plants in wild, improving living standards of indigenous people, by changing the attitude of people to take up cultivation of these plants, development of modern technologies for cultivation, making policies on restricting illegal trade. First step would be putting restriction on harvest of raw material from wild along with commercialization of these medicinal plants by providing incentives to the farmers for growing these species. Encouraging pharmaceutical industries for taking up cultivation of these medicinal plants in association with the farmers should be the next priority. Farmers should be provided knowledge and hands-on training on cultivation, harvesting, and post-harvesting of these medicinal plants so that they reap the harvest profitably. But for cultivation, elite strains are required, therefore, researchers should take up work on developing high yielding and short gestation strains of these plants. As we know that not all species are amenable for cultivation, therefore restricted harvesting along with in situ cultivation of such species should be promoted in association with governmental and nongovernmental organizations. Various biotechnological tools and ex situ techniques should also be deployed to conserve germplasm. Most

importantly, various institutes of Himalayan regions should be allotted prioritized species for tackling R&D issues and to avoid duplication of work. Moreover, state governments of the Himalayan region must develop policies to curb over exploitation and illegal trading.

13.7 Summary and Conclusion

Himalayan medicinal plants are wonderful gift of nature to us; their conservation coupled with sustainable use is the way of preserving them for our future generation. But due to various reasons, namely, illegal trade, unscientific harvest, habitat fragmentation, they are in peril and immediate attention along with well-defined steps and plan is need of the hour to save them for human beings and to maintain integrity and stability of the ecosystem. People involved in their trade and also pharmaceutical industries need to think sensibly to get involved in the sustainable, scientific harvesting of these herbs and must practice cultivation of these species for producing raw material. Concerted efforts need to be taken on research of these herbs especially to find out the exact amount of ongoing trade in these species along with finding out the number of species involved, to find out amount of raw material that can be harvested annually on sustainable basis, to promote reintroduction of these species into nature, and in developing conservation plan for these species.

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