Chapter 4
Chemical Diversity and Ethnobotanical Survey of Indian Medicinal and Aromatic Plants Species

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Abstract Plants are the source of important drugs. Their secondary metabolite content is subject to environmental influences. Scientific evaluation of the chemical diversity of plants may be useful in exploring their medicinal as well as other uses. Still there are numerous medicinal plants for which no results either of ethnopharmacological uses or phytochemical studies could be found in the literature. Ethnobotany deals with the relationship between humans and plants. It has played an important role in the development of new drugs for centuries. Ethnobotany is attracting professionals from diverse academic backgrounds and interest. Ethnobotany may play an important role in securing sustainable supplies, and it can also be of use in the search for new medicinal receipe which could be used to treat diseases for which no standard therapy has been reported. Harnessing chemical diversity based on phytochemical research of species containing potentially active principles would be more relevant in context of ethnobotanical research.

Keywords Biodiversity · Secondary metabolites · Ethnomedicine · Traditional medicine

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Á. Máthé, I. A. Khan (eds.), *Medicinal and Aromatic Plants of India Vol. 1*, Medicinal and Aromatic Plants of the World 8,
https://doi.org/10.1007/978-3-030-98701-5_4

4.1 Introduction

Secondary metabolites from plants are rich sources of bioactive compounds bringing forth many health beneficial effects in man and animals. Worldwide, medicinal plants have played a key role in providing health care. Since antiquity, medicinal plants have been employed in the treatment of a wide range of diseases and health conditions. Plants still continue to make important contributions both in providing lead molecules for further pharmaceutical research and as alternative sources of efficacious medication even in spite of the spectacular advances in the discovery of novel drugs that have occurred over the last few decades (Cragg et al. 1997; Shu 1998). Since time immemorial, plant products have been part of phytomedicines. Phytomedicines are composed of plant organs supplied either in natura (generally leaves, root or bark) or in processed form (typically liquid or powdered extracts). Commercial extracts normally contain the active principles of the plant material in crude or processed state, together with excipients, i.e. solvents, diluents or preservatives. The source and quality of the raw materials play a pivotal role in guaranteeing the quality and stability of the herbal preparations (Calixto 2000).

Scarcity coupled with strong demand on drugs has led to the cultivation of medicinal plants (Chopra et al. 1958). In an attempt to discover new drugs, multinational pharmaceutical companies typically spend an annual amount of US$ 110 billion (Nair et al. 2014). A vast majority of medicinal plants have been recklessly exploited. Therefore it is an imperative to rationalize the use of important medicinal plants (Sultan et al. 2008).

Bioactive phytochemicals are naturally occurring compounds present in or derived from a plant (Hardy 2000). Bioactive compounds of plant origin are those secondary metabolites that possess desired health/ wellness benefits for man and/or animals. These metabolites are both chemically and taxonomically extremely diverse compounds with frequently obscure functions (Yadav and Agarwala 2011).

Phytochemicals may function as antioxidant (protect cells against oxidative damage), antiproliferative (interfere with replication of undesirable cancerous cell), carcinogen detoxifier, hypocholesterolemic, stimulant of enzymes and hormones, antibacterial and antiviral, anti-inflammatory, ligand to cell wall (some phytochemicals bind physically to human cell thereby preventing the adhesion of pathogens) and potential inhibitor of different actions affecting the initiation and progression of several pathogenic processes (Kaur and Das 2011).

Secondary metabolites are frequently called the vast "Chemical library" of biological systems. Most of the drugs, herbs, ethnomedicines, essential oils, perfumes and cosmetics derive from them. Cultivation is an important practice to conserve endangered medicinal plants growing in the wild and it works as a practical method to make available natural raw materials without affecting their actual habitat (IUCN 1993). A prerequisite for breeding is the study of genetic diversity of available plant germplasm (Bernáth 2002). Germplasm characterization is necessary to enhance germplasm management and utilization. Genetic diversity is influenced by habitat types and the altitudinal range (Jugran et al. 2013, 2015). Diversity classification in germplasm collections is important for both plant breeding and germplasm collection. High diversity is an indicator of better adaptability of a population as a result of more fitness under rapidly changing environment. Wild plant species which can adapt easily in any conditions are always suitable for domestication or cultivation (Dhiman et al. 2020). The most important goals of any medicinal plant breeding program are to improve the morphological characteristics and increase the accumulation of biologically active substances. The quantitative and qualitative status of active constituents along with genetic diversity for a medicinal plant is the basis to devise conservation strategies and select right samples for maximum yields. Conservation strategies for populations should take into account both genetic diversity and chemical variation levels, especially in the case of populations having high differentiation to bioclimatic factors and the geographic location of populations (Nair et al. 2014).

Chemical constituents of MAP are the basis of their exploitation (Heywood 2002). Chemical markers are the group of chemical constituents derived from herbal/medicinal products. Chemical markers play an important role also in the quality control of herbal products and medicines. Chemical diversity plays an important role also in plant adaptation (Dhiman et al. 2020). Species, strains and geographical origin can be distinguished using chemical fingerprinting. It is imperative to identify elite plants/population based on their chemical attributes to ensure the quality of plant material (Jugran et al. 2015).

Association between the molecular markers and the phytochemical markers has been found to provide the best method of assessment of plant genetic diversity. This approach is used to screen and improve the gene pool of elite genotypes (Ray et al. 2019; Qaderi et al. 2019; Nair et al. 2014; Hennicke et al. 2016).

4.2 Chemical Diversity in Selected Threatened Indian Medicinal Plants

A species that has been described as species with small population is not presently endangered but is at risk. A species which is in danger of extinction throughout all or a significant portion of its range has been categorized as an endangered species. Threatened is a species that is likely to become endangered in the foreseeable future (IUCN 1978; Bryde 1979; Nayar and Sastry 1990). The chemical diversity in nine high value endangered medicinal plants of India is briefly described in terms of their major phytochemical principles. These species are not found in cultivation. They are collected from nature; therefore, their ecological study needs to be brought to the forefront, in addition to their *in-situ* conservation.

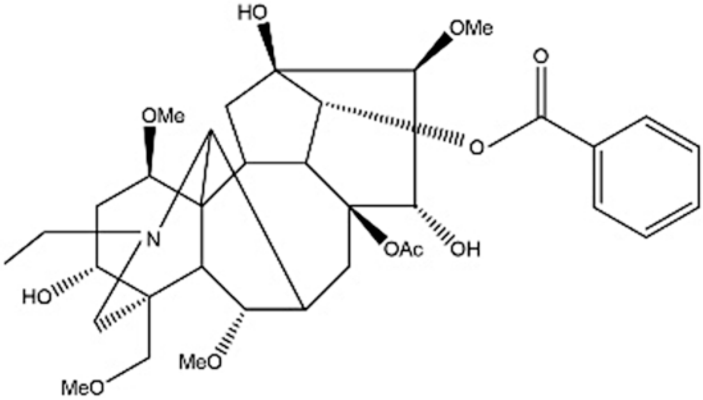


Fig. 4.1 Chemical structure of aconitine

4.2.1 Aconitum heterophyllum

Aconitum heterophyllum (Family: Ranunculaceae) is widely distributed across North Asia and North America. Worldwide about 300 species of *Aconitum* are found and 27 species, in India (Paramanick et al. 2017; Sharma et al. 1993). *A. heterophyllum* possesses potential immunomodulatory activity (Murayama and Hikino 1984; Weiner 1990). Content of aconitine (Fig. 4.1), an alkaloid, varies from species to species and also with place of origin (Prasad 2000; Hikino et al. 1983; Iwasa and Naruto 1996, Song et al. 1984). Variation of aconitine content in *A. chasmanthum* and *A. heterophyllum* from Kashmir Himalayas was reported by Jabeen et al. (2011). Aconitine content varied from 0.0310% to 0.0320%, 0.0014% to 0.0018% in *A. chesmanthum* and *A. heterophyllum*, respectively.

4.2.2 Ephedera foliata

Ephedera Linnaeus is a genus of about 40 species. Eight *Ephedera* species from India and adjoining regions were listed by Sahni (1990). Three additional species namely *E. kardangensis*, *E. khurickensis* and *E. sumlingensis* were also reported recently (Sharma and Singh 2015). *E. foliata* is a typical component of arid and semi arid regions of North-Western parts of India (Bhandari 1978). It is harvested on commercial basis in Gujarat (Gavali and Sharma 2004). However, over exploitation, extensive habitat destruction, very slow growth rate, poor regeneration, grazing and other anthropogenic pressure have caused tremendous reduction in its natural populations. It has now become a rare or endangered species from a vulnerable category (Kharin 2002; Joshi et al. 2013) and it is considered as a threatened

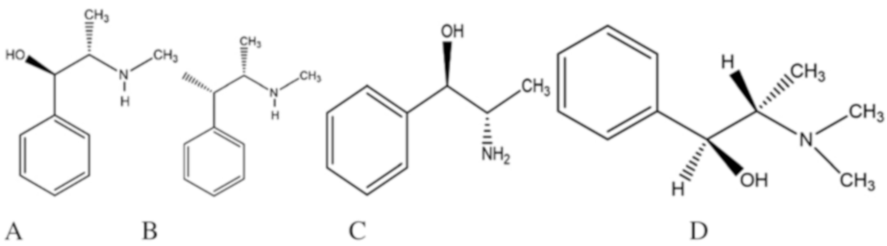


Fig. 4.2 Chemical structure of (**a**) (−)-ephedrine (**b**) (+)-pseudoephedrine (**c**) (−)-norephedrine (**d**) (+)-methylpseudoephedrine

species in India (Meena et al. 2019). Whole plant of *E. foliata* is used in fever, blood purification, asthma, dropsy, snake bite and as cardio tonic (Silori et al. 2005; Quattrocchi 2012). The major active principle in *Ephedra* is (−)-ephedrine and (+)-pseudoephedrine. Other minor alkaloids include (−)-norephedrine, (+)-methylpseudoephedrine (Fig. 4.2). Depending upon the species, the total alkaloid content in *Ephedra* can exceed 2% (Bruneton 1995; Chaudhary et al. 2020). The alkaloid content in Indian *Ephedra* ranged from 0.28–2.79% (Chauhan 1999; Polunin et al. 1987). Chaudhary et al. (2020) reported variation of metabolite content in *Ephedra* within same phytogeographical region of Kashmir Himalayas.The climatic conditions, physical and chemical property of soil (pH, soil moisture, macro-micro-nutrients, etc.) and other edaphic factors were attrtibuted for the variation of metabolites content in *Ephedra* from same phytogeographical region.

4.2.3 Malaxis acuminata

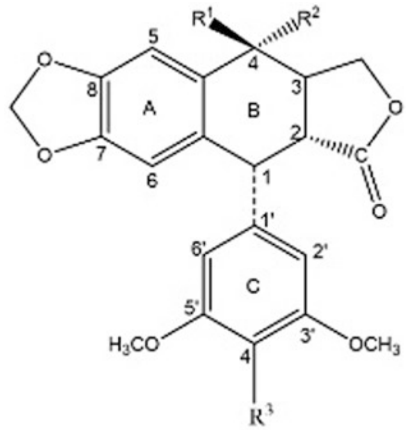
Malaxis acuminata is commonly known as "Jeevaka". It is a small, perennial, pseudobulbous terrestrial orchid with pale yellowish-green to pinkish flowers in terminal racemes (Bose et al. 2017). The dried pseudobulbs are important ingredient of very reputed Ayurvedic drug "Ashtavarga" and also used in the preparation of polyherbal tonic "Chyavanprash" (Cheruvathur et al. 2010; Govindarajan et al. 2007). Due to the rapid loss of forest cover, jhum cultivation, etc., *M. acuminata* has become threatened in the nature. It has been listed in CITES (Conservation of International Trade of Endangered Species of Wild Fauna and Flora) Appendix II (Jalal 2012; Lohani et al. 2013). Secondary metabolite profiling in various parts of *M. acuminata* was reported by Bose et al. (2017). Presence of fatty acids, α-hydroxy acids, phenolic acids, sterols, amino acids, sugars and glycosides were reported using GC-MS analysis of methanolic extracts of leaves and stems of wild as well as *in vitro* plantels of *M. acuminata*.

4.2.4 *Pterocarpus marsupium*

Pterocarpus marsupium is distributed in Central, Western and Southern regions of India (Devgun et al. 2009). It is listed as vulnerable plant in the INCN red data list (IUCN 2017). The Ayurvedic System of Medicine strongly recommends water stored in a tumbler made from hardwood of *P. marsupium* for effective diabetes control (Chopra et al. 1958; Jain 1968; Satyavathi et al. 1987). Mohankumar et al. (2012) reported that a high molecular constituent obtained from the fractionation of the aqueous extract of *P. marsupium* hardwood had potent insulinotrophic and insulin like properties. The heartwood of *P. marsupium* is important source of pterostilbene. Other secondary metabolites such as epicatechin, pterocarpol, pterosupin, pterocarposide and marsuposides have also been reported from *P. marsupium* (Teixeira da Sliva et al. 2018).

4.2.5 *Podophyllum hexandrum*

The rhizomes of *Podophyllum hexandrum* are well known in medicine, as a source of podophyllin resin. Podophyllotoxin (Fig. 4.3) is the major lignan present in the resin and it is the starting material of etoposide. Vepesid, commercial name of etoposide, is an FDA approved anticancer drug used to treat testicular as well as lung



	Compound	R^1	R^2	R^3
1	DPT	H	H	OCH_3
2	PPT	H	OH	OCH_3
3	4'-DMEP	OH	H	OH

Fig. 4.3 Chemical structure of podophyllotoxin

cancer by inhibiting replication of cancer cells (Becker 2000; Henderson 2000; Jackson and Dewick 1984). Podophyllotoxin preparations are also commercially available to treat genital warts (Beutner 1996). The Indian *P. hexandrum* is superior to its American species *P. peltatum* in terms of its higher podophyllotoxin content (higher than 5%) in dried roots in comparison to only 0.25% of *P. peltatum* (Panda et al. 1992; Mishra et al. 2005). Sultan et al. (2008) reported high diversity in the concentration of marker compounds (podophyllotoxin β-D-glycoside and podophyllotoxin) in 36 individuals from 12 accession of *P. hexandrum*.

4.2.6 *Rauvolfia serpentina*

The genus *Rauvolfia* comprises of 80 species and is represented by five species namely *R. hookeri, R. micrantha*, *R. serpentina*, *R. verticillata* and *R. tetraphylla* (Bindu et al. 2014). *R. serpentina* has been designated as critically endangered in India and is included in Appendix II of CITES, which restricts its export (Singh et al. 2010). Population of *R. serpentina* declined more than 50% during the period of 1985–1995 due to loss of habitat and overexploitation (Bindu et al. 2014). Government of India has banned export of this species from the wild in order to prevent over exploitation of this species (Sukumaran and Raj 2008). Roots are being indiscriminately collected from the wild to meet the growing demands of the pharmaceutical industry and this has rendered listing the species "endangered".

Indole alkaloids such as reserpine, reserpiline, rescinnamine, ajmaline, ajamalacine, rauvolfinine, serpentine, serpentinine and yohimbine, etc. have been reported from *Rauvolfia* species (Sahu 1983; Gao et al. 2012). Reserpine is the most prominent amomg these alkaloids (Nair et al. 2014). Reserpine (Fig. 4.4) has been known, documented and used to treat snakebites and insanity, however, the main use of the drug is as a sedative and hypnotic and for reducing blood pressure. The drug is now largely used in insanity and high blood pressure. It is more suitable for cases of mild anxiety or patients of chronic mental illness (Bleuler and Stoll 1955).

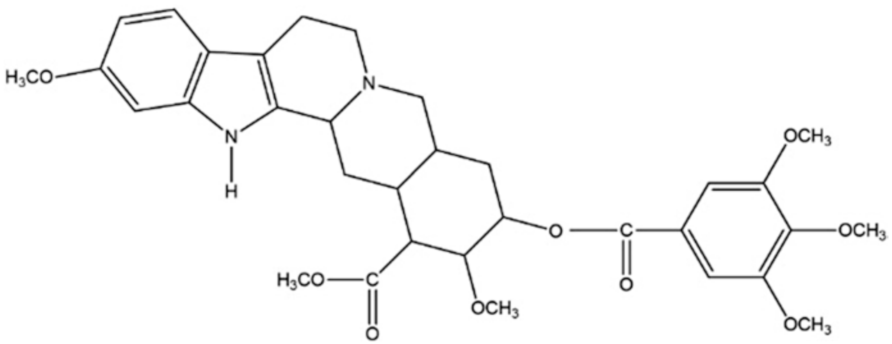


Fig. 4.4 Chemical structure of reserpine

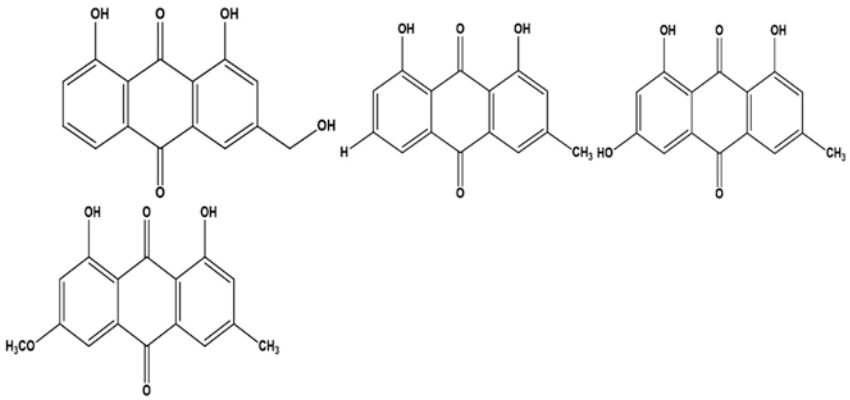
Bindu et al. (2014) reported that reserpine content was highest for *R. tetraphylla* (450.7 μg/g dry wt.) among five *Rauvolfia* species from India. Resperpine content was comparatively low in the *R. serpentina* (254.8 μg/g dry wt.). Reserpine content in 10 population of *R. serpentina* ranged from 0.192 g/100 g to 1.312 g/100 g. *R. micrantha*, which is an endemic *Rauvolfia* species in India, had significantly higher reserpine (422.1 μg/g dry wt.) content (Bindu et al. 2014). Chemical synthesis of reserpine is economically still not feasible (Farooqi and Sreeramu 2001). Significantly higher reserpine content in *R. micrantha* makes this species a suitable candidate as a source of resperpine, replacing *R. serpentina* and *R. tetraphylla*.

4.2.7 Rheum emodii

The genus *Rheum* belonging to family *Polygonacaeae* encompasses about 60 species. It is mainly distributed in the temperate and subtropical Asia (Anjen et al. 2003). Seven species from this genus have been reported from India (Hooker 1885). *Rheum emodii* is found at an elevation of 2000–3800 m in the temperate Himalayas from Kashmir to Sikkim (Zargar et al. 2011). Phytochemicals from *Rheum emodi* have been reported to possess antioxidant, antidiabetic, antimicrobial, antifungal, cytotoxic, hepatoprotective and nephroprotective activities. *R. emodii* has been used an ingredient in many herbal formulations used for treatment of various diseases, in particular for the regulation of blood fat, hepatitis and cancer (Zargar et al. 2011). Rhizome is the source of major phytochemicals from *R. emodii*. Free anthraquinones and their glycosides are the major phytochemicals from *R. emodii* (Fig. 4.5). Anthraquinone with carboxyl group (Rhein) and without carboxyl group including chrysophanol, aloe-emodin, emodin, physcion, chrysophanein and emodin glycoside and alkyl derivatives of anthraquinone namely 6- methyl rhein and 6-methyl aloe-emodin have also been reported from *R. emodii* (Malik et al. 2010; Singh et al. 2005). Anthrone C-glycoside derivatives, such as oxanthrone, ether (revandchinone-2) and revandchinone-3 have also been reported from *R. emodii* (Babu et al. 2003; Singh et al. 2005).

4.2.8 Swertia chirata

About 40 *Swertia* species are present in India. These species are randomly dispersed in the Western and Eastern Himalayan regions and Western Ghats. *Swertia* herb is used as a principal component in several commercial polyherbal formulations. *S. chirata* is known as the most well-known and elite species of *Swertia* (Kaur et al. 2019b). Amarogentin, swertiamarin (Fig. 4.6) and mangiferin are responsible for the therapeutic potential of *Swertia* (Kumar and Van Staden 2015). Kaur et al. (2019b) reported phytochemical diversity among 48 accessions of five *Swertia*



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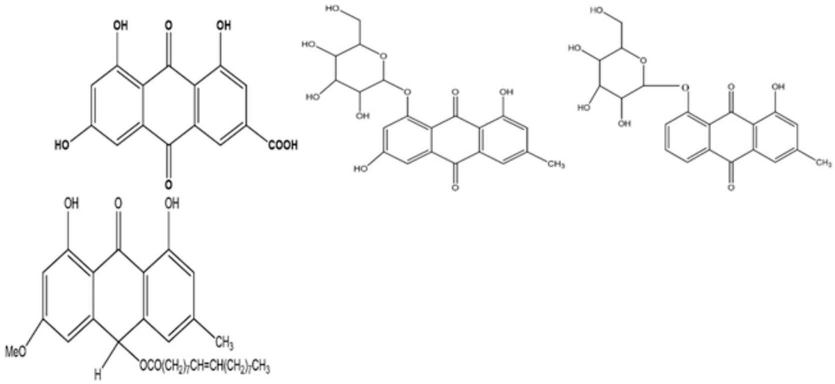

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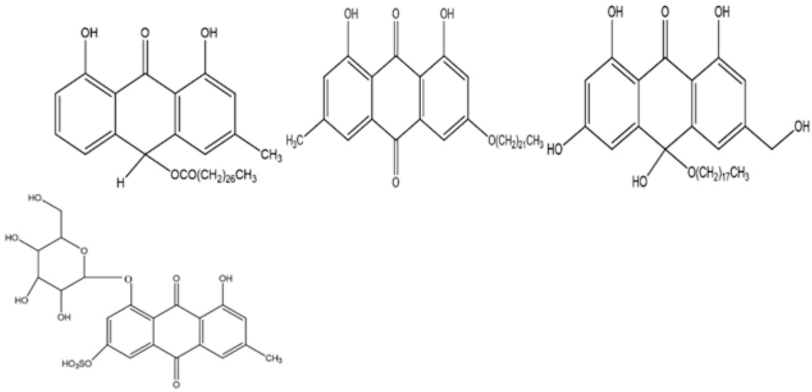


I J K L

Fig. 4.5 Chemical structures of (**a**) aloe-emodin (**b**) crysophanol (**c**) emodin (**d**) physicon (**e**) rhein (**f**) emodin glucoside (**g**) crysophanol glucoside (**h**) revandchinone–I, (**i**) revandchinone–II, (**j**) revandchinone–III (**k**) revandchinone–IV and (**l**) sulfemodin -8-O-glucoside

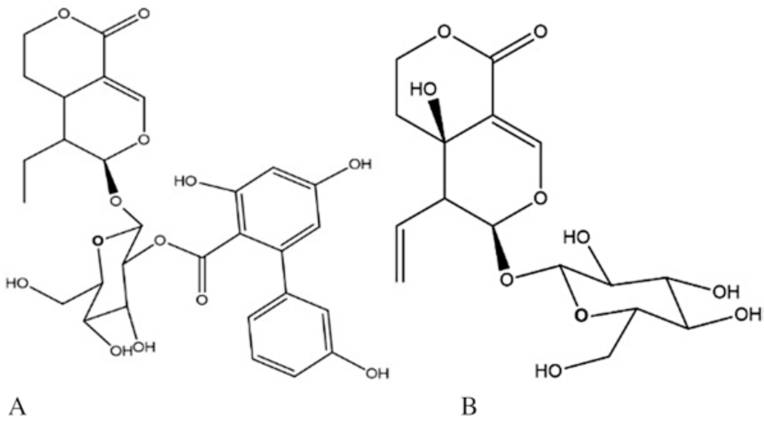
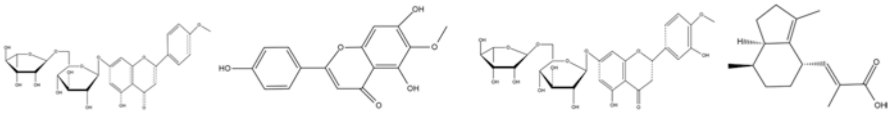


Fig. 4.6 Chemical structure of (**a**) amarogentin and (**b**) swertiamarin

species collected from Western Himalaya, India (*S. chirata*, *S. cordata*, *S. nervosa*, *S. paniculata* and *S. angustifolia*). Maximum yield of amarogentin (0.75 ± 0.20%) and swertiamarin (6.68 ± 0.10%) was found in *S. chirata* accessions and it was followed by *S. paniculata* accessions that had 0.66 ± 0.10 amarogentin and 5.76 ± 0.03% swertiamarin content. Also, substantial amount of secoiridoid glycosides were recorded in accessions of *S. angustifolia*. Similar results were reported in another study that represented high level of phytochemical diversity in the *Swertia* species/population on the basis of four triterpenoids namely oleanolic acid, ursolic acid, betulinic acid and lupeol (Kaur et al. 2019a).

4.2.9 Valeriana jatamansi

Valeriana jatamansi belonging to family *Valerinaceae*, is commonly known as the Indian Valerian of Tagar. *V. jatamansi* is used in both traditional and modern systems of medicine. Among the top selling herbal supplements, the drug valerian ranks at eighth place (Blumenthal 2001). *V. jatamansi* has a long history of uses as a medicine in the Rigveda, Charak Samhita and modern medicine (Jugran et al. 2019). It is used as an ingredient in the preparation of 39 Ayurvedic formulations (Prakash and Mehrotra 1991; Rawat and Vashishta 2011). Valepotriates and valerenic acid (Fig. 4.7) derived from the roots/rhizomes of *V. jatamansi* and other related species of the genus are considered to constitute the chemical fingerprint of these species. These two phytochemicals are used for assuring the quality of the plants (Singh et al. 2006, 2010; Jugran et al. 2015). Valerenic acid has been reported to possess sedative and antispasmodic properties (Houghton 1999). Content of valerenic acid in *V. jatamansi* has been explored (Singh et al. 2006, 2010; Jugran et al. 2015). Jugran et al. (2015) reported significant variation in valerenic acid content (%) in aerial and root portions of 25 population of *V. jatamansi*. It was in the



A B C D

Fig. 4.7 Chemical structure of valepotriates (**a**) linarin (**b**) 6-methylapigenin (hispidulin) (**c**) hesperidin and valerenic acid (**d**)

Table 4.1 Chemical diversity of nine selected Indian medicinal plants

Medicinal plant	Selected phytochemical markers	Reference
Aconitum heterophyllum	Aconitine	Jabeen et al. (2011)
Ephedera foliata	Alkaloid (ephedrine, (−)-ephedrine and (+)-pseudoephedrine, (−)-norephedrine, (+)-methylpseudoephedrine)	Bruneton (1995), Chaudhary et al. (2020)
Malaxis acuminata	Fatty acids, α-hydroxy acids, phenolic acids, sterols, amino acids, sugars and glycosides	Bose et al. (2017)
Pterocarpus marsupium	Pterostilbene, epicatechin, pterocarpol, pterosupin, pterocarposide and marsuposides	Teixeira da Sliva et al. (2018)
Podophyllum hexandrum	Podophyllotoxin	Sultan et al. (2008)
Rauvolfia serpentina	Reserpine, reserpiline, rescinnamine, ajmaline, ajamalacine, rauvolfinine, serpentine, serpentinine and yohimbine	Sahu (1983), Gao et al. (2012), Nair et al. (2014)
Rheum emodi	Anthraquinone, alkyl derivatives of anthraquinone, anthrone C-glucosides	Malik et al. (2010), Singh et al. (2005), Babu et al. (2003)
Swertia species (S. chirata, S. cordata, S. nervosa, S. paniculata and S. angustifolia)	Amarogentin, swertiamarin	Kaur et al. (2019b)
	Oleanolic acid, ursolic acid, betulinic acid and lupeol	Kaur et al. (2019a)
Valeriana jatamansi	Valerenic acid	Jugran et al. (2015)

range of 0.13 ± 0.01 to 0.57 ± 0.04 and 0.20 ± 0.03 to 1.70 ± 0.02 for aerial parts and roots, respectively.

The major phytochemicals present in the selected nine medicinal plants have been described in Table 4.1. Selected major phytochemical marker compounds may find use as reference for the purpose of certification of authentic materials, processing, quality control and value addition for post cultivation magement. This information could be utilized to explore the cultivation prospects of these species in terms of technical and economical feasibility as well as marketability.

4.3 Ethnobotanical Research of MAP in India

4.3.1 Role of Ethnic Knowledge in Drug Discovery

Ethnobotanical knowledge is still transmitted from generation to generation chiefly by word of mouth. The botanical collections of early explorers and the later ethnobotany have played an important role in the development of new drugs for many centuries. In the middle of the last century interest in this approach had declined dramatically, but has risen again during last decade, when also new focuses have developed. Paul and Balick (1994) pointed out some important drugs discovered in different parts of the world, based on the ethnomedicinal knowledge (Table 4.2). Historically, much corporate drug discovery has depended on indigenous knowledge delivered to modern science through ethnobotany. Over 50% of modern prescription medicines have originally been discovered from plants and the reason behind that is that the plants were used in indigenous medicine and some common drugs were first used only on a local scale. In Europe, for example, aspirin was first isolated from *Filipendula ulmaria* because it had long been used in folk medicine. Another European folk cure that has become a drug was derived from *Digitalis purpurea*. The leaves of this plant were first used to treat congestive heart failure. Its active ingredients, digitoxin and digoxin have remained an important treatment for heart ailments. Balick and Cox (1996) showed that at least 89 plant-derived medicines used in the industrial world had originally been discovered by studying indigenous medicine. Among them, the best known is quinine, used in South America to treat fever. This has been the single most effective cure for malaria. Quinine comes from the bark of *Cinchona* trees that grow in the Andean region. More recently, the drugs vincristine and vinblastine were discovered in the rosy periwinkle (*Catharanthus roseus*) from Madagascar. When the Eli Lilly Company studied this plant, they found that the periwinkle had anti-cancer properties. Vincristine has given children with leukemia a likelihood of remission and vinblastine has cured many people with Hodgkin's disease. Native American peoples used the mayapple (*Podophyllum peltatum*) to treat warts. Two important drugs have been derived from

Table 4.2 Important drugs discovered on the basis of ethnomedicinal knowledge

Drug	Plant name	Medicinal use
Aspirin	Filipendula ulmaria	Reduces pain and inflammation
Codeine	Papaver somniferum	Eases pain and suppresses coughing
Ipecac	Psychotria ipecacuanha	Induces vomiting
Pilocarpine	Pilocarpus jaborandi	Reduces pressure in the eye
Pseudoephedrine	Ephedra sinica	Reduces nasal congestion
Quinine	Cinchona pubescens	Against malarial fever
Reserpine	Rauvolfia serpentina	Lowers blood pressure
Scopolamine	Datura stramonium	Eases motion sickness
Theophylline	Camellia sinensis	Open bronchial passages
Vinblastine	Catharanthus roseus	Combats Hodgkin's disease

it and are *teniposide* to treat bladder cancer and podophyllotoxin from which a powerful anti-tumor agent has been synthesized (Balick and Cox 1996).

To date, in India, based on ethnomedicinal knowledge, several drugs have been developed (Table 4.3). These are marketed by the pharmaceutical companies and research is going on in the development of drugs for some ailments including cardiovascular drugs from *Terminalia arjuna*; antdiabetic drugs from *Momordica charantia*, *Gymnema sylvestre* and *Andrographis paniculata*; antiprotozoal drugs from *Selaginella bryopteris*; anti malaria drugs from *Azadirachta indica, Ancistrocladus heyneanus*; for antileishmanial drugs *Diospyros spp*., and *Plumbago spp*. (Bhutani and Gohil 2010).

4.3.2 Future Scope of Ethbotanical Research in India

Medicinal plant species still unknown from a phytochemical point of view, have been used to cure of ailments of different types. Ethnic population makes resort to traditional medicine because of difficult access to Western medicine as well as their high cost. These people use a wide range of plants therapeutically to maintain their health. There is great promise for new drug discovery based on traditional plant uses. Globally, 119 plant derived drugs from 90 plants are in use (Farnsworth and Morris 1985). Significantly, 77% of these were obtained as a result of examining the plants based on ethnomedical uses (Cordell 2000).

The value of ethnomedicine was recognized about six decades back in India with the pioneering work of Jain (1994). The Tropical Botanic Garden and Research Institute (TBGRI) conducted an ethnobotanical field study in the forests of southwest India in 1987. These forests are home to the Kani tribe, nomadic traditional

Table 4.3 Important drugs developed in India based on ethnomedicinal knowledge

Drug	Plant name	Medicinal use
Vasicine	Adathoda zeylanica	Bronchial disorder
Flavonoids	Euphorbia prostrata	Piles
Sennosides	Cassia spp.	Constipation
Baccosides	Bacopa monnieri	Memoray enhancer
Tylophorine	Tylophora indica	Bronchial disorder
Conessine	Holarrhena antidysenterica	Antiamoebic
Shatavarin	Asparagus racemosus	Tonic
Monoterpenes	Ocimum sanctum	Respiratory disease
Flavonoids	Bauhinia variegata	Diarrhoea, piles
Monoterpenes	Cyperus rotundus	Antibacterial
Boerhavinones	Boerhavvia diffusa	Hepatoprotective
Anthocyanins	Syzygium cumini	Anti diabetic
Flavonoids	Vitex negundo	Anti inflamatory

collectors of non-timber forest products. The Kanis use a wild plant species for energy that they called arogyapacha, identified as *Trichopus zeylanicus* by the TBGRI. It provided a lead in the development of the drug "Jeevani" (giver of life) after the TBGRI transferred the manufacturing license to an Ayurvedic drug company in India. The TGBRI agreed to share 50% of the license fee and the 2% royalty on profits with the Kani (Anuradha 1998). Ethnobotany remains a fascinating and promising area of study for northeast India. The information about folk medicine of North-East India are still not gathered in systemic way or not documented in old literature, these are generally passed over generation to generation vocally. Multidisciplinary research and development work using the traditional folk medicinal plants based upon their traditional knowledge can provide deep motivation for identification of new pharmacophores. Newer approaches utilizing collaborative, multidisciplinary research on ethnomedicinal knowledge will help in near future in improving healthcare worldwide particularly from northeastern region of India. Some of the preliminary laboratory works carried out based on ethnobotanical knowledge in northeast India has been described here. Kar et al. 2005 carried out investigation based on traditional knowledge of Karbi and Hmar tribe of Assam on antimicrobial properties of extracts of *Curunga amara* Juss. against human pathogenic microorganisms. Tayung and Kar (2005) carried out investigation based on traditional knowledge of Monpa tribe of Arunachal Pradesh on antimicrobial activity of *Thalictrum javanicum* (Blume) root extracts against some human pathogens. Kalita et al. (2012) carried out antimicrobial study on *Paederia foetida* and *Hibiscus esculentus* which are generally used against stomach troubles, diarrhoea, hypertension, skin diseases, in urinary troubles and dental problem by the tribes of Assam. Similarly, *Hibiscus esculentus* extract was tested against the growth of *Staphylococcus aureus*. It possessed the potentiality against the growth of *E. coli*. Vijayakumar et al. (2012) carried out investigation on the *Illicium griffithii* fruit and seed from Arunachal Pradesh based on the ethnic knowledge. Phytochemical qualitative analysis revealed the presence of phenols, tannins, flavonoids, triterpenoids, steroids, alkaloids in the seeds. Ethyl acetate extract of fruits showed significant activity against *Staphylococcus aureus, Bacillus subtilis*, *Yersinia enterocolitica, Vibrio parahaemolyticus*, *Salmonella paratyphi, Xanthomonas oryzae* and *Pseudomonas aeruginosa*; methanol extract showed activity agains *S. aureus, Bacillus subtilis* and *Xanthomonas oryzae*. Haripyaree et al. (2013) carried out microbial investigation *Mimosa pudica* L*, Vitex trifolia* Linn*, Leucas aspera* Spreng*, Centella asiatica* (L) Urban and *Plantago major* Linn against antimicrobial screening of six organisms viz., *Ceratocystis paradoxa, Aspergillus niger, Penicillium citrinum*, *Macrophomina phaseoli*, *Trichoderma viride* and *Rhizopus nigricans* in Manipur and reported that *M. pudica* showed highest antifungal activities against more than one microorganism. Methanol and hexane extract of *M. pudica* and *V. trifolia* showed moderate and strong activities against *C. paradoxa*. *C. asiatica* extract showed activity against *M. phaseoli; Leucas aspera* exhibited antifungal activity against pineapple fruit rotting fungus *C. paradoxa*. Kalita et al. (2012) carried out an investigation on local medicinal plants *of Assam*. Some of the research institutes of northeast India are doing research on drug formulation based on ethnic knowledge and few of them are *Cajanus cajan* against jaundice, *Gomphostemma spp*. against malarial fever, *Terminalia spp*. against fungal diseases, *Oroxylum indicum* against cancer, *Dillenia indica* against diabetes. In addition to that some of research institute outside of northeast India collect plant sample from northeastern states and doing research in their laboratory. The above-mentioned species are some of the numerous examples only and there seems to be a possibility to explore more number of medicinal plants from this part of India for the development of useful drugs.

Existing rich ethnic heritage of India could be further explored through more dedicated ethnobotanical studies. It has also been gratifying that integrated forms of modern and traditional medicine have remained a part of reality. Information gathered from Ethnobotanical study would also be useful for conservation of traditional knowledge which is essentially required to save the cultural heritage of the natives. In this context confirmation of the therapeutical uses of the plants with scientific criterea and fostering phytochemical research on species containing potentially active principles would be more relevant for harnessing the value of ethnobotanical research carried out.

Silambarasan and Ayyanar (2015) carried out ethnobotanical studies in Eastern Ghats and recorded a total of 118 plants. Gairola et al. (2014) recorded a total of 948 plant taxa (923 angiosperms, 12 gymnosperms and 13 pteridophytes) belonging to 129 families, 509 genera, 937 species and 11 varieties from Jammu and Kashmir and Ladhakh for which no traditional medicinal use by indigenous communities of have been reported. Dey and De (2012) reported 56 plant species used against different types of gastrointestinal disorders like indigestion, stomach pain, vomiting tendency, constipation, piles, diarrhea, dysentery, cholera, loss of appetite, liver complaints, intestinal worms etc. Tetali et al. (2009) recorded 182 plants from Pune district of Maharastra used by tribes and natives for different ailments. From these plants, 28 flowering plants were documented for diarrhoea. Amongst the 28 plants, antidiarrhoeal activity of five plants viz., *Caesalpinia sepiaria*, *Dioscorea pentaphylla*, *Launaea pinnatifida*, *Syzygium rubicundum* and *Ziziphus jujuba* has not been reported previously.Two species viz., *Ziziphus xylopyra* and *Syzygium rubicundum* are endemic to India. Bisht and Adhikari (2018) reported 70 medicinal plants from Uttarakhand which have been used against 31 ailments. Kaur et al. (2011) recorded 15 medicinal plant species used to treat leprosy, arthiritis, nasal bleeding, ulcer etc. from Himachal Pradesh. Kaur et al. (2020) reported 51 plant species used to treat gastrointestinal disorder. Parul et al. (2017) recorded 18 medicinal plants from Harayana which have been used against digestive disorder.

4.4 Conclusions

Increasing demand on MAPs frequently comes along with the illegal overharvesting and unscrupulous collection practice of endangered plant species from the wild. Future strategies, regarding the conservation of the endangered plant species, are a major concern. Adaptation of some advanced plant biotechnological techniques, namely micro-propagation, hairy root technologies and synthetic seed production may be useful in securing surplus supplies of such plant species to meet its future demand. Isolation of most effective compounds and development of analytical tools of various *in vitro* and *in vivo* studies may result numerous opportunities to further unravel the potential bioactivities of the species. Additionally, *in silico* molecular docking techniques may play an important role in the identification/design of the most effective molecules.These effective molecules may be synthesized from their analogues available in higher quantity to reduce the pressure on their natural habitats. Also, research on chemical diversity to identify the active constituents will up open up opportunities to discover new chemotypes, as promising sources of drugs. There is a great scope for ethnobotanical studies as it points out to the species which most urgently should be studied scientifically. However, this approach in search of new pharmaceuticals is woefully underutilized.

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