EXPLORING MEDICINAL PLANTS

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ETHNOBOTANY AND ETHNOPHARMACOLOGY OF MEDICINAL AND AROMATIC PLANTS

Steps Towards Drug Discovery

Edited by
Mohd Adnan
Mitesh Patel
Mejdi Snoussi

Ethnobotany and Ethnopharmacology of Medicinal and Aromatic Plants

Medicinal and aromatic plants are beneficial to human health. Plant-derived molecules possess biological activities that can be used to prevent many infectious diseases and metabolic disorders. *Ethnobotany and Ethnopharmacology of Medicinal and Aromatic Plants* summarizes techniques and methods used to study the biological activities of plant-derived extracts and compounds to study ethnobotanical and ethnopharmacological features of medicinal and aromatic plants.

This book:

- Includes computational approaches to study the pharmacological properties of biomolecules in medicinal and aromatic plants.
- Details methods in ethnopharmacology including chromatographical and analytical techniques.
- Demonstrates trends in sustainable use and management of medicinal and aromatic plants.
- Features information on databases and tools used in computational phytochemistry for drug designing and discovery.
- Elucidates the importance of phytochemicals as immunomodulators in herbal drug development including their nanoformulations.

A volume in the Exploring Medicinal Plants series, *Ethnobotany and Ethnopharmacology of Medicinal and Aromatic Plants* will be of interest to those working with plant extracts, including botanists and ethnobotanists, pharmacologists and ethnopharmacologists, as well as scientists and researchers interested in natural compounds and their potential applications.

Exploring Medicinal Plants

Series Editor:
Azamal Husen
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Medicinal plants render a rich source of bioactive compounds used in drug formulation and development; they play a key role in traditional or indigenous health systems. As the demand for herbal medicines increases worldwide, supply is declining as most of the harvest is derived from naturally growing vegetation. Considering global interests and covering several important aspects associated with medicinal plants, the Exploring Medicinal Plants series comprises volumes valuable to academia, practitioners, and researchers interested in medicinal plants. Topics provide information on a range of subjects including diversity, conservation, propagation, cultivation, physiology, molecular biology, growth response under extreme environment, handling, storage, bioactive compounds, secondary metabolites, extraction, therapeutics, mode of action, and healthcare practices.

Led by Azamal Husen, Ph.D., this series is directed to a broad range of researchers and professionals consisting of topical books exploring information related to medicinal plants. It includes edited volumes, references, and textbooks available for individual print and electronic purchases.

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He has acted as a referee/reviewer for 70+ internationally recognized peer-reviewed journals and grant reviewer for many prestigious universities and organizations. In addition, he is a member of SFAM, UK and ESCMID, Switzerland, and an Elected Member of Royal Society of Biology, UK. He currently holds an Associate, Academic, Review, and Guest Editor positions in various reputed journals. Dr. Adnan is recently (September 2022) listed among the Top 2% Scientists in the World.

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1 Introduction to Medicinal and Aromatic Plants
Diversity, Biogeographic Distribution and Conservation Status

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1.1 INTRODUCTION

The definition of "medicinal plants" can be broadened to include all plants and herbs possessed of therapeutic properties or that have been shown to exert a beneficial pharmacological effect on the body of animals or humans (Bajaj 2012), whereas the term "aromatic plant" refers to a special kind of plant that is used for its flavours and aromas. A number of these plants are also used as medicines for a variety of ailments. A wide variety of aromatic compounds can be found in different parts of a plant (Rao, Palada and Becker 2004). In general, the term "Medicinal and Aromatic Plants" (MAPs) refers to botanical raw materials, also called herbal drugs, used as components of

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cosmetics and medicinal products and other natural health products. MAPs are primarily utilized as therapeutic, aromatic or culinary ingredients (Lubbe and Verpoorte 2011). There are a number of MAPs that represent a significant segment of the flora, providing raw materials that are used in the pharmaceutical, beauty, and for the production of other natural products. Medicinal plants, also known as medicinal herbs, are plants that possess therapeutic properties or exert pharmacological effects that are beneficial to the human or animal body in some way (Miguel 2010). Aromatic plants are plants whose aroma is pleasing to the human or animal senses. The aroma of aromatic plants is used extensively as spices, flavouring agents, perfumery and medicine, all of which have a wide range of uses. Additionally, these plants also serve as a major source of raw materials for the production of a number of important industrial chemicals (Costa et al. 2015).

It is generally accepted that plants that possess medicinal and aromatic properties, which are frequently used in pharmacy and/or perfumery, should be defined as medicinal and aromatic plants; however, as many medicinal and aromatic plants are also utilized in cosmetics, it might be better to call them medicinal, aromatic and cosmetic plants (Fierascu et al. 2021). In order to be classified as aromatic, a plant must contain aromatic compounds – basically volatile essential oils that are released, when the plant is in its natural state. It is well-known that essential oils are highly concentrated compounds with an odour, volatile properties and hydrophobic properties. Among the sources of these substances are roots, wood, bark, twigs, leaves, buds, flowers, fruits and seeds (Christaki et al. 2020). There are a number of complex mixtures of secondary metabolites found in essential oils, the majority of which consist of low-boiling-point phenylpropenes and terpenes. Aromatherapy and health care are two of the many industries where essential oils are widely used due to their characteristic flavour and fragrance properties, as well as their biological properties (Skendi et al. 2022). They have also been used extensively in spices, flavouring and fragrance, herbal beverages, pesticides, repellents and cosmetics. Some of the most popular examples of essential oils include eucalyptus, spearmint, ajwain, lemongrass, turpentine, grapefruit oil, mentha, patchouli, palmarosa and citronella (Aftab and Hakeem 2021) (Table 1.1).

There has been a long history of the use of MAPs for medicinal purposes, dating back well before the prehistoric period. The use of MAPs has been described in ancient Unani manuscripts as well as Egyptian papyrus and Chinese writings (Giannenas et al. 2020). Since over 4,000 years ago, the practice of MAPs medicine has been used as a form of treatment in Europe and throughout the Mediterranean region by different medicinal practitioners. MAPs have been traditionally used as part of the healing rituals of indigenous cultures throughout the world, such as Rome, Egypt, Iran, Africa and America, and there are a number of traditional systems of medicine that also incorporate herbal therapies into their traditional medicine systems (Faydaoğlu and Sürücüoğlu 2011). As far as traditional systems of medicine are concerned, they continue to be widely practiced on a variety of levels. In recent years, a number of factors have led to the increasing use of plant materials as a source of medicines for a wide variety of human ailments. These factors include an increase in population, insufficient supply of drugs, high prices for treatments, side effects of several synthetic drugs, and the emergence of resistance to current medicines used for infectious diseases (Máthé 2015).

Recent statistics by WHO estimates that 80% of the population of the world relies on herbal medicines for one or more aspects of their primary healthcare needs. There are approximately 21,000 species of plants that have the potential to be used as medicinal plants according to the WHO (Schippmann, Leaman and Cunningham 2002). There are more than 30% of all plant species on earth that have been used in some way or another for medicinal purposes at some point in time. In developed countries such as the United States, there has been an estimate that plant medicines contribute to as much as 25% of the total amount of medicine that is prescribed, while in fast developing countries such as India and China, this number could reach as high as 80% (Farnsworth and Soejarto 1991). Due to this fact, in countries like India, the economic importance of medicinal plants is much greater than in other countries in the world. Several of these countries are the source

TABLE 1.1
List of Several Important Medicinal and Aromatic Plants, Their Origin and Uses

Medicinal and Aromatic Plants	Place of Origin	Medicinal Uses	Drug Derived from MAPs
 *Aloe vera*	South Africa, Arabian Peninsula	In wounds and burn treatment	Aloe
 *Salix babylonica*	Europe	Good heart health, thinning of blood, pain relief	Aspirin
 *Cimicifuga racemosa*	Eastern United States and Canada	Hormonal disorder treatment, rheumatic disorder treatment	Black cohosh
 *Sanguinaria canadensis*	Southeastern United States	Cancer and skin disorder treatment	Bloodroot
 *Cinnamomum camphora*	Asia	Relief in rheumatic pain	Camphor

(*Continued*)

TABLE 1.1 (*Continued*)
List of Several Important Medicinal and Aromatic Plants, Their Origin and Uses

Medicinal and Aromatic Plants	Place of Origin	Medicinal Uses	Drug Derived from MAPs
 *Papaver somniferum*	Southeastern Europe, Western Asia	Cough suppression, pain relief	Codeine
 *Colchicum autumnale*	Eurasia	Gouty arthritis and cancer treatment	Colchicine
 *Oplopanax horridus*	Western North America	Cure infection, tuberculosis and diabetes treatment	Devil's club shrub
 *Digitalis purpurea*	Europe	Cardiac arrest treatment	Digitalis

(*Continued*)

TABLE 1.1 (*Continued*)
List of Several Important Medicinal and Aromatic Plants, Their Origin and Uses

Medicinal and Aromatic Plants	Place of Origin	Medicinal Uses	Drug Derived from MAPs
 *Oenothera biennis*	North America	Atopic dermatitis, cancer and nerve damage treatment	Gamma-linolenic acid
 *Hoodia gordonii*	South Africa	Reduce weight	Hoodia
 *Camptotheca acuminata*	China	Lung, ovarian and colon cancer treatment	Irinotecan, Topotecan
 *Catharanthus roseus*	Madagascar	Treatment of Hodgkin's lymphoma and leukaemia	Madagascar periwinkle

(*Continued*)

TABLE 1.1 (*Continued*)
List of Several Important Medicinal and Aromatic Plants, Their Origin and Uses

Medicinal and Aromatic Plants	Place of Origin	Medicinal Uses	Drug Derived from MAPs
 *Ephedra sinica*	China	Stuffy nose or nasal congestion, allergies, bronchodilation	Pseudoephedrine (Sudafed)
 *Pilocarpus pennatifolius*	Amazon Basin	Chronic glaucoma treatment	Pilocarpine
 *Cinchona pubescens*	South America	Heart and Malaria disease treatment	Quinine, quinidine
 *Datura stramonium*	Americas	Motion sickness, sedation	Scopolamine

(*Continued*)

TABLE 1.1 (*Continued*)
List of Several Important Medicinal and Aromatic Plants, Their Origin and Uses

Medicinal and Aromatic Plants	Place of Origin	Medicinal Uses	Drug Derived from MAPs
 *Illicium verum*	Asia	Viral diseases treatment (Influenza)	Shikimic acid (e.g. Tamiflu)
 *Ulmus rubra*	Southeastern United States	Gastrointestinal ailments, relief in coughs, skin irritations	Slippery elm bark lining
 *Taxus baccata*	North America, Asia	Breast cancer treatment	Taxol
 *Strychnopsis thouarsii*	Madagascar	Treatment of Malaria (in development)	Tazopsine

(*Continued*)

TABLE 1.1 (*Continued*)
List of Several Important Medicinal and Aromatic Plants, Their Origin and Uses

Medicinal and Aromatic Plants	Place of Origin	Medicinal Uses	Drug Derived from MAPs
 *Chondrodendron tomentosum* Roberson (2008).	South America	Relaxation in surgical muscle	Tubocurarine

of two thirds of the plants used in the modern system of medicine, and indigenous systems of medicine still provide the majority of health care to rural populations (Pan et al. 2014).

The use of medicinal plants for the treatment of various ailments is considered very safe since there are no or very few side effects (Adnan, Siddiqui, Arshad, et al. 2021; Siddiqui et al. 2021; Awadelkareem et al. 2022; Elasbali et al. 2022). One of the main advantages of these remedies is that they are in sync with nature. The golden truth is that the use of herbal treatments is not affected by age or gender (Reddy et al. 2020; Adnan, Siddiqui, Hamadou, et al. 2021). However, in the past few decades, certain groups of people have significantly benefited from the exploitation of biodiversity and the conversion of natural ecosystems to human-dominated ecosystems. The unfortunate thing is that such gains have often been achieved at the expense of biodiversity loss and degradation, which in turn has resulted in the exacerbation of poverty for other groups (Chandra 2016). In spite of our growing appreciation of the potential benefits that might accrue from systematic exploration of this vast storehouse of plants, we are also becoming increasingly aware that there is a simultaneous decline in the number of species available, which may lead to catastrophic results. Biodiversity is in decline, largely due to the activities of humans, such as the destruction of natural landscapes or the deforestation (Braddick 1994).

As a result of these occurrences, sustainable development is posed with a serious danger because our planet's species diversity is among the most valuable and irreplaceable resources we have. The loss of biodiversity is a grave matter of concern for human civilization, as it has become a matter of paramount concern (Shafi et al. 2021). As such, emergency measures need to be taken in order to prevent further diminution of the number of potential medicinal and biological agents (Heywood 2002). It is therefore the purpose of this chapter to introduce the readers to MAPs, their biodiversity, biogeographic distribution and discussion on their conservation.

1.2 DIVERSITY OF MAPs WORLDWIDE

In some cultures, there have been several plant species that have been used medicinally at one time or another in some form, but it is impossible to estimate the exact number. From an enumeration that was conducted by the WHO in the late 1970s, 21,000 medicinal species are listed (Penso 1978). According to Rafieian-Kopaei (2012), of 26,092 native species originating from China alone, 4,941 are used as medicines in Chinese traditional medicine, resembling 18.9% of the total species. If this calculation is considered for other well-known medicinal floras and then applied to the total number of species of flowering plants worldwide that exist (422,000), it has been estimated that in the world, there are more than 50,000 species of plants that can be used as medicinal plants. Worldwide,

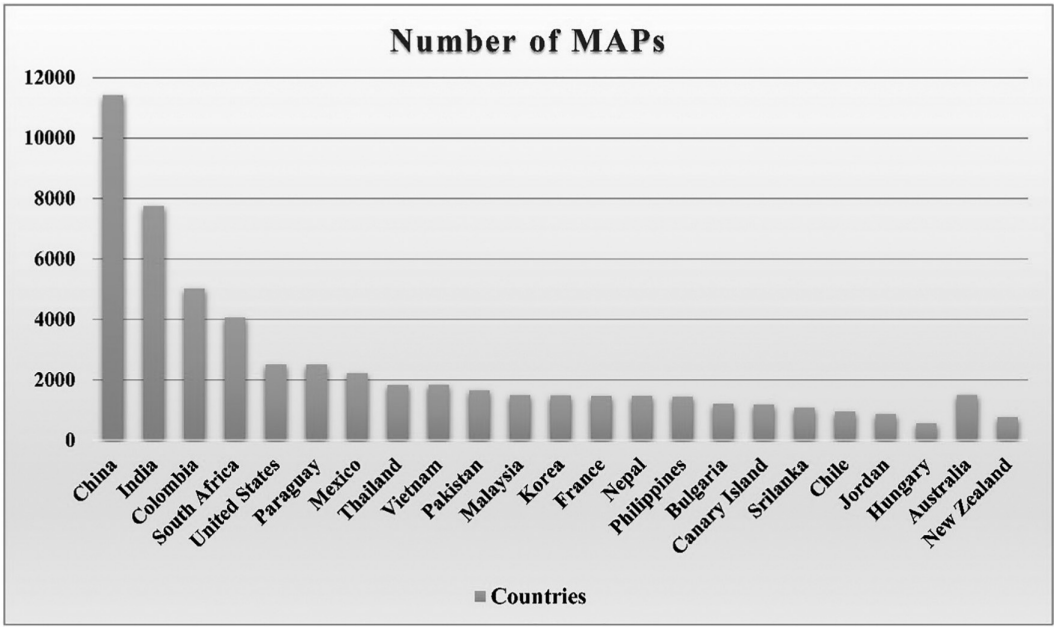

FIGURE 1.1 Number of medicinal and aromatic plants species in different countries of the world.

India and China are the two countries that have the highest utilization rate of medicinal and aromatics plants. Other countries, such as Colombia, South Africa, the United States, and 16 other countries, also utilize medicinal plants in great numbers (Figure 1.1) (A. Hamilton 2003; Balunas and Kinghorn 2005; Srujana, Konduri, and Rao 2012).

However, it is important to recognize that there are some plant families that are more likely to have medicinal values than other plant families. The following are some examples: Apocynaceae, Apiaceae, Araliaceae, Asclepiadaceae, Canellaceae, Guttiferae and Menispermaceae. Furthermore, it is imperative to note that these families are not distributed uniformly throughout the world. Thus, it is no surprise that some floras have higher proportions of medicinal plants than others and that certain plant families have a higher proportion of species that are threatened than others (Huang 2011).

1.3 BIOGEOGRAPHIC DISTRIBUTION OF MAPs

The science of biogeography studies how living things are distributed across the globe, and how abiotic and biotic factors influence the distribution of those living things. The abiotic factors like temperature and rainfall are mainly influenced by factors, such as latitude and elevation. As a consequence of these changes in abiotic factors, plant communities as well as animal communities are also likely to change in composition. It is important to note that some species are endemic, which means they can only be found in certain regions, while others are generalists, which means they can be found anywhere. The geographical distribution of important MAPs is presented in Figure 1.2.

1.4 MAPs OF AMERICA AND THEIR IMPORTANCE

The Amazon rainforest is home to a huge variety of medicinal plants that can be used to treat various ailments. There are many medicinal plants used in the United States that are listed in the "United States Pharmacopoeia" (Revision 2008). Similarly, the medicinal plants used in Brazil are listed in the "Brazilian Pharmacopoeia" (Zhou et al. 2021). There is a palm tree in the Amazon Basin

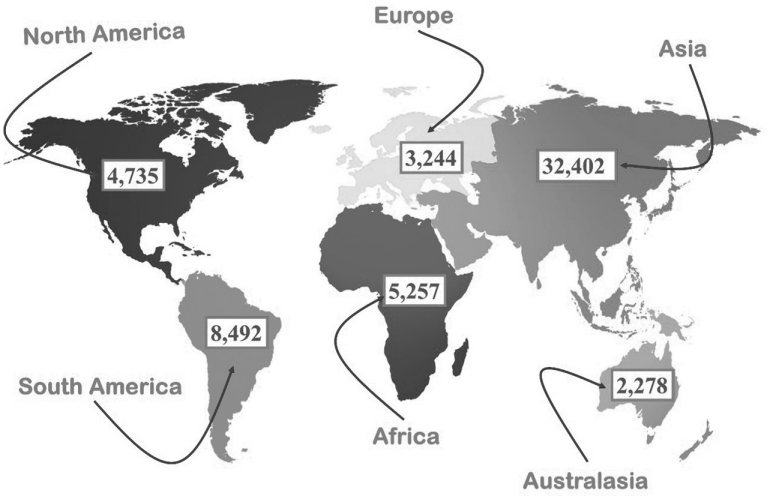

FIGURE 1.2 The geographic distribution of medicinal and aromatic plants around the world.

called *Euterpe oleracea* (Arecaceae). Due to the presence of anthocyanins in its fruits, it exerts medicinal properties (Desmarchelier 2010). In regions such as Peru, *Myrciaria dubia* (Myrtaceae) commonly known as Camu-Camu is another plant that grows in the Western Amazon Basin. There is a high level of vitamin C in the fruit that makes it an antioxidant (Desmarchelier 2010). *Croton lechleri* (Euphorbiaceae) is a small tree or shrub that produces red viscous latex that is referred to as Dragon's Blood. Traditionally, this latex has been used as a substance for wound-healing, anti-inflammatory, antiviral, and antitumour purposes in the Amazon Valley. This plant has several bioactive compounds, such as the alkaloid taspine, the lignan 3,4-O-dimethylcedrusin, a variety of polyphenols and anthocyanidins (Desmarchelier 2010). There is a large and woody vine called *Uncaria tomentosa* (Rubiaceae), commonly known as "Cat's claw," found in the rainforests of the western Amazon Basin of Peru, Bolivia and Ecuador. An anti-inflammatory action is provided by its quinovic acid glycosides and alkaloids, which contains quinovic acid. As high as 4,000 meters above sea level, there is a plant known as *Lepidium meyenii* (Brassicaceae) grows in the Andes. As a result of its isothiocyanate content, it has stimulant properties. There is also another Asteraceae plant that can be found in the Andes called *Smallanthus sonchifolius* (also known as Yacón). Due to its contents of oligofructans and phenolic compounds, it has been shown to be effective in treating hyperglycaemia and kidney problems. Moreover, fructo-oligosaccharides are also found in high levels in this tuber (Desmarchelier 2010).

In the Amazon rainforest, *Paullinia cupana* (Sapindaceae) is a plant that produces a fruit that contains high levels of caffeine and has stimulant effects (Desmarchelier 2010). It has been found that there are many medicinal plants in Brazil (Benko-Iseppon and Crovella 2010). The root decoction from *Aleurites moluccanus* (Euphorbiaceae) can be applied for the treatment of inflammations of the urinary tract and the ovaries. In particular, the stem bark of *Amburana cearensis* (Fabaceae) and also fresh leaves and seeds can be highly effective in the treatment of external ulcers as well as vaginal and throat infections caused by infected bacteria. There is a certain antimicrobial property in the rhizomes of *Costus spiralis* (Zingiberaceae). In order to treat hepatitis, other liver diseases, as well as diarrhoea, *Bromelia laciniosa* (Bromeliaceae) is used. In the north-eastern part of Brazil, *Hancornia speciosa* (Apocynaceae) is found. It has also been found that Mate (*Ilex paraguariensis*, Aquifoliaceae) can also be used as a remedy for stomach diseases and diabetes (Benko-Iseppon and Crovella 2010). Mate can be found in north-eastern Argentina, Southern Brazil and Paraguay. In addition to being used as a tea, it can also be used as an ingredient in dietary supplements and as a

food. There are several types of xanthine alkaloids in this plant, which contribute to its stimulant and tonic effects. Paraguay's Stevia plant (*Stevia rebaudiana*, Asteraceae) contains a substance called stevioside in its leaves, which is a natural sweetener. One of the uses of stevia is as a sweetener in some foods that is low in calories (Desmarchelier 2010).

1.5 MAPs OF AFRICA AND THEIR IMPORTANCE

There is a wide variety of medicinal plants in Africa that are described in the "African Herbal Pharmacopoeia" (Brendler et al. 2010). The African continent is home to a rich diversity of MAPs. In the Dioncophyllaceae family, one species of such plant is *Triphyophyllum peltatum*. The drug has been shown to have antimalarial properties against *Plasmodium falciparum* (Khalid 2009). This activity can be attributed to the alkaloid 5-O-demethyl-8-O-methyl-7-epidioncophylline A, which has a unique structure. The antifungal activity of *Dolichos marginata* ssp. *erecta* (Fabaceae, contains sphenostylis in the bark of the roots) and *Chenopodium procerum* (Chenopodiaceae, contains isoflavonoids in the roots) has been observed recently. There are prenylated xanthones present in the root bark of South African *Garcinia gerrardii* (Clusiaceae) that are fungicidal (Khalid 2009). A plant called *Diospyros usambarensis* (Ebendaceae) is found in Malawi that contains quinones that have both molluscicidal and fungicidal effects, and *Hypericum revolutum* (Clusiaceae) contains chromenes, which are also fungicidal (Khalid 2009). Diterpene lactones present in *Parinari capensis* (Chrysobalanaceae) are antifungal compounds that are found in Zimbabwe. *Bauhinia rufescens* Lam (Fabaceae), growing in the Niger region of West Africa, has also been found to contain tetracycline, an antifungal compound. In Madagascar, *Lepidagathis alopecuroides* (Acanthaceae) has antifungal properties because of two diterpenes it contains: fluricoserpol A and dolabeserpenoic acid A, both of which are diterpenes. There is a crop called *Swartzia madagascariensis* (Fabaceae) that is grown in East Africa. There is a saponin in the seeds that is molluscicidal. It has been demonstrated that the saponins contained in the leaves of the endemic tree *Polyscias dichroostachya* (Araliaceae), growing in Mauritius, are capable of killing molluscs (Khalid 2009).

1.6 MAPs OF ASIA AND THEIR IMPORTANCE

"The Indian Pharmacopoeia" (Pharmacopoeia and Commission 2010) and the "Pharmacopoeia of the People's Republic of China" are two important pharmacopoeias in Asia (Xu et al. 2021). Asian MAPs are very diverse, when it comes to their medicinal properties. There are several plants included in this chapter that come from India, Vietnam, Laos and China. A few of these plants include: *Swertia angustifolia* (Gentianaceae), which can be used in the treatment of fever and malaria; *Stemona tuberosa,* which can be used to treat asthma and tuberculosis and *Dillenia indica* (Dilleniaceae), which can be used to treat diarrhoea and dysentery (Rai 2012). In the Lauraceae family, *Litsea verticillata* is an example of a medicinal plant from Vietnam. Plants such as this one contain an anti-HIV substance known as litesane sesquiterpene and litsea verticillol, which can be isolated from the leaves and twigs of the plant. There are various macrocyclic trichothecene sesquiterpenoids that can be found in the leaves and stem bark of *Ficus fistulosa* (Moraceae), but one of the most active ones is verrucasin L acetate. There is evidence that it has antimalarial activity (Soejarto et al. 2006). *Asparagus cochinchinensis* (Asparagaceae) has been found to have anti-HIV activity in Laos, while *Nauclea orientalis* (Rubiaceae) has been discovered to have antimalarial activity (Soejarto et al. 2006). Thailand and China both have species of *Crassocephalum crepidioides*, which are the members of the Asteraceae family. Jacoline and jacobine are the main components of the plant. A decoction of the whole plant is used as a treatment for fever, dysentery, gastroenteritis, urinary tract infections and mastitis (Roeder 2000). An Asteraceae plant called *Senecio integrifolius* var. *fauriri* (also known as *Senecio integrifolius*) is a traditional Chinese herb that is used as a remedy for dysentery, conjunctivitis and tumefactions. A number of alkaloids are present in it, including integrifoline, 7-angeloyltumeforcidine, 1,2-dihydrosenkirkine and 7-angeloylheliotridine.

1.7 MAPs OF AUSTRALIA AND THEIR IMPORTANCE

A comprehensive list of medicinal plants found in Australia and New Zealand is available in the "Australian and New Zealand Pharmaceutical Formulary" (Gill 1934). It has been shown that *Amyema quandang* leaves (Loranthaceae), *Eremophila duttonii* leaves (Myoporaceae) and *Lepidosperma viscidum* stem bases (Cyperaceae) have antibacterial activity against gram-positive bacteria such as *Bacillus cereus*, *Enterococcus faecalis*, *Staphylococcus aureus* and *Streptococcus pyogenes*. There are a number of traditional medicinal plants that are used to treat colds (*Lepidosperma viscidum*), fever (*Amyema quandang*), respiratory tract infections, sore throats, skin cuts, earaches or eye inflammation (*Eremophila duttonii*), as well as other conditions (Palombo and Semple 2001). Several gram-negative bacteria, such as *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Salmonella typhimurium*, are partially inhibited by *Euphorbia australis* (Euphorbiaceae). The traditional use of *Euphorbia australis* has been to treat skin sores and to make medicinal washes. Among the plants that have been found to have antiviral activity against poliovirus are *Dianella longifolia* var. *grandis* (Liliaceae, roots) and *Pterocaulon sphacelatum* (Asteraceae, green aerial parts). The extracts from *Euphorbia australis* and *Scaevola spinescens*, both of which belong to the Euphorbiaceae, have also shown activity against human cytomegalovirus. A variety of plant extracts have been found to be effective in the treatment of Ross River virus, such as *Eremophila latrobei* (Myoporaceae) and *Pittosporum phillyraeoides* var. *microcarpa* (Pittosporaceae) (Semple et al. 1998).

1.8 MAPs OF EUROPE AND THEIR IMPORTANCE

"The European Pharmacopoeia," "The German Pharmacopoeia" and "The British Pharmacopoeia" (Plitzko et al. 2009; Anderson 2010; Yacoub, Cibis, and Risch 2014) list a wide variety of medicinal plants that are used in Europe. There are also a number of medicinal plants from Italy and Spain. There is an Italian traditional medicine that uses the juice of *Chelidonium majus* (Papaveraceae) to treat warts. Topically, it is applied to the skin. To treat abdominal pain, the aerial parts of *Echium italicum* (Boraginaceae) are applied externally. In addition to its use as an antiseptic, the buds and flowers of *Crocus napolitanus* (Liliaceae) are also used as an external poultice in order to prevent lice from spreading. For the treatment of shingles (*Herpes zoster*), the bulbs of *Lilium candidum* (Liliaceae) can be useful. There is a use for the entire *Parmelia* sp. (Parmeliaceae) as a cholagogue (Pieroni 2000). A Spanish plant called *Phlomis lychnitis* (Lamioideae) can be found in the Mediterranean region. A decoction made from this plant proves to be effective at treating haemorrhoids. As a vulnerary and disinfectant, the bark of *Quercus suber* (Fagaceae) can be used to treat wounds and for disinfection of wounds. The use of *Marrubium vulgare* (Lamiaceae) has also been found to be effective in the treatment of asthma. *Leuzea conifera* (Asteraceae) should also be mentioned, as its decoction is used for treating gastritis and colitis (Vázquez, Suarez, and Pérez 1997).

1.9 CONSERVATION STATUS

It is becoming increasingly common to harvest medicinal plants in increasing quantities, mainly from wild populations of plants. Over the course of the last decade, Europe, North America and Asia have experienced an increase in the demand for wild resources of 8–15% per year (Simmonds 2006; Bentley et al. 2014). It has been shown that reproductive capacities of important MAPs can become irreversibly reduced below a certain threshold (Soulé et al. 2005; Semwal et al. 2007). Different sets of recommendations regarding the conservation of MAPs have been developed over the years, including the provision of *in situ* and *ex situ* conservation measures (Huang 2011; Liu, Chen, and Yu 2011). It is well established that natural reserves, as well as wild nurseries have an important role to play in preserving the medicinal efficacy of plants in their natural habitats, while botanic gardens and seed banks hold an important place for the conservation of *ex situ* plants and the replanting of

future crops (Sheikh, Ahmad, and Khan 2002; Coley et al. 2003). In order to determine whether a species is best conserved in nature or in a nursery, the geographical distribution and biological characteristics of medicinal plants must be known in order to guide conservation activities.

1.10 IN SITU CONSERVATION

In most endemic MAPs, the medicinal properties are caused by secondary metabolites that are formed when plants are exposed to certain stimuli, and it seems that these secondary metabolites do not have the same effect in cultivation conditions (Coley et al. 2003; Figueiredo and Grelle 2009). It is only by preserving whole communities out of *in situ* that it is possible for us to preserve indigenous plants, maintain natural communities and also take into account their intricate network of relationships in order to conserve them (Gepts 2006). Furthermore, the practice of *in situ* conservation is known to increase the amount of biodiversity that can be protected (Forest et al. 2007), and it facilitates the connection between resource conservation and sustainable use (Chunlin et al. 2003). Globally, *in situ* conservation efforts focus on the establishment of protected areas and ecosystem-centric approaches, rather than species-specific approaches (Ma, Rong, and Cheng 2012). For MAPs to be successfully conserved in their natural habitats, rules, regulations and potential compliance are essential (Soulé et al. 2005; Volis and Blecher 2010).

Degradation of habitats and destruction of MAPs are major factors, resulting in the loss of important resources (Camm et al. 2002). The purpose of natural reserves is to protect and restore biodiversity by preserving and restoring important wild resources (Chiarucci, Maccherini, and De Dominicis 2001; Rodríguez et al. 2007). There are over 12,700 protected areas around the world, covering 13.2 million km^2, or 8.81% of the Earth's surface (Huang et al. 2002). It is important to assess the contributions and ecosystem functions of individual habitats when conserving MAPs by protecting natural habitats (Liu et al. 2001). Natural wild plant habitats cannot all be protected due to competing land uses and cost considerations (Soulé et al. 2005; Kramer and Havens 2009). In a natural habitat, protected area or a place that is close to where the plants naturally grow, a wild nursery is established to cultivate and domesticate endangered MAPs (Schipmann et al. 2005; A. C. Hamilton 2004; Strandby and Olsen 2008). Overexploitation, habitat degradation and invasive species are putting heavy strain on many wild species, but wild nurseries can provide an effective method for conserving endemic and endangered MAPs *in-situ* (Li and Chen 2007; Wani et al. 2021).

1.11 EX SITU CONSERVATION

There is no sharp line between *ex situ* conservation and *in situ* conservation; however, the latter is often an effective complement to the former, especially when it comes to those MAPs that have been overexploited and are endangered, because they have slow growth, low abundance and a high susceptibility to replanting (A. C. Hamilton 2004; Havens et al. 2006; Yu et al. 2010). As part of *ex situ* conservation, plants are cultivated and naturalized to ensure that they can survive for as long as possible, and they are also sometimes used to create large amounts of plant material for creating drugs, so it is a direct step towards saving medicinal plants (Pulliam 2000; Swarts and Dixon 2009). In addition to retaining their potency even when grown far from their natural habitat, many previously wild medicinal plants can store their reproductive materials for future replanting in seed banks (A. C. Hamilton 2004).

1.12 BOTANIC GARDENS

Ex situ conservation is important at botanic gardens (Havens et al. 2006), which keeps ecosystems healthy to ensure the survival of rare and endangered plants (Huang et al. 2002). In terms of genetic conservation, living collections generally contain only a few individuals per species (Yuan et al. 2010), botanic gardens offer multiple advantages. Usually, they feature diverse taxonomical and

ecological flora grown together under common conditions (Primack and Miller-Rushing 2009). MAPs can be conserved by botanic gardens through propagation and cultivation protocols, as well as breeding and domestication programs (Maunder, Higgens, and Culham 2001). Genetic diversity of medicinal plants can be stored better *ex situ* in seed banks than in botanic gardens, and seed banks should be used to preserve biological diversity (Schoen and Brown 2001; Li and Pritchard 2009). Royal Botanic Gardens in Britain is the most noteworthy seed bank (Schoen and Brown 2001). By allowing quick access to samples, seed banks help conserve the remaining natural populations by providing information about their properties (Schoen and Brown 2001; Li and Pritchard 2009). To restore wild populations, seed banks must reintroduce plant species back into the wild and assist in their reintroduction (Li and Pritchard 2009).

1.13 PRACTICES RELATED TO CULTIVATION

Domestic cultivation of MAPs is widely used and generally accepted, despite wild-harvested plants being considered more efficacious (Gepts 2006; Leung and Wong 2010; Joshi and Joshi 2014). Through cultivation, new techniques can be used to resolve common problems encountered in the production of MAPs, such as toxic components, pesticide contamination, low active ingredient content and misidentification of herbal origin (Raina, Chand, and Sharma 2011). In order to improve yields of active compounds, which are almost invariably secondary metabolites, cultivation under controlled growth conditions can enhance yields and ensure stable production of active compounds. In order to obtain increased yields of the target products, cultivation practices are designed to provide the optimal levels of water, nutrients, optional additives and environmental factors, such as temperature, light and humidity, in order to provide the best conditions for cultivation (Liu, Chen, and Yu 2011; Wong et al. 2014). It has been shown that increased cultivation of MAPs results in a decrease in the harvest volume, assists in the recovery of their wild resources and lowers their prices to levels that are more reasonable (Schipmann et al. 2005; A. C. Hamilton 2004; Larsen and Olsen 2006).

1.14 GOOD AGRICULTURAL PRACTICES (GAP)

There have been a number of good agricultural practices (GAPs) developed for MAPs with the aim of regulating production, ensuring quality and assisting in the standardization of herbal drugs. An effective GAP approach ensures that herbal drugs (or crude drugs) of high quality are safe for use and are pollution free by making use of available knowledge to address a variety of problems (Muchugi et al. 2008). An environmental gap analysis includes germplasm, cultivation, collection and pesticide detection quality aspects, forensic authentication, identification of bioactive compounds and metal inspection (Makunga, Philander, and Smith 2008). GAP is actively promoted by many countries. It can be seen, for example, that Chinese authorities are promoting GAP as a means to cultivate plants that are commonly used medicinally in regions where they are traditionally grown (Ma, Rong, and Cheng 2012; Wani et al. 2021).

Moreover, the benefits of organic farming for MAPs are becoming increasingly well-known for their ability to create an integrated, humane, environmental and economic sustainably produced system (Rigby and Cáceres 2001; Macilwain 2004). The primary objectives of organic farming of MAPs include producing plants of higher quality and with greater productivity, ensuring their conservation and sustainable utilization and ensuring their quality and productivity. Among the most distinctive characteristics of organic farming is the lack of the use of synthetic nutrients, pesticides and herbicides. According to many current organic certification standards in both Europe and North America, synthetic fertilizers, pesticides and herbicides are not allowed in organic cultivation (Rigby and Cáceres 2001). As a natural method of farming, organic farming is benign to

the environment, and using farm-derived renewable resources is one of the most effective means of maintaining the biological processes of medicinal plants and maintaining the ecological balance of their habitats (Rigby and Cáceres 2001; Chan et al. 2012). In addition to providing nutrients to soil continuously, organic fertilizers improve soil stability, thereby contributing to the growth of medicinal plants and the biosynthesis of essential compounds. For example, when organic fertilizers were applied, the biomass yield of *Chrysanthemum balsamita* was increased and its essential oil content was high relative to those free from organic fertilizers (Reddy 2010). It is becoming increasingly important to cultivate medicinal plants organically to ensure their longevity and sustainability (Macilwain 2004).

1.15 UTILIZATION WITH SUSTAINABILITY

Destructive harvesting is generally associated with resource exhaustion and even extinction of MAPs that are limited in abundance and grow slowly (Larsen and Olsen 2006; Baker et al. 2007). As a result, good harvesting practices should be established in order to ensure the sustainable use of MAPs. Harvesting roots and whole plants (e.g. herbs, shrubs and trees) cause more damage to medicinal plants than harvesting leaves and flowers. Leaves can be used as an alternative to whole plants or roots in herbal remedies.

1.16 CONCLUSION

Over the centuries, different cultures around the world have used MAPs for a variety of purposes, including the treatment of illness and the maintenance of good health. MAPs are readily available to rural populations who are much more dependent on them for their healthcare regimens than they are on modern medicines. Currently, the majority of drugs that are available on the market have been derived from MAPs and have been largely used for various purposes. Consequently, it has become increasingly important for scientists and businesses to pay attention to MAPs that can be found in natural environments. However, we have yet to discover the treasure trove of MAPs that inhabit around the world. It has been estimated that less than 1% of all tropical plants had been screened for the possibility of being used as a pharmaceutical. Moreover, the harvesting of MAPs from wild populations is becoming more difficult as scientific and commercial attention increases on them. Several medicinal species are thought to be at risk of extinction due to the overharvesting of their medicinal properties. Therefore, it is essential to study and conserve MAPs. A growing number of species and habitats are being lost across the globe as a result of global climate change, which intensifies this urgency. Around 15,000 medicinal plants may be on the verge of extinction within the next few decades around the world. It is estimated that approximately one major drug is lost every two years, according to experts. Therefore, there is an urgent requirement for the protection and conservation of MAPs. Consequently, the need to conserve and protect the MAPs is urgent, as they have a great deal of importance. Several *in situ* and *ex situ* conservation approaches, practices related to cultivation, good agricultural practices can be widely utilized for the conservation purposes of MAPs. There are several advanced technologies that can be used in order to boost the conservation approach. For example, genetic engineering can make it possible to synthesize natural products on a large scale, and advances in tissue culture of MAPs can make it possible to produce important bioactive compounds at scale and with high efficiency. By encapsulating propagules in tissue, micropropagation can allow both storage and transportation of propagules and also promote faster regeneration. Synthetic seeds can also offer an alternative to normal seeds that may be used for cultivation, when they are not sufficient for propagation. In addition, molecular markers are available that can be used in breeding improvements in order to make improvements to the genome, and the breeding process can be significantly shortened through the application of genetic marker.

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