Medicinal Plants and their Utilization

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Earth, Environmental and Marine Sciences and Technologies
ICS-UNIDO, AREA Science Park
Padriciano 99, 34012 Trieste, Italy
Tel.: +39-040-9228108 Fax: +39-040-9228136
E-mail: elisa.roa@ics.trieste.it

Preface

Medicinal and aromatic plants have played an important role in the socio-cultural, spiritual and health-care needs of rural and tribal people of the emerging and developing countries. In many developing countries, a large section of the population still relies on traditional systems of medicine to meet their health-care needs. Also, more and more people in the developed countries have turned to alternative therapies and herbal medicines resulting in many fold increase in the demand of medicinal plants and their products in these parts of the world.

On one hand, the global resurgence of interest in medicinal plants provides opportunities for the emerging and developing countries to derive economical benefit, and on the other hand, it threatens the existence of natural resources of medicinal plants under the pressure of unsustainable collections and allurements of short-term monetary gains. The demand for medicinal and aromatic plants in the international market has shot-up suddenly not giving enough time to developing countries to rise to the occasion. Over-harvesting of high-value or high-demand medicinal plants has already threatened the existence of many valuable plant species. The situation is precariously balanced and requires all countries to make proper assessment of natural resources and sustainable quantities that can be taken out without jeopardizing the interest of our future generations.

The utilization of medicinal plants to develop value-added products is under-explored and under-developed in most developing countries except few states like India and China. The lack of appropriate technologies for processing, value addition, standardization, and inadequate information of domestic resources and international marketing opportunities are some of the bottlenecks in developing medicinal plant-based industry in the developing countries.

The International Centre for Science and High Technology (ICS-UNIDO) in its endeavour to promote sustainable utilization of medicinal plants in emerging and developing countries, has conducted a series of training courses and workshops to build technical know-how in developing countries, to emphasize the sustainable use of medicinal plant resources and to promote value addition of medicinal plants before they are exported to the international market. From time to time, ICS conducts workshops to update information on sensitive aspects of medicinal plant industry. In the year 2001, it organized a workshop to discuss the status of medicinal and aromatic plants in different parts of the world and many of the compiled papers in this document were presented at that workshop.

This publication has consolidated the information generated at different workshops conducted by ICS and gives a detailed account of medicinal and aromatic plant resources, their utilization pattern, R&D activities, marketing and trade situation in different countries of Asia, Africa and Latin America. The document also carries information on quality control and standardization of herbal medicinal products; bio-pesticides and their role in environment; the role of biotechnology in medicinal plants; and trade in herbal medicinal products. Although the information in this publication is not complete, it gives an overview of the prevailing situation in different parts of the world to stimulate those associated with any aspect of medicinal and aromatic plants. It will serve as information source for policy-makers, scientists, farming community and entrepreneurs to develop strategies for the development of the medicinal plant sector, and to formulate plans for the conservation and sustainable use of medicinal plant biodiversity.

Gennaro Longo
Area Director
Earth, Environmental and Marine
Sciences and Technologies

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Chapter 1
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by Krisana Kraisintu

Introduction

Medicinal plants have played a significant role in various ancient traditional systems of medication such as the Chinese, Ayurvedic, Unani, and their secondaries in many Asian countries. Medicinal plants still play an important role in emerging and developing countries of Asia, both in preventive and curative treatments, despite advances in modern western medicine. They also generate income to the people of many Asian countries who earn their livelihood from selling collected materials from the forest, or by cultivating on their farms.

The development of modern medicine in the 1900s, along with the introduction of modern drugs produced by pharmaceutical companies, have dealt a strong blow to traditional medicine which was accused of being inefficient, labour-intensive in preparation and, most important, unavailable due to scarcity of raw material. This is exacerbated by the lack of traditional doctors unable to earn a living without basic material (medicinal plants) and demand (customers).

The high cost of modern drugs (most of which are imported from the West), their unavailability in remote areas, and, in particular, the serious side effects of certain drugs, have all led the pendulum of medical treatment to swing back to the side of traditional medicine in recent years. The importance and value of traditional and indigenous herbal medicine were the subject of a campaign of the World Health Organization (WHO). This effort, in the 1970s, led to an appeal to all member countries to do their utmost to preserve their national heritage in the form of ethno-medicine and ethno-pharmacology and to bring back the use of known and tested medicinal plants and derivatives into primary health care in rural areas and as alternatives when modern medicine was not available. Moreover, since a large portion of drugs produced by pharmaceutical industry are derived from medicinal plants, the demand for their raw materials is steadily rising. Such demand is met by obtaining material from naturally-occurring plants through indiscriminate collection, or sometimes from cultivated sources.

Asia is unique among geographical regions of the world and possesses the highest biological diversity worldwide, deriving from the ecological conditions particularly in the tropical rain forests. There is thus abundant raw material for production of modern drugs. The high diversity of the region is well reflected in a number of species including medicinal plants that are present in the region.

Asia is not only rich in biological diversity, but also in cultural diversity. Since the dawn of human history, biodiversity and humanity have become inextricably linked, for example areas of high biological diversity are culturally the most rich, with a large number of distinct communities inhabiting adjacent areas, each with its own language, culture, and system of traditional medicine. The latter category depends on the availability of medicinal plants easily found within the community. A wealth of traditional knowledge about medicinal plants for curing illnesses has been accumulated over a long period and has been handed down from generation to generation.

There existed ancient civilization in East and South Asia parallel with cultural diversity which took place in isolated areas in the jungles of tropical Asia. Unlike the ruins of many empires of other regions, the Chinese and the Indian cultures were quite successful, prosperous, and above all, healthy. A simple argument for their being healthy is the number of people presently living in the two most populous countries of the world. Indonesia, which is the fourth most populous country, can also claim to have "healthy" people as well as ancient civilization. The peoples in the past had made extensive use of medicinal plants to cure their ailments based on local knowledge of drugs. From China and India, systems of traditional medicine spread to all other Asian countries. They were later modified and adopted to become systems of their own.

Asia has been well known in the modern world as the storehouse of raw material for western pharmaceutical manufacturers. Until the last decade, the majority of these raw materials were easily available from the wild. Along with cheap raw materials, accumulated traditional knowledge of native peoples on their use was also exported freely for further development and exploitation by western pharmaceutical companies. Owing to their long history of use by Asian people, an enormous number of medicinal plant species are known to them.

The Status of Medicinal and Aromatic Plants in Cambodia

Covering an area of 181,035 square km, Cambodia is bordered by Thailand to the west, Laos to the north and Vietnam to the east. Once a French colony, it was the least known Indo-Chinese country. It has a wide basin where farming communities live a simple life, in an original civilization and philosophy of mildness, surrounded by highlands. About 90% of the Cambodian population is Khmer and rest are Chinese, Vietnamese, Chams, Burmese, Thai and small minorities of hill tribes.

Cambodia lies in a tropical zone between 10 and 14° latitude north of the equator and has a warm and humid climate. The annual average temperature and humidity average are between 25 to 30°C and 80 to 90%, respectively.

The Mekong river traverses the country for about 500 km in a north-south direction forming a delta in Vietnam up to Phnom Penh. The Tonle Sap river, a tributary of the Mekong, flows for most of the year from its origin, the Tonle Sap lake, to the Mekong river. During the southeast Asian rainy season, it flows from the Mekong to the Tonle Sap lake causing floods in the area.

The central part of Cambodia has fertile plains with mountain ranges forming a natural boundary with Thailand. It has the Cardamom Mountains (named after the spice cardamom) in the west, the Elephant Mountains in the southwest, and the Dangrek Mountain ranges in the northern part of the country. Still today, these mountain ranges are densely covered with forest and only sparsely populated. About three-quarters of the landmass is covered with tropical forests, roughly one-fifth is arable, and the bulk of the remainder consists of sandy and infertile soils.

Cambodian Traditional Medicine

In Cambodia, herbal medicines were used for thousands of years for health-care needs. The practice continues even today because of its biomedical benefits and place in cultural beliefs throughout the country. Cambodia has the potential to make use of raw materials from more than 500 available medicinal plant species (Table 1).[1]

Locally, the medicinal plants are used in the form of a decoction, liquor or powder. The extract of a plant can be used singly or in combination, externally or internally. With the menace of HIV spreading rapidly in Cambodia, it is hoped that herbal medicines will provide some relief from this fatal disease in the coming years.

The Khmer system of traditional medicine has made a great contribution to maintain health in Cambodia. Similar to other Asian systems of traditional medicine, the history of Khmer traditional medicine is closely linked to the history of religion. For example, during the reign of Emperor Jayavarman VII in the XII century, it was well developed and a hospital health facilities network spread throughout the country.

In 1950, modern medicines began to be used in treatments, but only the rich had access while the rest of the population continued to depend on traditional medicines for their health-care needs.

During the Pol Pot era, most of the remaining Bali books, the valuable documents containing the experiences of intellectuals, monks and good traditional healers, were either destroyed or lost. However, during the same period, traditional medicines underwent a period of renaissance, since in most parts of the country they represented the only type of medical treatment available to all levels of the society.

Table 1: Medicinal and aromatic plants of Cambodia

Botanical name	Family	Chemical composition	Use(s)/indication(s)
Allium cepa L.	Liliaceae	Allicin	Asthenia, fatigue
Allium odorum L.	Liliaceae	Odorine	Cough, digestive, carminative
Allium sativum L.	Liliaceae	Allicin	Antivenomous, hypertension
Amomum krevanh Pierre	Zingiberaceae	Alpha-pinene, alpha-terpineol, borneol	Carminative, expectorant
Artabotrys odoratissimus R. Br. ex Ker. Gawl.	Annonaceae	Essential oils	Diuretic, carminative
Atalantia monophylla (L.) DC.	Rutaceae	Essential oils	Cough, digestive
Blumea balsamifera (L.) DC.	Asteraceae	Essential oils	Laxative, febrifuge
Cinnamomum cambodianum Lecomte	Lauraceae	-	Carminative, digestive
Citrus aurantium L.	Rutaceae	Cineol, linalol	Cough, digestive
Citrus grandis Osbeck	Rutaceae	Citral	Cough, digestive
Citrus hystrix DC.	Rutaceae	Essential oils	Influenza
Citrus medica L.	Rutaceae	Terpene, limonene, alpha-pinene	Cough, digestive, antispasmodic
Citrus nobilis Lour.	Rutaceae	Delta-limonene, citral	Cough, digestive
Citrus sinensis (L.) Osbeck	Rutaceae	Essential oils	Cough, digestive
Coleus amboinicus Lour.	Lamiaceae	Coleine, carvacrol	Cough
Coriandrum sativum L.	Apiaceae	Linalol, delta-pinene	Digestive
Curcuma longa L.	Zingiberaceae	Curcumin	Haemostasis, gastritis, pneumonia, flatulence
Cymbopogon nardus (L.) Rendle	Poaceae	Citral, citronellol, geraniol, Citronellal	Febrifuge, carminative
Cyperus rotundus L.	Cyperaceae	Cyperene, cyperol	Emmenagogue, colic, diuretic
Eryngium foetidum L.	Apiaceae	Essential oils	Febrifuge, digestive
Eucalyptus globulus Labill.	Myrtaceae	Cineol, eucalyptol, cajeputol	Febrifuge, antiseptic
Eugenia caryophyllus Bullock of Harrison	Myrtaceae	Eugenol, kaempferol	Local anaesthetic
Eugenia zeylanica Wight	Myrtaceae	Cajeputol, eucalyptol	Analgesic, sprain
Feroniella lucida Swingle	Rutaceae	Essential oils	Influenza, digestive
Illicium verum Hook. f.	Magnoliaceae	Anethole	Carminative, antispasmodic
Jasminum sambac (L.) Ait.	Oleaceae	-	Antispasmodic
Melaleuca leucadendron L.	Myrtaceae	Cajeputol, eucalyptol	Cough, febrifuge, sprain
Mentha arvensis L.	Lamiaceae	Menthol, menthone	Digestive
Michelia champaca L.	Magnoliaceae	Essential oils	Carminative, febrifuge
Murraya paniculata Jack	Rutaceae	Essential oils	Diuretic, carminative
Ocimum basilicum L.	Lamiaceae	Eugenol, geraniol, linalol, eucalyptol	Antispasmodic, carminative, digestive
Ocimum gratissimum L.	Lamiaceae	Gratissimine, eugenol	Influenza, sudorific
Ocimum sanctum L.	Lamiaceae	Eugenol	Antispasmodic, carminative
Petroselium sativum Hoffm.	Apiaceae	Apiol, myristine	Headache
Piper betle L.	Piperaceae	Cineol, eugenol, cathecol	Carminative, cough
Piper cubeba L. f.	Piperaceae	Essential oils, piperine	Migraine, rheumatism, boils
Piper lolot G. DC.	Piperaceae	Geraniol, borneol	Carminative, diarrhoea
Piper nigrum L.	Piperaceae	Essential oils, piperine	Digestive, carminative
Polygonum odoratum Lour.	Polygonaceae	Essential oils	Alimentary toxicosis and infections
Spilanthes acmella Murr.	Asteraceae	Stigmasterol, spiranthol	Analgesic, febrifuge
Tagetes erecta L.	Asteraceae	Quercetagitrin, tagetiin	Cough, detoxicant
Zingiber officinale Roscoe	Zingiberaceae	Zingerol, zingerone, shogaol	Hypocholesterolemia, antirheumatismal, tonic

Government Policy

After 1979, the government officially integrated traditional medicine into the national health system and involved a policy of support that has promoted, at different levels but in an uncoordinated manner, a variety of activities, most of which are still running.

The policy was aimed at organizing research on fundamental sciences applicable to traditional medicine and diseases treated effectively with these medicines. It dictates that efforts should be made to establish methodologies and technologies to develop traditional remedies, enhance the quality of traditional medicine to appropriate level, provide training to professional health workers on traditional medicine and pharmacy, promote the use of traditional medicine in primary health care, increase the importance of Cambodian traditional medicine and encourage traditional practice as a complement to modern medicine.

Network of Traditional Medicine System

In 1982, the Centre for Research on Traditional Medicine and Pharmacy was opened at central level with aid from the United Nations Children Fund (UNICEF), the Netherlands Organization for International Development Cooperation (NOVIB), the International Cooperation for Development and Solidarity (CIDSE), the Foundation Danielle Mitterrand (FRACE-LIBERTES) and the World Health Organization (WHO). A traditional medicine hospital in Phnom Penh was set up to provide the services of both traditional healers and medical doctors. The traditional practitioners were accepted in each district hospital and commune dispensary and a garden of the most needed medicinal plants for treatment was established. The Phnom Penh municipal health service and non-governmental organizations (NGOs) had trained traditional medicine healers in fundamentals of medical science.

The above-mentioned network deteriorated and today the traditional medicine hospital is no longer functional. The reasons might be those that caused Khmer traditional medicine to lose its knowledge base, namely competition with newly formulated traditional remedies, lack of collaboration between traditional healers and medical doctors, benefit-sharing problems and budget scarcity.

National Centre for Traditional Medicine

The National Centre for Traditional Medicine, under the Ministry of Health (formerly the Centre for Research on Traditional Medicine and Pharmacy), has been restarted from the outset with inappropriate infrastructure and human resources, and lack of means. The Centre has been running with donations from various NGOs since its establishment. It is undertaking activities with a manpower of six pharmacists, one assistant pharmacist, one traditional healer and thirty other staff members. It lacks a laboratory for analysis of plant material and quality control of the products. The qualified personnel working in this branch are unskilled and need to be trained.

Objectives of the Centre

The Centre is responsible for collecting information on: traditional remedies of importance in primary health care; medicinal plant species of commercial or industrial interest; diseases or disorders treated by traditional medicine, partly to promote the appropriate use of traditional medicine in communities. The studies on conservation and reproduction aspects of medicinal plants species, manufacture of herbal medicinal products methods and technologies for quality control of herbal medicines and development of traditional remedies are conducted by the Centre. It also provides consultancy to the Ministry of Health on issues related to traditional medicine, acts as national coordinator for the network on traditional medicine, and it is responsible for the development of monographs of selected plants and the Medflore database.

Achievements of the Centre

A total of 514 plants of therapeutic value have been documented in an inventory of medicinal plants in six provinces of the country. A booklet of *40 Medicinal Plants for Common Diseases*; three volumes of *Medicinal Plants*; two volumes of illustrated brochures on *Medicinal Plants in Cambodia and Medicines in Your Garden* (the booklet contains 11 medicinal plants commonly used for primary health care) have been published by the Centre to date. It has also compiled a list of selected diseases treated with medicinal plants in the primary health-care system and medicinal plant species of industrial and economical interest and those with toxic effects.

The pharmaceutical dosage forms from medicinal plants, with ensured quality and efficacy, have been developed through clinical trials for a variety of problems like diarrhoea, dysentery, toothache, cough, constipation, earache and ointment for shingles and skin diseases. For example, berberine has been extracted from *Coscinium usitatum* Pierre and is made into pomade, tablets and tincture for use.

The Centre organized a National Workshop on Traditional Medicine and Natural Products with support from WHO, in October 1997, at Phnom Penh and has developed the Medflore database with information on 160 medicinal plants. To process medicinal plants into suitable formulations, the Centre has acquired equipment for cutting, grinding, extracting, tableting and coating operations.

Regulatory Situation of Traditional Medicine

In Cambodia, traditional medicines are regulated by the Minister of Health's decision issued on 6 October 1998 for opening, closing and changing traditional medicine stores; a sub-decree issued on 28 April 1998 regarding production, import, export and trade; and a procedure for regulation of locally-produced traditional medicine and imported products have been issued by the Department of Drugs, Foods, Medical Materials and Cosmetics of the Ministry of Health.

The implementation of these regulations promotes the assurance of quality, safety and efficacy of traditional remedies using up-to-date technologies; controls the private sector regarding traditional medicine; differentiates and separates activities of manufacturers, wholesalers, retailers and healers; registers traditional products and strengthens the National Centre for Traditional Medicine in creating inventories and carrying out surveys of medicinal plants. In addition, these regulations are also helpful in documenting and cataloguing the information on traditional medicines; training staff for identification of medicinal plants and in physical and chemical assays; procuring basic laboratory equipment for the Centre; and preparing the National Traditional Pharmacopoeia.

The Status of Medicinal and Aromatic Plants of Lao PDR

The tropical rainforests, covering about 47% area of the Lao People's Democratic Republic (PDR), are not only important for the conservation of biodiversity but also serve as a large reserve of natural resources, including medicinal and aromatic plants. Over the last few decades, these plants have not only been exploited by pharmaceutical companies for production of medicines but also used by traditional practitioners as domestic raw material for the preparation of their remedies. The medicinal and aromatic plants play an important role in national socio-economics of the country and have contributed significantly to improving the life of the people of Laos.

Today, many precious medicinal and aromatic plant species have been threatened to extinction due to extensive clearing of the forests at the rate of 10,000 hectares annually. The slash and burn practice has been followed by the minority ethnics of Laos for cultivation of agricultural crops. The government has discouraged this practice in mountainous areas, implementing reforestation programmes in order to maintain the balance of biodiversity and preserve environment.[2]

Current Status of Medicinal and Aromatic Plants in Laos

Laos is rich in diversity of medicinal and aromatic plants (Table 2). At the same time, no company in the country undertakes the business on *materia medica*. Only a small-scale factory in the southern part of the country produces raw material for medicine from plants, and another in the centre produces terpentine oil from pine (*Pinus* spp.).

There are some pharmaceutical factories in the capital (of which three belong to the government sector, one is a joint-venture with China and the rest are privately owned), which produce only a small quantity of plant-based medicines. The factories in the private sector produce largely modern medicines and only a small portion from plant material. Most traditional medicine factories in the private sector produce only traditional remedies consisting of one or more medicinal plants. The raw material is pretreated and processed (such as cleaning, chopping, mixing, dosage formulation and packaging) for both domestic sale and export purposes.

Table 2: Aromatic and medicinal plants of Laos

Botanical name	Family	Local name	Part(s) used	Use(s)/indication(s)	Ecology
		AROMATIC PLANTS			
Acorus gramineus Soland.	Araceae	Hangkhao	Rhizome	Arrhythmia, asthma	Wild, cultivated
Adenosma spp.	Scrophulariaceae	Cheenaikorm	Whole herb	Coryza, cholagogue	Wild
Canangium odorata Hook.	Annonaceae	Kdannga	Flower, wood	Hypertension	Wild, cultivated
Chenopodium ambrosioldes L.	Chenopodiaceae	Sbanthong	Essential oil	Anthelmintic	Wild
Cinnamomum camphora (L.) J. Presl	Lauraceae	Eetooton	Wood, essential oil	Coryza, colic, chest pain	Wild
Cinnamomum cassia Bl.	Lauraceae	Khae horm	Bark, essential oil	Coryza	Wild, cultivated
Cinnamomum cortechinii Gamble.	Lauraceae	Sar juang	Leaf	Influenza	Wild
Cinnamomum iners Reinw.	Lauraceae	Khae phet	Bark, essential oil	Influenza	Wild
Cinnamomum obtusifolium (Roxb.) Nees.	Lauraceae	Khae moo	Bark, essential oil	-	-
Elsholtzia cristata Willd.	Lamiaceae	Niao mar	Whole herb	Cold, headache	Wild
Eucalyptus spp.	Myrtaceae	Nammankieo	Leaf, essential oil	Influenza	Cultivated
Eugenia zeylanica Wight	Myrtaceae	Samek	Young leaf		Wild
Glycosmis citrifolia Lindl.	Rutaceae	Somsun	Root, leaf	Asthma	Wild
Hibiscus abelmoschus L.	Malvaceae	Portaseua	Seed, root, essential oil	Diuretic, constipation	Wild
Homalomena occulta (Lour.) Schoot	Araceae	Born horm	Rhizome	Rheumatism	Wild, cultivated
Hyptis suaveolens (L.) Poit.	Lamiaceae	Sap haeng	-	Cold, insecticide	Wild
Litsea cubeba (Lour.) Pers.	Lauraceae	Seakhaiton	Fruit	Stomachic	-
Micromelum falcatum Tanaka	Rutaceae	Smart	Whole herb	Asthma	Wild
Ocimum basilicum L.	Lamiaceae	Bualaphar	Seed	Nausea, fever, kidney diseases	Cultivated
Ocimum gratissimum L.	Lamiaceae	Spaulomdeng	Whole herb, essential oil	Cold, caries	Wild, cultivated
Ocimum sanctum L.	Lamiaceae	Sapanlemkao	Whole herb	Malaria	-
Pinus khesya Royle ex Gordon	Pinaceae	Pack horm	Wood resin, essential oil	Cough, antiseptic	Wild, cultivated
Zanthoxylum spp.	Rutaceae	Khaen	Fruit	Flatulence	Wild, cultivated

Continued

Botanical name	Family	Local name	Part(s) used	Use(s)/indication(s)	Ecology
		MEDICINAL PLANTS			
Ageratum conyzoides L.	Asteraceae	Nia kee lo	Whole herb	Bleeding disorders	Wild
Alocasia macrorrhiza (L.) G. Don	Araceae	Karbook	Rhizome	Malaria, asthma	Wild
Alpinia officinarum Hance	Zingiberaceae	Khaar	Rhizome	Cholic, stomachic	Wild, cultivated
Alstonia scholaris (L.) R. Br.	Apocynaceae	Tin pact	Bark	Malaria, gastric disorders	Wild
Amomun xanthioides Wall.	Zingiberaceae	Mark naeng	Fruit	Flatulence	Wild, cultivated
Amorphophallus riviera Durr.	Araceae	Dookdeua	Tuber	Malaria	Wild
Andrographis paniculata Nees	Acanthaceae	Rasabee	Whole herb	Dysentery, antiseptic, tonic	Wild, cultivated
Artemisia annua L.	Asteraceae	Nart harm bay noy	Leaf	Malaria, fever	Wild, cultivated
Artemisia vulgaris L.	Asteraceae	Nat noy	Whole herb	Headache	Wild, cultivated
Artocarpus lakoocha Roxb.	Moraceae	Hart mee	Wood	Tapeworm infestation	Wild
Asparagus cochinchinensis (Lour.) Merr.	Liliaceae	See sarn	Rhizome	Diuretic, cough	Wild
Azadirachta indica A. Juss.	Meliaceae	Kar dau sarng	Wood	Malaria	Wild, cultivated
Bidens pilosa L.	Asteraceae	Nia kon jarm	Whole herb	Headache, caries, hiccough	Wild
Blumea balsamifera (L.) DC.	Asteraceae	Nat luang	Leaf	Coryza, flatulence	Wild
Caesalpinia sappan L.	Fabaceae	Farn daeng	Wood	Tonic, dysentery	Wild
Cassia alata L.	Fabaceae	Keylack ban	Root, leaf	Eczema	Wild
Cassia occidentalis L.	Fabaceae	Lamg kaet	Seed	Eye disorders, constipation	Wild
Catharanthus roseus (L.) G. Don.	Apocynaceae	Kao bok	Leaf	Leukaemia	Wild
Cinchona ledgeriana Moens.	Rubiaceae	Kaengkeenar	Bark	Malaria, tonic	Wild, cultivated
Coscinium usitatum Pierre	Menispermaceae	Kheua haem	Vine	Dysentery, cholagogue	Wild
Costus speciosus Smith.	Zingiberaceae	Euang bon	Rhizome	Arthritis	Wild
Crataegus pinnatifidus Bunge	Rosaceae	Mark jan	Fruit	Stomachic, cardiotonic	Wild
Curcuma longa L.	Zingiberaceae	Khamin	-	Gastritis	Wild
Curcuma spp.	Zingiberaceae	-	-	Prolapsus	Wild, cultivated
Curcuma zedoaria Rose.	Zingiberaceae	Khmaemdarm	-	Cholic, stomachic, cough	Cultivated
Dichroa febrifuga Lour.	Hydrangeaceae	Horm sarng	Leaf	Malaria	Wild
Drynaria fortunei J. Smith.	Polypodiaceae	Karpkae hean	Rhizome	Rheumatism	Wild
Eclipta alba (L.) Hassk.	Asteraceae	Hormkeo	Whole herb	Bleeding disorders	Wild
Elephantopus scaber L.	Asteraceae	Kefinokkhum	Root	Allergy, diarrhoea, fever, diuretic	Wild

Continued

Botanical name	Family	Local name	Part(s) used	Use(s)/indication(s)	Ecology
		MEDICINAL PLANTS			
Embelia ribes Burm. f.	Myrsinaceae	Som lo	Fruit	Tapeworm infestation	Wild
Eupatorium odoratum L.	Asteraceae	Nia falang	Root, leaf	Bleeding disorders, appendicitis	Wild, cultivated
Evodia lepta (Spr.) Merr.	Rutaceae	Khao mai	Root	Asthma	Wild
Gnaphalium indicum L.	Asteraceae	Phark kaep	Flower	Cough, bronchitis	Wild
Heliotropium indicum L.	Boraginaceae	Nguangsanmg	Root	Backpain	Wild
Holarrhena antidysenterica (Roxb. ex Fleming) Wall. ex A. DC.	Apocynaceae	Mook may	Bark, seed	Dysentery	Wild
Justicia adhatoda L.	Acanthaceae	Hoohardong	Leaf	Bone fractures	Wild
Kaempheria galanga L.	Zingiberaceae	Van tupmup	-	Gastric ulcer, chest pain	Wild, cultivated
Lasia spinosa (L.) Thwaites	Araceae	Born nam	Rhizome	Angina, oedema	Wild
Leea sambusina Willd.	Leeaceae	Tarng kai	Root	Tonic, rheumatism	Wild
Mahonia bealei Carr.	Berberidaceae	Baerberin	Wood	Conjunctivitis	Wild
Melia azedarach L.	Meliaceae	Hiern	Root bark	Anthelmintic	Wild
Morinda citrifolia L.	Rubiaceae	Njo	Wood, fruit	Arterial hypertension, constipation	Wild
Rauvolfia canescens L.	Apocynaceae	Khar niom	Root bark	Hypertension	Cultivated
Rauvolfia serpentina (L.) Benth. ex Kunz	Apocynaceae	Khar niom	Root bark	Hypertension	Wild, cultivated
Rauvolfia verticillata (Lour.) Baill.	Apocynaceae	Khar niom	Root bark	Hypertension	Wild, cultivated
Schefflera elliptica Harms.	Araliaceae	Lepmunang	Bark	Nervine tonic, rheumatism	Wild
Smilax glabra Roxb.	Smilacaceae	Jia hua	Rhizome	Tonic	Wild
Spilanthes acmella (L.) L.	Asteraceae	Park kart	Flower, leaf	Caries	Wild
Stephania glabra Miers.	Menispermaceae	Tom ngeuan	Bulb/tuber	Tranquillizer	Wild
Sterculia lychnophora Hance	Sterculiaceae	Mark jong	Fruit	Constipation	
Streptocaulon extensus Wight L.	Asclepiadaceae	Oysarm suan	Vine	Anthelmintic	Wild
Streptocaulon juventas (Lour.) Merr.	Asclepiadaceae	Kheua soot	Root	Tonic	Wild
Strychnos nux vomica L.	Loganiaceae	Saeng bena	Seed	Neurasthenia, tonic	Wild
Styrax tonkinensis (Pierre) Craib	Styraceae	Nian khao	Resin	Cough, bronchitis	Wild
Tetrapanax papyrifer (Hook.) K. Koch	Araliaceae	Tarng	Root, wood	Diuretic, galactogogue	Wild
Wedelia calendulacea Less.	Asteraceae	Kardum kham	Whole herb	Antibiotic	Wild, cultivated
Xanthium strumarim L.	Asteraceae	Nia kee on	Fruit	Allergy, goitre	Wild
Zingiber officinale Roscoe	Zingiberaceae	Khing	-	Influenza, cholic haemorrhagia	Wild

In order to study the richness of medicinal plants, the Laos government set up the Research Institute of Medicinal Plants (RIMP) in 1976, with the objectives of conducting surveys of medicinal plant resources and traditional formulae in practice; organizing a network of provincial traditional medicine and medicinal plants stations; studying the efficacy of formulae and their method of processing and improving the galenic forms of Lao traditional medicines.[3,4] Through the qualitative survey, the Institute has collected information on more than 200 species of medicinal value. Although it is still a small unit that lacks experience, it is considered as the headquarters of medicinal and aromatic plants research and development in Laos. It has one pilot plant for extraction of medicinal plants, which has produced the antimalarial drug artemisinin, through extraction and purification from *Artemisia annua* L.[5] The distillation of essential oils has also been carried out in this pilot plant (Table 3).[5]

Table 3: Essential oils distilled at the Research Institute of Medicinal Plants (RIMP), Laos

Botanical name	Local name	Essential oil yield (%)
Alpinia galanga (L.) Willd.	Khar	0.10
Artemisia annua L.	Nart horm bay noy	0.05
Cinnamomum cassia Bl.	Khae horm	0.15
Citrus hystrix DC.	Khee hoot (fruit)	0.40
Citrus hytrix DC.	Khee hoot (leaf)	0.78
Cunninghamia sinensis R.Br.	Long laeng (wood)	0.60
Curcuma longa L.	Khamin	0.32
Cymbopogon citratus (DC.) Stapf	See khai kheuang	0.75
Cymbopogon nardus (L.) Rendle	See khai	0.62
Elsholtzia blanda Benth.	Nieo mar	9.20
Enhydra fluctuans Lour.	Kha niaeng	0.30
Eucalyptus globulus Labill.	Nammankieo	0.92
Foeniculum dulce Mill.	Phark see	0.60
Hyptis suaveolens Pour.	Sarp haeng	1.00
Mentha arvensis L.	Slar nart	0.35
Ocimum basilicum L.	Spaolom khao	1.00
Pinus kesiya Royle ex Gordon	Pack	2.50
Zanthoxylum rhetsa DC.	Khuarng	0.16
Zanthoxylum nitidum (Roxb.) DC.	Khaen	1.90
Zingiber officinale Rosc.	Khirng	0.10

The search for medicinal plants and traditional remedies has produced some medicines for common diseases such as diarrhoea, dysentery, liver diseases, malaria, gastritis, leucorrhoea, and tapeworm infestations. These medicines therefore contribute to the improvement of people's health, especially in rural areas which lack access to modern medical care. The list of raw material for traditional medicine and essential oil production in the country is given in Table 4.[5]

The production size of governmental and private companies is so small that the demand of people can only be met at domestic level (Table 5).[5]

Table 4: Raw material for traditional medicine and essential oil production in Laos

Botanical name	Local name	Value (US$/tonnes)	
		Unprocessed	Semi-processed
Adenosma capitatum Benth.	Jeenikorm	162	16,432
Amomum spp.	Naeng	-	4,000
Amorphophallus rivieri Durr.	Dookdeua	216	-
Aquilaria crassna Pierr. ex Lee	Kaet snar	-	-
Artemisia annua L.	Nart horm bay noy	216	300,000 (artemisinin)
Cinchona spp.	Kaengkeena	3,892	-
Cinnamomum cassia Bl.	Khaec horm	3,240	-
Curcuma longa L.	Khamin	270	5,621
Curcuma odora L.	Varn narng	216	5,621
Cymbopogon nardus Rendle	See khai	30	-
Eleutherine subaphylla Gagn.	Bua leuat	324	-
Eucalyptus globulus Labill.	Nammankieo	-	32,432
Helminthostachis zeylanica L. Hook.	Kout noknhung	326	-
Homalomena aromatica (Roxb.) Schott	Born horm	216	-
Leonurus heterophyllus Sweet	Nart soy	108	46,432
Ocimum spp.	-	540	-
Polygonum multiflorum Thunb.	Marn ornling	1,297	-
Ricinus communis L.	Hoong sar	325	-
Santalum spp.	Por heuang (grade A)	600,000	-
	Por heuang (grade B)	200,000	-
	Por heuang (grade C)	120,000	-
Smilax glabra Roxb.	Jia hua	648	-
Sterculia lychnophora Hance	Mark jong	540	-
Strychnos nuxvomica L.	Saeng beua	100	-
*Styrax tonk*inensis (Pierre) Craib	Nyarn	-	8,000-10,000
Zingiber cassumunar Roxb.	Varn pye	216	-

Table 5: Some production units of plant-based drugs and aromatics in Laos

Name of unit	Scale of operation	Products
Government sector:		
Pharmaceutical Development Centre (PDC 1)	Medium	Semi-finished
Pharmaceutical Factory 2	Small	Finished
CBF Pharma Co. Ltd. (Champasack PF)	-	-
Pharmaceutical Factory Km 20	-	-
Saravane Province Extraction Unit	-	-
Research Institute of Medicinal Plants (RIMP)	Pilot scale	-
Private sector:		
TRM Factory "Golden Mouse" Brand	Small	Traditional remedies
TRM Factory "Dragon" Brand	-	-

The exploitation of aromatic plants at industrial level is very limited. At the beginning of 1996, a French company submitted an application to the government of Laos to undertake business on aromatic plants and set up a unit for essential oil production. Given the abundant resource of forest products, many foreign businessmen are interested

in cooperating with the RIMP to study the feasibility of exploiting medicinal and aromatic plants.

The prices of raw materials vary at the place of harvest and port of exportation: for instance, the price of cardamom in the Bachiang district where it is grown, is US$ 410 per tonne but this increases to US$ 2,440 per tonne when exported to the Champasack province.[6]

Problems and Constraints

In Laos, essential oil production from aromatic plants is considered as a new branch of economy. No systematic inventory has been made of potential aromatic plant species and their abundance.

With regard to medicinal plants, there is a lack of concrete data on potential plant resources for both exploitation and conservation. A lack of experience and facilities for carrying out studies on efficacy and safety, as well as pharmacological, pharmacodynamic, pharmacokinetic, toxicological and clinical studies of active constitutents from plants, and lack of funds to organize specialized training are the major constraints for research and development of medicinal and aromatic plants.

Future Directions

In order to improve the status of medicinal and aromatic plants, a list of priority medicinal and aromatic plants should be determined for their exploitation. The national policy should support the industrial utilization of medicinal and aromatic plants by providing financial support to initiate the industrialization of medicinal and aromatic plants production. National institutions, such as the ministries of public health, agriculture and forestry and commerce, and the Cooperation and Planning Committee (CPC) should provide adequate support for the basic studies on medicinal and aromatic plants, including the processes of extraction, quality control, clinical trials and marketing. Collaboration between forestry and medicinal and aromatic plants branches of public and private sectors should be promoted. The RIMP of Laos should request technical assistance from the United Nations Industrial Development Organization (UNIDO), the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO) and other organizations, especially to support resources surveys, training of manpower for active participation in the industrialization of medicinal and aromatic plants, and basic equipment needed to initiate the industrial utilization of medicinal and aromatic plants.

Conclusions

Since Laos is a small country, there are at present only a few industries dealing with herbal and medicinal plants. Even though demand of raw material from pharmaceutical factories is fairly attractive, there is still very little turnover in this sector. This is due to the lack of qualified personnel and appropriate materials, shortage of information on research and development, and competition from the international market. The constraints

of financial support from the government limit the development work necessary to manage the supply and demand of Laos.

In order to exploit the potential of herbal and medicinal plants for the benefit of human health, technical assistance from international organizations and relevant institutions of collaborating countries is needed, especially for the upgrading of production units of traditional medicine, including analysis equipment, technology transfer, short-term consultancy, short- and long-term training abroad, exchange of information regarding research and development on medicinal plants.

Furthermore, technical cooperation among southeast Asian countries is also important, because these have common problems. The exchange of information can minimize duplication of efforts through joint planning of research and development and complementary projects. In the near future, the RIMP would like to carry out a survey of plant species with curative properties and their potential economic values. In order to accomplish this plan, assistance from domestic and international institutions is vital. Appropriate means and qualified personnel are required to implement these plans. The outcome would provide basic data concerning quantities of material resources of medicinal plants, that would be of further use in safeguarding the environment from the threat of overharvest.

The Status of Medicinal and Aromatic Plants in The Philippines

Since the establishment of the Asian Network on Medicinal and Aromatic Plants (ANMAP) in June 1993, new developments and remarkable progress have taken place in the area of medicinal and aromatic plants in The Philippines. This is mainly due to the improving economy and the active participation of both governmental and private sectors, particularly in efforts to integrate medicinal and aromatic plants cultivation in the existing farming system in rural areas.

The medicinal plants listed in the 1993 Country Report and many others continue to provide basic and alternative health care to the peoples of The Philippines, especially in the remote islands, which lack modern medical facilities. The research and development efforts on medicinal and aromatic plants that abound the country have brought about major changes in the health-care industry. Many pharmaceutical companies have expanded into manufacturing of herbal medicines and body-care products. The essential oils industry has grown immensely compared to some years ago.

Many herbal products, especially herbal teas and cosmetics, are exported from the country. There is a strong movement from folk medicine to pharmaceuticals, and herbal medicines are now considered a strong partner in the health-care delivery system. Medicinal plants, which were earlier regarded as decoctions and poultices dispensed by herbalists, are now available in dosage forms like tablets, capsules, syrups, liniments, lotions,

ointments, lozenges and tinctures. Among body-care products, herbal soaps, shampoos, skin and body lotions, powders and colognes are quite popular on the market.[7]

Herbal Medicine Research in The Philippines

The Philippines have a rich tradition of herbal medicines, from the traditional healers in the countryside to the housewife who concocts remedies from her back garden. Medicinal plants are the major source of medicines in traditional healing practices. This tradition dates back centuries and has been handed down from generation to generation. Although seemingly taken over by modern medical practices, herbal medicines in The Philippines continue to flourish.

As the cost of health care continues to escalate and the rise of drug prices remains unabated, alternative modes of treatment have been sought out by both governmental and non-governmental sectors. A practical solution to this problem is to use natural remedies that are already in use by many Filipinos. A scientific validation of these remedies can provide a reliable and economical way of treating diseases to the public at large. Researchers in The Philippines have individually attempted to scientifically validate the use of certain herbal preparations for the treatment of specific diseases. In general, the output of this research has not been fully used as there was no venue where such knowledge could be consolidated and put to practical use. Only in 1974, a group of researchers from different sectors and institutions put up the National Integrated Research Programme on Medicinal Plants (NIRPROMP), which aimed to systematize the study of medicinal plants in The Philippines with an end goal of providing safe, effective, and affordable pharmaceutical products derived from commonly available plants.

To date, a number of plants have been studied and proven to be safe and effective in curing various diseases. The pharmaceutical dosage forms of some of these plants have already been marketed and are sold to the general public as affordable alternatives to modern drugs. The scientific validation of more plants is underway. In addition, many other institutions are now taking interest in herbal medicine research. Although there is still a long way to go, medicinal plant research in The Philippines continues to thrive and will hopefully pave the way for more affordable medicines for the Filipinos. The chronology of herbal medicine research in The Philippines is given in Table 6.[8]

National Integrated Research Programme for Medicinal Plants (NIRPROMP)

The National Integrated Research Programme for Medicinal Plants, overseen by the Philippine Council for Health Research and Development of the Department of Science and Technology, was initiated in 1974 to spearhead herbal medicine research in the country. It involved institutions like the faculties of agriculture, science, medicine and pharmacy of the University of The Philippines; the National Institute of Science and Technology; and the Department of Health, Education, Culture and Sports.

The need for a more systematic way of studying medicinal plants to provide affordable medicines and to discover novel or better cures for diseases was the driving force for

the foundation of the NIRPROMP. Whereas the initial goal of earlier herbal medicine researchers was to find the active principles responsible for efficacy of plants in curing diseases, this proved to be cumbersome and too costly. Thus, it was incumbent for the NIRPROMP not only to prove the safety and efficacy of medicinal plants but also to find easier and more cost-effective ways of using such plants. Although finding the active principle of the medicinal plant would be the eventual goal, the use of whole plant parts provided the easiest, fastest and more cost-effective way of exploiting the medicinal value of the identified plants.

Table 6: Chronology of herbal medicine research in The Philippines from 1991 to 2000

Year	Achievements
1991	Clinical trials revealed the effectiveness of sambong (*Blumea balsamifera* (L.) DC.) in treating urolithiasis and akapulko (*Cassia alata* L.) as an antifungal.
1992	Clinical trials confirmed the efficacy of "lagundi" (*Vitex negundo* L.) as a cough remedy.
1993	Research guidelines for the evaluation of safety and efficacy of herbal medicines were developed by the World Health Organization (WHO).
1994	The Department of Science and Technology and the Department of Health launched the antifungal lotion "Akapulko" on the market.
1994	The Bureau of Food and Drugs developed guidelines for registering medicinal products for those adopting National Integrated Research Programme on Medicinal Plants (NIRPROMP) technologies.
1995	Technology for production of "Lagundi tablet" cough remedy was transferred to Pascual Laboratories Inc.
1996	Herbal products lagundi (Ascof) and sambong (Re-leaf) were introduced to the market by Pascual Laboratories Inc.
1997	Ascof and Re-leaf won the silver medal (medicine category) at the 25th International Exhibition of Inventions, New Techniques and Products held in Geneva, Switzerland. Pascual Laboratories Inc. was given the "Golden Shell Award Rising Star" citation for innovative products with huge potentials in the international market. The Philippine Institute of Traditional and Alternative Health Care was created under Republic Act 8423 with herbal medicine research and development as one of its prominent features. Guidelines for the appropriate use of herbal medicines were developed by the WHO.
1998	Technology for production of Akapulko lotion and Lagundi syrup was transferred to the private sector. NIRPROMP strengthened herbal medicine programme in the country. Preclinical studies on mahogany seeds (*Swietenia macrophylla* King.) were completed.
1999	List of new priority plants finalized.
2000	Clinical trials of dosage formulations of tsaang gubat (*Ehretia microphylla* Lam.) as antispasmodic, yerba buena (*Mentha arvensis* L.), ampalaya (*Momordica charantia* L.) for diabetes and preclinical studies of new plants possibly effective for malaria, dengue fever, and tuberculosis were undertaken.

The initial research activities consisted of verifying the folklore claims for identified plants by using basic pharmacological techniques and rapid clinical screening methods. The information on plants that proved to be safe and effective (e.g. indications for use and methods for preparation of decoction, infusion, juice or poultice) were then provided to health workers at community level for dissemination to their constituents, i.e. traditional medicine practitioners. The data gathered from these studies were compiled and published in guidebooks on the proper use of medicinal plants, which now have been adopted by the Department of Health, Education, Culture and Sports, and various health NGOs. It has helped to promote the use of herbal medicines in the rural areas.

At present, there are ten plants which have been identified for such purposes and have passed safety and efficacy tests. The use of these medicinal plant products can be promoted to provide safe, effective and low-cost alternative modes of treatment.

The production of commercial dosage forms (e.g. tablets, syrups, ointments or lotions) from these plants is the goal of the NIRPROMP. It has already transferred the technology of drug preparation for three identified plants to the local pharmaceutical companies and drugs derived from these plants are now commercially available at affordable prices. More plants are being studied, and commercial ulitization of their products is expected in the future.

The NIRPROMP will spearhead the identification of the active principles of the plants already available for commercial use. The participation of the private sector is needed for their in-depth phytochemical and pharmacological studies.

In the meantime, more plants are being screened for possible inclusion in pharmacological and clinical studies. The NIRPROMP continues to work unrelenting in this respect.

Germplasm Collection and Conservation

The government laboratories and agencies conduct most of the research and development work at the University of The Philippines, private schools and laboratories. An active involvement of NGOs and private industry is a welcome development in recent years. The collection of germplasm and its conservation are the major actvities of the University of The Philippines, Los Baños (UPLB) through the Institute of Biological Sciences (IBS), the National Institute of Molecular Biology and Biotechnology (BIOTECH), the Department of Horticulture, the National Plant Genetics Research Laboratory (NPGRL), and the colleges of arts and science, agriculture and forestry. The Bureau of Plant Industry of the Department of Agriculture and the Department of Environment and Natural Resources (DENR) also contribute to this work. Most of the NGOs and private companies employ graduates from the universities and obtain assistance in terms of funding and equipment from other governmental agencies, like the Department of Science and Technology (DoST).[8]

Breeding and Improvement of Medicinal and Aromatic Plants

The studies on breeding and improvement of selected species particularly towards increasing the yield of the active constituent have been undertaken by various institutes in The Philippines. The technology of dwarfing aromatic plants, started some years ago, is attracting considerable interest. The dwarf plants are more suitable for cultivation. The tissue culture and hairy root culture of some medicinal and spice plants have been carried out by the scientists at the IBS and the BIOTECH, where most of the work centres on the rapid propagation of species that are difficult to propagate by usual methods. Extensive cytological and karyotype studies on medicinal plants have been performed at the genetics laboratory of IBS, UPLB, and tissue culture studies on certain medicinal and aromatic plants have been carried out at the NPGRL. Some work on breeding and improvement is in progress at the research laboratories of the essential oils industry.

Philippine Institute of Traditional and Alternative Health Care (PITAHC)

The PITAHC was created under the Traditional and Alternative Medicine Act (TAMA) 8423, signed into law in 1997. Among the programmes covered by theTAMA there is the use of herbal medicine. A development fund has been appropriated for the activities of the PITAHC. With the establishment of the PITAHC, it is hoped that the development of traditional and alternative health care in The Philippines will improve. The objectives of the Institute include encouragement of scientific research and development, and promotion and advocation of the use of traditional and alternative health-care systems, which have been proved to be safe and effective. The herbal preparations standardized by the Institute are given in Table 7.[9]

At present, the PITAHC has supported the efforts of the NIRPROMP by publishing manuals on the use of ten common plant medicines. It has also provided financial support for research projects on herbal medicines, such as the ethnomedical documentation of medicinal plants conducted by the Complementary and Traditional Medicine Programme of the National Institute of Health, University of the Philippines, Manila. The PITAHC coordinates with the governmental and non-governmental sectors for the promotion of herbal medicine research in the Philippines.

Other Institutes Working on Herbal Medicines

Herbal medicine research in The Philippines is expanding rapidly. Of late, many other institutions have become interested in the promotion of herbal medicine research. At the forefront are the leading universities in the country, such as the University of The Philippines, the University of Santo Tomas, Ateneo de Manila University and De La Salle University. The success of commercialized plant dosage forms has prompted other pharmaceutical companies and health NGOs to express interest in herbal medicine research.

Production, Processing, Utilization and Marketing of Medicinal and Aromatic Plants

Production

The increasing demand for natural products has brought the establishment of more production farms and the expansion of the existing ones. Plantations of several species, initiated to supply raw material to various research laboratories, are now catering for the needs of herbal processing and manufacturing units even in the private sector. All the government manufacturing units are operative, but still cannot meet the demand of herbal products.

The available data on production of some medicinal and aromatic plants show a definite growth and progress in the countryside. The plantations that have existed for over ten years continue to produce sustainable quantities to earn livelihoods for the communities dependent upon them. Some Philippine regions are more active and the production of aromatic plants is much higher than other medicinal plants in most areas.

Table 7: Herbal preparations from the Philippine Institute of Traditional and Alternative Health Care

Plant source	Common name	Use(s)/indication(s)	Part(s) used	Preparation	Mode of administration	Remarks
Allium sativum L.	Garlic	To lower blood cholesterol levels	Bulb cloves	Sauté; broil; soak in vinegar for about 30 minutes or blanch with boiled water for about 5 minutes.	Two cloves thrice a day after meal.	Consume garlic after meals in order to avoid ulcerations of the stomach. Cloves are also used to add flavour to food.
Blumea balsamifera L. DC.	Sambong	Oedema, urinary tract stones	Leaf	Boil 2 g in 15 ml water for 15 minutes. Divide the decoction in three parts.	Each part is taken thrice a day. Children are given half the dose of adults.	Not used for urinary tract infections. Mature and healthy leaves are dried and stored in air tight plastic bags or an amber coloured jars.
Cassia alata L.	Akapulko	Fungal infections, scabies	Leaf	Pound fresh healthy mature leaves.	The juice is applied on the affected area once or twice a day.	Use of decoction is recommended for patients allergic to fresh leaves.
Ehretia microphylla Lam.	Tsaang Gubat	Abdominal pain	Leaf	Boil 2 g in 15 ml water for 15 minutes. Divide the decoction in two parts.	Each part is taken every four hours. Children are given half the dose of adults.	Also used as gargle to strengthen teeth.
Mentha spicata L.	Yerba Buena	Body ache and pains	Leaf	Boil 2 g in 15 ml water for 15 minutes. Divide the decoction in three parts.	Each part is taken thrice a day. Children are given half the dose of adults. Fresh leaves also minced and applied on the painful area in the body.	Mature and healthy leaves, dried, stored in air-tight plastic bags or an amber coloured jars.
Momordica charantia L.	Ampalaya	Diabetes mellitus (type-2)	Leaf	Boil 2 g in 15 ml water for 15 minutes. Divide the decoction in three parts.	Each part is taken thrice a day half an hour before meal or 1g of steamed young leaves is eaten twice a day.	Fruits and leaves are consumed as vegetable.
Peperomia pellucida (L.) Kunth	Ulasimang Bato	Lower serum uric acid levels in gout patients	Leaf	Boil 2 g in 15 ml water for 15 minutes. Divide the decoction in three parts.	Consume one part thrice a day after meals. As salad: 1.5 g of fresh leaves divided into three parts, one part is consumed thrice a day.	Use healthy leaves only.

Continued

Plant source	Common name	Use(s)/indication(s)	Part(s) used	Preparation	Mode of administration	Remarks
Psidium guajava L.	Guava	Wound dressing, oral antiseptic	Leaf, shoot	Boil 2 g in 15 ml water for 15 minutes. Divide the decoction in three parts.	Wounds washed with cooled decoction twice a day; gargle with lukewarm decoction.	-
Quisqualis indica L.	Niyug-niyogan	*Ascaris* infection	Seed	Use dry freshly opened seeds, 8-10 seeds for adults; children are given half the adult dose.	Consumed 2 hours after supper.	Adverse effects include hicough, abdominal pain and diarrhoea. Ripe (gold coloured) air-dried fruits are stored in air-tight jars.
Vitex negundo L.	Lagundi	Cough, asthma, fever	Leaf	Boil 2 g in 15 ml water for 15 minutes. Divide the decoction in three parts.	For cough and asthma: consume each part of decoction thrice a day. For fever: consume each part of decoction every four hours.	Avoid lagundi plants bearing 1 to 3 leaves.Young healthy leaves collected during initiation of flowering are stored in tightly sealed plastic bags or amber coloured jars.

The production volumes of onion and garlic for the year 1993 in The Philippines are shown in Table 8.[10] The northern provinces are the traditional garlic- and onion-producing areas, followed by the Southern Tagalog and Central Luzon regions.

Table 8: Area under onion and garlic production in The Philippines

Region	Onion		Garlic	
	Area (ha)	Volume (tonnes)	Area (ha)	Volume (tonnes)
Cordillera Autonomous Region	1	1	5	3
Ilocos Region	2,742	22,640	3,006	7,886
Cagayan	175	915	10	14
Central Luzon	3,299	35,976	350	1,162
Southern Tagalog	76	253	762	3,302
Bicol Region	10	33	105	394
Western Visayas	17	53	13	47
Central Visayas	42	107	11	29
Eastern Visayas	0	0	0	0
Western Mindanao	15	59	0	0
Northern Mindanao	9	50	0	0
Southern Mindanao	38	101	0	0
Central Mindanao	5	24	0	0
Autonomous Region of Muslim Mindanao	0	0	0	0
Total	6,429	60,212	4,262	12,837

The pilot projects on selected essential oil crops were launched in 1991 in the Region IV-Southern Tagalog, with the establishment of production farms in two provinces. These are the nucleus production areas in the region. A twenty-seven hectares production farm for citronella *(Cymbopogon nardus* (L.) Rendle*)* is located in Visayas and almost the same size farm operates in Southern Tagalog. Additionally, in Southern Tagalog there are eight hectares farm for lemon grass *(Cymbopogon citratus* DC. Stapf*)*, three hectares for patchouli *(Pogostemon cablin* (Blanco) Benth.*)*, around five hectares for ylang-ylang *(Cananga odorata* (Lam.) Hook. f. & Thomson*)*, and all are operational. Many more areas devoted to aromatic plants are present in different regions, but records are not available at the moment and some of the production farms are experiencing management problems.

Processing and Utilization

The establishment of processing units in potential areas are based on crop suitability, land availability, cooperator's commitment and market tie-up. For aromatic plants, the DoST has established processing units in suitable areas. Moreover, the DoST assists farmers who need technical assistance or help in marketing. Table 9 lists the aromatic plants used in the private sector essential oil industry.

In medicinal and aromatic plants' utilization, the post-harvest technology is of prime concern. The effect of physiological factors and various post-harvest handling practices on the active principles of the plants has been studied. For instance, some studies have

shown that for most of the plants, cultural practices do not have much effect, but for aromatic plants, harvesting and post-harvest handling affect the quality not only of the drug, but also of the essential oil. The processing is important in minimizing crop losses, and methods and precautions for proper processing are necessary in training technicians who would be engaged in the processing of these plants.[9]

Table 9: Medicinal and aromatic plants used in the private sector of essential oil industry

Botanical name	Common name	Family
Cananga odorata (Lam.) Hook. f. & Thomson	Ilang-ilang	Anonaceae
Canarium luzonicum (Blume) A. Gray	Pili	Burseraceae
Cymbopogon citratus (DC.) Stapf	Lemon grass	Poaceae
Cymbopogon nardus (L.) Rendle	Citronella grass	Poaceae
Hedychium coronarium J. König	White ginger lily	Zingiberaceae
Jasminum sambac (L.) Aiton	Arabian jasmine	Oleaceae
Lagerstroemia speciosa L. Pers.	Banaba	Lythraceae
Moringa oleifera Lam.	Horseradish tree	Moringaceae
Ocimum basilicum L.	Sweet basil	Lamiaceae
Pogostemon cablin (Blanco) Benth.	Patchouli	Lamiaceae
Polianthes tuberosa L.	Tuberose	Agavaceae
Vetiveria zizanioides L. Nash	Vetiver	Poaceae

Marketing

The dissemination of information plays an important role in the marketing of medicinal and aromatic plants and their products. Seminars, exhibits, media presentations, all have proven the effective means of raising public awareness on medicinal and aromatic plants and their products. Coordination among production, processing and marketing sectors is instrumental in developing the essential oil industry and in identifying the potential markets for essential oil producers.

Herbal products are preferred by those who are disappointed with modern synthetic drugs, are health-conscious and prefer natural products, are well-informed about medicinal plants and herbal medicines, and among those who cannot afford the high cost of modern medicines. Interestingly, these categories include most of the population, therefore no problem exists with regards to market potential of herbal medicines. A rather current problem is how to cope with the rising demand. At present, most herbal products are distributed through the Department of Health (DOH), its subsidiaries, and community projects throughout the country. A number of imported herbal products have also entered the Philippine market.

There is remarkable interest in the therapeutic power of highly concentrated pure essential oils, in terms of stress reduction and care of common ailments, besides beauty preservation. Today the market priority is health and beauty care. Therefore, industry should focus its research and development activities in continuously satisfying needs, hopes, expectations and immediate problems of identified target markets, with an edge over competition.

Constraints and Problems

Production activities are not effectively sustained owing to lack of operational funds, management and organizational inefficiencies and imaginary market demand. The international market prices of essential oils are not attractive to local producers who need to sell their products at a higher price due to the low production volume and the high cost of production. The large manufacturing firms seldom disclose figures on demand and consumption. Partnerships among the different sectors from the industry, academia, producers, processors and market still have to be realized. As the primary concern of the government is food production for the ever-increasing population, medicinal and aromatic plants fall into a low-priority area.

The biotic and abiotic, as well as technological constraints in medicinal and aromatic plants production, processing and utilization in The Philippines may easily be overcome as long as partnership among the different sectors in industry and academia is established and fostered (even with a little government support), if the full potential of these plants is to be harnessed for improvement of the life quality of Filipinos.

Future Directions

At present, the NIRPROMP continues to spearhead research in herbal medicine with its efforts at demonstrating the safety and efficacy of medicinal plants. The pharmaceutical dosage forms are continuously being developed from various medicinal plant materials and new plants are being identified and subjected to various pharmacological/toxicological tests and bioassays. Clinical trials are also underway for a number of plants. The technology transfer protocols will be prepared for plants which have passed safety and efficacy testing.

Various agencies and institutions, such as the NIRPROMP, the PITAHC, the DOH, the National Institute of Health and the University of The Philippines in Manila, among others, continue to cooperate with each other and forge new alliances with the aim of undertaking rich and promising research endeavours. A wide range of activities are also being carried out to augment and update knowledge of researchers in the field of herbal medicine.

In future, the data amassed from all these research endeavours should be used to integrate the use of herbal medicine into the national health-care delivery system. It is hoped that with such knowledge, safe, effective and low-cost modes of treatment will be available to the general public. The realization of this goal may still take some time but the necessary foundations have already been laid to achieve the final purpose.

The Status of Medicinal and Aromatic Plants in Thailand

Thailand is bestowed with rich natural resources and has diverse ecological conditions and ethnic diversity including ancient civilizations. There are more than 10,000 species of plants out of which about 1,400 are listed as indigenous medicinal and aromatic plants used in Thai Traditional *Materia Medica* (Table 10).[11,12] An enormous amount of plant-based raw material is produced and used globally in pharmaceutical, perfumery, cosmetics, aroma-chemicals, and related industries. Several medicinal and aromatic plants are used in domestic consumption and exported as raw materials or intermediary chemicals to Europe, the USA and Japan. The cultivation is largely dependent upon the market demands outside the country. The potential species include: senna *(Cassia angustifolia* Vahl.*)*, pepper *(Capsicum* spp.*)*, chili pepper *(Capsicum frutescens* L.*)*, sweet basil *(Ocimum basilicum* L.*)*, citronella *(Cymbopogon nardus* (L.) Rendle*)*, jasmine *(Jasminum* spp.*)*, champaca *(Michelia* spp.*)*, ylang-ylang *(Cananga odorata* (Lam. Hook. f. & Thomson*))* and lemon grass *(Cymbopogon citratus* DC. Stapf*)*.

Table 10: Medicinal and aromatic plants grown in Thailand

Botanical name	Common name	Family
Abelmoschus esculentus (L.). Moench	Okra, lady's finger	Malvaceae
Abrus precatorius L.	American pea, crab's eye vine	Fabaceae
Acacia farnesiana (L.) Willd.	Cassie flower, sponge tree	Fabaceae
Acacia mangium Willd.	-	Fabaceae
Acacia pennata Willd. subsp. *insuavis* Nielson	-	Fabaceae
Acacia rugata Buch.-Ham. ex Benth.	-	Fabaceae
Acanthus ebracteatus Vahl	Sea holy	Acanthaceae
Achyranthes aspera L.	Prickly chaff	Amaranthaceae
Acorus calamus L.	Sweet flag, myrtle grass	Araceae
Acrocarpus fraxinifolius Wight & Arn.	Coral-wood tree, red sandal-wood tree	Fabaceae
Adenium obesum (Forssk.) Roem. & Schult.	Impala lily	Apocynaceae
Adenochlaena siamensis Ridl.	Adenochlaena	Euphorbiaceae
Aegle marmelos Corr.	Bael fruit tree, bengal quince	Rutaceae
Aglaia domestica Pelleg.	Langsat	Meliaceae
Aglaia odorata Lour.	-	Meliaceae
Alangium salviifolium (L. f.) Wang. subsp. *hexapetalum* Wang.	-	Alangiaceae
Albezia myriophylla Benth.	-	Fabaceae
Albezia procera (Roxb.) Benth.	White siris	Fabaceae
Allemanda cathartica L.	Golden trumpet	Apocynaceae
Allemanda violacea Gard. & Field.	-	Apocynaceae
Allium ascalonicum L.	Shallot	Alliaceae
Allium sativum L.	Garlic	Alliaceae
Alocasia indica (Lour.) Spach	-	Araceae
Aloe vera (L.) Burm. f.	Star cactus, aloe	Liliaceae
Alpinia galanga (L.) Sw.	Greater galangal, fabe galangal	Zingiberaceae
Alpinia nigra (Gaertn.) B. L. Burtt.	-	Zingiberaceae
Alstonia scholaris (L.) R. Br.	Blackboard tree, devil tree	Apocynaceae
Alternanthera sessilis (L.) R. Br. ex DC.	-	Amaranthaceae
Alternanthera triandra Lamk.	-	Amaranthaceae
Altingia siamensis Craib.	-	Hamamelidaceae

Continued

Botanical name	Common name	Family
Alyxia nitens Kerr.	-	Apocynaceae
Alyxia reinwardtil Bl. var. *lucida*	-	Apocynaceae
Amaranthus spinosus L.	Spiny amaranth	Amaranthaceae
Amomum krervanh Pierre ex Gagnep.	Siam cardamom	Zingiberaceae
Amomum xanthioides Wall.	Bastard cardamom	Zingiberaceae
Amorphophallus spp.	-	Araceae
Anacardium occidentale L.	Cashew nut tree	Anacardiaceae
Anamirta cocculus (L.) Wight & Arn.	-	Menispermaceae
Anaxagorea javainica Bl.	-	Annonaceae
Andrographis paniculata (Burm. f.) Wall. ex Nees	-	Acanthaceae
Anethum graveolens L.	Dill	Apiaceae
Annona squamosa L.	Sugar apple, sweetSop	Annonaceae
Antigonon leptopus Hook & Arn.	Mountain rose, chain of love	Polygonaceae
Aquilaria crassna Pierre. ex. H. Lee.	Eagle wood	Thymelaeaceae
Ardisia pendurifera Pit.	-	Epacridaceae
Areca catechu L.	Areca palm, betel-nut palm	Arecaceae
Arfeuillea arborescens Pierre.	-	Sapindaceae
Artbotrys siamonsis Mig.	Gara-wek	Annonaceae
Artemisia vulgaris L.	Mugwort, worm wood	Asteraceae
Artocarpus heterophyllus Lamk.	Jack fruit tree	Moraceae
Artocarpus lakoocha Roxb.	-	Moraceae
Arundinaria sp.	-	Poaceae
Aster cordifolius L.	Silver leaf	Asteraceae
Averrhoa bilimbi L.	Bilimbi	Oxalidaceae
Averrhoa carambola L.	Star fruit, caramobola	Oxalidaceae
Azadirachta indica Juss. f. var. *siamensis* Vahl	Thai neem tree	Meliaceae
Baccaurea ramiflora Lour.	-	Euphobiaceae
Bambusa arundinacea Willd.	-	Poaceae
Barleria lupulina Lindl.	-	Acanthaceae
Barleria prionitis L.	-	Acanthaceae
Barringtonia acutangula Gaertn.	-	Barringtoniaceae
Basella alba L.	East India spinach	Basellaceae
Bauhinia acuminata L.	-	Fabaceae
Bauhinia malabarica Roxb.	-	Fabaceae
Bauhinia monardra Kurz	Yothakaa	Fabaceae
Bauhinia pottsii G. Pon. var. *decipiens*	Changkho	Fabaceae
Bauhinia purpurea Linn.	Purple bauhinia, orchid tree	Fabaceae
Bauhinia scandens L. var. *horsfieldii* K. & S. Larsen	-	Fabaceae
Bauhinia winitii Craib	-	Fabaceae
Beaumontia brevituba Oliv.	Herald trumpet	Apocynaceae
Beaumontia grandiflora (Roxb.) Wall.	-	Apocynaceae
Begonia inflata C. B. Clarke	Begonia	Begoniaceae
Beilschmiedia roxburghiana Nees	-	Lauraceae
Belamcanda chinensis DC.	Blackberry lily, leopard flower	Iridaceae
Betula alnoides Buch. Ham.	-	Betulaceae
Boesenbergia rotunda (L.) Mansf.	-	Zingiberaceae
Brassaia actinophyllus Endl.	Octopus tree, umbrella tree	Orchidaceae
Brucea javanica (L.) Merr.	-	Simaroubaceae
Brunfelsia calycena Benth.	Yesterdang today	Solanaceae
Caesalpinia sappan L.	Sappan tree	Fabaceae

Continued

Botanical name	Common name	Family
Calophyllum inophyllum L.	Borneo mahogany, Alexandrian laurel	Clusiaceae
Camellia sinensis var. *assamica* (J. W. Mast.) Kitam	Tea plant	Theaceae
Cananga odorata (Lam.)Hook. & Thoms.	Kradangugaa	Annonaceae
Capsicum frutescens L.	Chili, chyenne pepper	Solanaceae
Cardiospermum halicacabum L.	Balloon vine	Sapindaceae
Carthamus tinctorius L.	Safflower	Asteraceae
Cassia alata L.	Ringworm bush, candle stick	Fabaceae
Cassia angustifolia Vahl	Senna	Fabaceae
Cassia fistula L.	Golden shower tree	Fabaceae
Cassia garrettiana Craib.	-	Fabaceae
Cassia javanica L.	Pink-and-white shower tree	Fabaceae
Cassia siamea Lamk.	Copperpod tree, cassod tree	Fabaceae
Cassia singueana Del.	-	Fabaceae
Cassia tora L.	Foetid cassia	Fabaceae
Catharanthus roseus (L.) G. Don.	Madagascar periwinkle	Apocynaceae
Centella asiatica (L.) Urban.	Asiatic pennywort	Apiaceae
Cestrum diurnum L.	Day jasmine	Solanaceae
Cestrum nocturnum L.	Queen of the night	Solanaceae
Chrysanthemum morifolium Ram.	-	Asteraceae
Cinchona ledgeriana (Howard) Bern. Moens ex Trimen	Quinine tree	Rubiaceae
Cinnamomum bejolghota (Buch.-Ham.) Sweet.	Cinnamon	Lauraceae
Cinnamomum camphora (L.) J. Presl.	Camphor tree	Lauraceae
Cinnamomum iners Reinw.	-	Lauraceae
Cinnamomum zeylancium Bl.	Cinnamon	Lauraceae
Cissamepelos pareira L.	-	Menispermaceae
Cissus quadrangularis L.	-	Vitaceae
Citrus aurantifolia (Christm.) Swingle	Lime	Rutaceae
Citrus hystrix DC.	Leech lime, kaffirlime	Rutaceae
Citrus maxima (Burm.) Merr.	Pommelo	Rutaceae
Clerodendrum petasites S. Moore.	-	Lamiaceae
Clerodendrum serratum (L.) Moon.	-	Lamiaceae
Clerodendrum thomsoniae Balf.	Bluding Hert	Lamiaceae
Clerodendrum viscosum Vent.	Nang yam	Lamiaceae
Clinacanthus nutans Burm.	-	Acanthaceae
Clitoria ternatea L.	Butterfly pea	Fabaceae
Coccinia grandis (L.) Voigt.	-	Cucurbitaceae
Coffea bengalensis B. Heyne ex Schult.	Bengal coffee	Rubiaceae
Coix lacryma-jobi L.	Job's tear	Poaceae
Coleus amboinicus Lour.	Indian borage	Lamiaceae
Combretum quadrangulare Kurz.	-	Combretaceae
Congea tomentosa Roxb.	-	Verbenaceae
Costus speciosus (J. König) Smith.	Crape ginger	Costaceae
Crateva magna DC.	-	Capparaceae
Crescentia cujete Linn.	Calabash tree	Bignoniaceae
Croton oblongifolus Roxb.	-	Euphorbiaceae
Croton sublyratus Kurz.	-	Euphorbiaceae
Croton tiglium (L.) J.	Purging croton	Euphorbiaceae
Curcuma aeruginosa Roxb.	-	Zingiberaceae
Curcuma domestica Valeton	Turmeric	Zingiberaceae
Curcuma xanthorrhiza Roxb.	-	Zingiberaceae

Continued

Botanical name	Common name	Family
Curcuma zedoaria (Christm.) Roscoe	-	Zingiberaceae
Cuscuta chinensis Lam.	Zedoary	Cuscutaceae
Cyathula prostrata (L.) Bl.	Dodder	Amaranthaceae
Cymbopogon citratus (DC.) Stapf.	Lemon grass	Poaceae
Cymbopogon nardus (L.)Rendle	Lemon grass	Poaceae
Cymbopogon winterianus Jowitt	Lemon grass	Poaceae
Cyperus rotundus L.	Citronella grass	Cyperaceae
Dalbergia abbreviata Craib.	Nutgrass	Fabaceae
Datura metel L.	-	Solanaceae
Delonix regia (Bojer ex Hook.) Raf.	Flambuoyant tree, flame of the forest	Fabaceae
Dendrocalamus asper (Schult. f.) Backer ex K. Heyne	-	Poaceae
Dendrophthoe pentandra (L.) Miq.	-	Laranthaceae
Derris elliptica (Wall.) Benth.	Derris, tuba root	Fabaceae
Derris scandens (Roxb.) Benth.	Malay jewelvine	Fabaceae
Desmodium triflorum (L.) DC.	Three-flowers beggarweed	Fabaceae
Desmos chinensis Lour.	-	Annonaceae
Dieffenbachia seguine (Jacq.) Schott	Dumb cane	Araceae
Dioscorea hispida Dennst.	Asiatic bitter yam	Dioscoreaceae
Diospyros decandra Lour.	Ebony, persimmon	Ebenaceae
Diospyros mollis Griff.	Ebony tree	Ebenaceae
Diospyros rhodocalyx Kurz.	Ebony	Ebenaceae
Dizygotheca elegantissima (hort. Veitch ex Mast.) R. Vig. & Guill.	-	Araliaceae
Dolichandrone spathacea (L. f.) K. Schum.	-	Bignoniaceae
Duranta repens L.	Golden dew drop	Verbenaceae
Elaeis guineensis Jacq.	African palm	Arecaceae
Elaeocarpus hygrophilus Kurz.	-	Elaeocarpaceae
Elephantopus scaber L.	Elephant's foot	Asteraceae
Elettaria cardamomum (L.) Maton	Cardamom	Zingiberaceae
Eleutherine americana Merr.	-	Iridaceae
Eucalyptus citriodora Hook.	Eucalyptus	Myrtaceae
Eucalyptus globulus Labill.	Eucalyptus	Myrtaceae
Eugenia caryophyllus (Spreng.) Bullock & Harrison	Clove	Myrtaceae
Eurycoma longifolia Jack.	-	Simaroubaceae
Excoecaria cochinchinensis Lour. var. *viridis* Merr.	-	Euphorbiaceae
Feronia limonia (L.) Swingle	Wood apple	Rutaceae
Feroniella lucida (Scheff.) Swingle	-	Rutaceae
Fibraurea tinctoria Lour.	-	Menispermaceae
Foeniculum vulgare Mill.	Fennel	Apiaceae
Friesodielsia fomicata D. Das	-	Annonaceae
Garcinia hanburi Hook. f.	Gum cambodge tree, gambodge	Clusiaceae
Garcinia mangostana L.	Mangosteen	Clusiaceae
Garcinia nigrolineata Planch. ex T. Anderson	-	Clusiaceae
Garcinia schomburgkiana Pierre.	-	Clusiaceae
Gardenia coronaria Ham.	-	Rubiaceae
Gardenia jasminoides J. Ellis	Cape-jessamine	Rubiaceae
Globba obscura K. Larsen.	-	Zingiberaceae
Gloriosa superba L.	Climbing lily	Liliaceae
Hedychium coronarium J. König	Butterfly lily	Zingiberaceae
Hibiscus sabdariffa L.	Roselle	Malvaceae

Continued

Botanical name	Common name	Family
Hibiscus vitifolius L.	-	Malvaceae
Holarrhena antidysenterica (Roxb. ex Fleming) Wall. ex A. DC.	Kurchi	Apocynaceae
Ipomoea aquatica Forssk.	Kangkong	Convolvulaceae
Ipomoea batatas (L.) Lam.	Sweet potato	Convolvulaceae
Ipomoea pes-caprae (L.) R. Br.	Goat's-foot-convolvulus	Convolvulaceae
Ixora barbata Roxb.	-	Rubiaceae
Jasminum auriculatum Vabl.	Jasmine vine, star jasmine	Oleaceae
Jasminum grandiflorum L.	Star jasmine	Oleaceae
Jasminum pubescens (Retz.) Willd.	Arabian jasmine	Oleaceae
Jasminum sambac (L.) Ait.	Arabian jasmine	Oleaceae
Kaempferia galanga L.	Galanga	Zingiberaceae
Litsea elliptica Boerl.	-	Lauraceae
Lobelia chinensis Lour.	-	Campanulaceae
Lonicera japonica Thumb.	Japanese honeysuckle	Caprifoliaceae
Magnolia henryi Dunn.	Magnolia	Magnoliaceae
Malpighia glabra L.	Barbados cherry	Malpighiaceae
Mammea siamensis Kosterm.	-	Clusiaceae
Mangifera indica L.	Mango	Anacardiaceae
Melia azedarach L.	Bastard cedar, persian lilac, bead tree	Meliaceae
Mentha spicata L.	Kitchen mint	Lamiaceae
Mentha piperita Huds.	Peppermint	Lamiaceae
Michelia figo (Lour.) Spreng.	Champac, dwarf champaka	Magnoliceae
Mimusops elengi L.	Medlar	Sapotaceae
Momordica charantia L.	Balsam pear, bitter cucumber	Cucurbitaceae
Morinda citrifolia L.	Indian mulberry	Rubiaceae
Murraya paniculata (L.) Jack.	China box tree, orange jasmine	Rutaceae
Musa paradisiaca L.	Banana	Musaceae
Myriopteron extensum Schum.	-	Asclepiadaceae
Myristica fragrans Houtt.	Nutmeg tree, mace	Myristicaceae
Nelumbo nucifera Gaertn.	Lotus	Nelumbonaceae
Nyctanthes arbor-tristis L.	Night flower jasmine	Verbenaceae
Nymphaea spp.	Water lily	Nymphaeaceae
Ocimum americanum L.	Hoary basil	Lamiaceae
Ocimum basilicum L.	Sweet basil	Lamiaceae
Ocimum gratissimum L.	Shrubby basil	Lamiaceae
Ocimum stolonifera Wall.	-	Lamiaceae
Ocimum teniflorum L.	Holy basil	Lamiaceae
Olea europea L.	Olive	Oleaceae
Oroxylum indicum (L.) Vent.	-	Bignoniaceae
Orthosiphon aristatus (Bl.) Miq.	Cat's wiskers, java tea	Lamiaceae
Orthosiphon grandiflorus Bolding.	-	Lamiaceae
Oryza sativa L.	Rice	Poaceae
Pachyuptera hymenaea A. Gent	Garlic vine	Bignoniaceae
Pandanus amaryllifolius Roxb.	Toei hom	Pandanaceae
Pandanus odoratissimus L. f.	-	Pandanaceae
Pandanus tectorius Parkinson	Pandan, screw pine	Pandanaceae
Passiflora laurifolia L.	Sweet cup	Passifloraceae
Phyllanthus amarus Schum. & Thonm.	-	Euphorbiaceae
Phyllanthus emblica L.	Emblic, marabolan	Euphorbiaceae
Piper betle L.	Betel pepper	Piperaceae
Piper chaba W. Hunt.	Indian long pepper	Piperaceae

Continued

Botanical name	Common name	Family
Piper nigrum L.	Pepper, black pepper	Piperaceae
Piper sarmentosum Roxb.	Jia ju	Piperaceae
Plumbago indica L.	Rose-captured leadwort	Plumbaginaceae
Plumbago zeylanica L.	-	Plumbaginaceae
Porana volubilis Burm. f.	Snow-vine	Convolvulaceae
Punica granatum L.	Pomegranate	Lytheraceae
Rauvolfia cambodiana Pierre ex Pit.	-	Apocynaceae
Rauwenhoffia siamensis Scheff.	Nom-maew	Anonaceae
Ravenia spectabilis (Lindl.) Planch. ex Griseb.	-	Rutaceae
Rhinacanthus nasutus (L.) Kurz.	-	Acanthaceae
Rhynchostylis gigantea Ridl.	-	Orchidaceae
Rosa spp.	Rose	Rosaceae
Saccharum officinarum L.	Sugarcane	Poaceae
Sarcostemma acidum (Roxb.) Voigt.	-	Asclepiadaceae
Scaphium macropodum (Miq.) Beaumée ex K. Heyne	-	Sterculiaceae
Schoutenia glomerata king subsp.	Pereging rockmet	Tiliaceae
Sesamum indicum L.	Sesame	Pedaliaceae
Sesbania grandiflora (L.) Pers.	Sesban, scarlet wistaria-tree	Fabaceae
Shorea roxburghii G. Don.	-	Dipterocarpaceae
Solanum indicum L.	-	Solanaceae
Solanum sanitwongsei Craib.	-	Solanaceae
Spathiphyllum cannifolium (Dryand) Schatt.	Spathe flower	Araceae
Talauma mutabilis Bl.	Yee-hoob	Magnoliaceae
Telosma minor Craib.	Cowslip creeper	Asclepiadaceae
Tetracera loureirai Craib.	-	Dilleniaceae
Themeda triandra Forssk.	Kangaroo grass	Poaceae
Theobroma cacao L.	Cocoa tree	Sterculiaceae
Thryallis glauca (Cav.) Kuntzl	Calphinin	Malpighiaceae
Tropis scandens subsp. *scadens*	Crow ash	Moraceae
Vitex trifolia L.	Indian wild peper, Indian privet	Verbenaceae
Walsura robusta Roxb.	-	Meliaceae
Zingiber cassumunar Roxb.	-	Zingiberaceae
Zingiber officinale Roscoe	Ginger	Zingiberaceae

In 2000, there were 699 traditional drug manufacturing factories (including 248 in Bangkok and 451 in the rural areas) and 136 traditional drug stores. In 1998, local traditional drug stores were 398 in Bangkok and 1,600 in the rural areas.

The policy on the utilization of medicinal and aromatic plants was included in the Seventh National Economic and Social Development Plan (1992 to 1996). The emphasis is on primary health care and replacement of modern medicines.

Production, Processing, Utilization and Marketing of Medicinal and Aromatic Plants in Thailand

Production

The major intercropping crops of medicinal and aromatic plants include pepper,

betel nut, allium, turmeric, ginger, nutmeg, citronella, etc., for coconut and palm. There are medicinal and aromatic plants nurseries in each institution for ensuring a steady raw material supply for research laboratories involved in the national programme. The production figures for commercial medicinal and aromatic plants is given in Table 11.[13,14]

Table 11: Production of commercial medicinal and aromatic plants in Thailand

Item	1992		1993		1994		1995	
	Area (ha)	Volume (tonne)	Area (ha)	Volume (tonne)	Area (ha)	Volume (tonne)	Area (ha)	Volume (tonne)
Pepper[1]	2,843	12	2,847	11,518	2,640	10,232	2,642	10,948
Clove[2]	50	32	56	39	64	432	96	65
Betel nut[2]	8,989	187,929	10,357	123,460	10,924	133,025	10,999	132,755
Betel pepper[2]	1,374	20,105	1,664	19,513	1,465	20,198	1,480	20,048
Garlic[2]	24,124	107,886	25,125	115,575	24,703	110,433	24,123	121,252

The small-scale production of medicinal plants is usually carried out by NGOs, woman's groups, etc. The high technological improvement in production has been achieved through tissue culture, the fastest method of propagation, of priority plants possessing good potential as therapeutic agents. Studies have been undertaken on cultural requirements such as effect of physiological factors such as light, moisture stress, fertilizers, nutrients and yield of active constituents of the priority plants.

Studies on harvesting, storage and monitoring of active content of selected plants have been carried out. Factors such as varieties, maturity, climatic conditions before and after harvesting, drying methods and storage conditions of five medicinal and aromatic plants have also been studied with respect to drug quality.

Processing and Utilization

Medicinal and aromatic plants with potential for commercial production are processed by several methods for isolation of active constituents or distillation of essential oils. The methods of essential oil extraction are known, namely steam distillation, water-steam distillation, solvent extraction, maceration to produce extract, essential oil, concrete, absolute extract, tincture or oleoresin. These semi-products are obtained from leaf, flower, fruit, seed, bark, root, rhizome or whole plant. All production phases are carried out using several methods conforming to the Good Manufacturing Practices (GMP).

Marketing

The marketing channel of medicinal and aromatic plants in Thailand is shown in Figure 1.

Most of the raw materials are collected from the forests, but some also come from the cultivated farms. They are passed on to the local traders or district centres. These are then transported to the wholesalers, which are pharmaceutical or traditional drug stores in major

cities like Bangkok. The wholesalers arrange further transportation to overseas markets. The volume exported is approximately 90% of the total volume of trade.

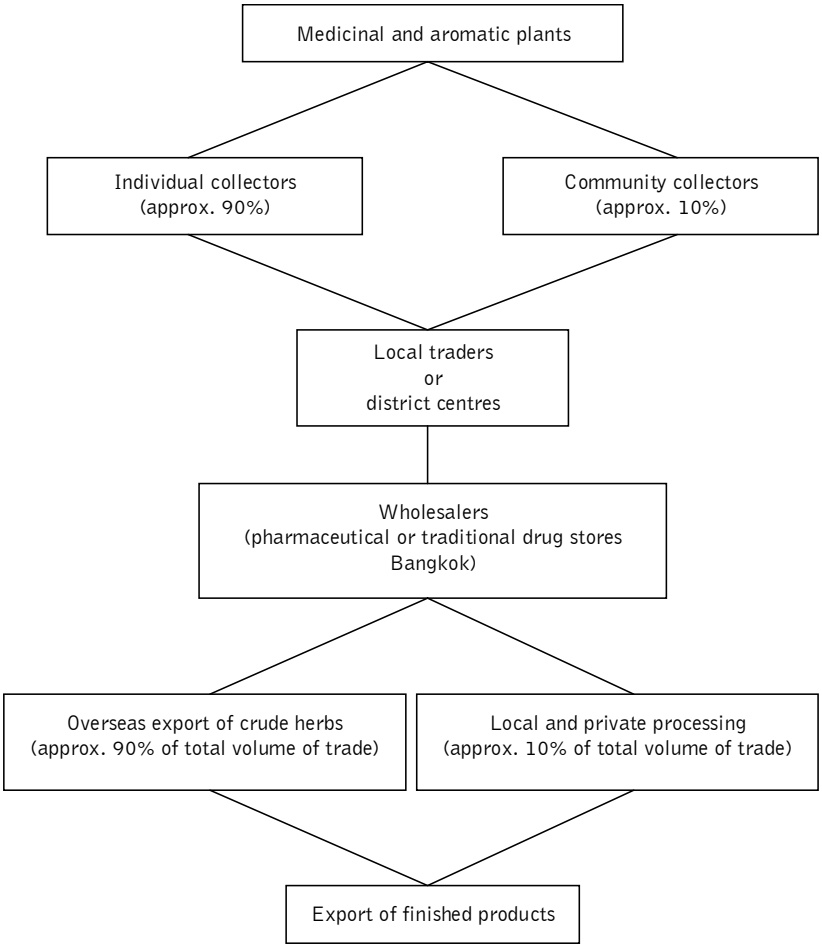

Figure 1: Marketing chain of medicinal and aromatic plants in Thailand

Research and Development of Medicinal and Aromatic Plants in Thailand

The Ministry of Public Health established a Committee on Medicinal Plants comprising eight sub-committees for the promotion and utilization of medicinal plants with special emphasis on the development of new drugs for domestic use. The main objectives are focused on the use of medicinal plants in primary health care, development of medicinal plants and utilization of research results in primary health care, and manufacture of pharmaceuticals.

Research and Development Institutions

Several institutions are engaged in research and development of medicinal plants (Table 12); a number work on the transfer of technology to private sector.

Table 12: Institutes involved in medicinal and aromatic plants research and development in Thailand

Institute	Affiliation	Responsible division	Address	Mandate
Thailand Institute of Scientific and Technological Research (TISTR)	Ministry of Science, Technology and Environment	Agro-technology Department, Pharmaceuticals and Natural Products Department, Industrial Co-operation and Promotion Centre	196 Phahonyothin Rd., Chatuchak, Bangkok 10900, Tel.: +66-2-5795515, Fax: +66-2-5614771	Research and development (R&D) on essential oil crops including evaluation of chemical and physical property, marketing studies and transfer of technology.
Department of Science Services (DSS)	Ministry of Science, Technology and Environment	Chemical Division	Rama VI Rd., Bangkok 10400, Tel.: +66-2-2480291 or 2460065 Ext. 259	Chemical analysis of essential oils, evaluation of oil quality and R&D on product development.
Department of Medical Sciences (DMS)	Ministry of Public Health	Division of Medicinal Plants, Research and Development	88/7 Moo 4, Soi Bamrasnaradura Hospital Talat Khwan, Amphoe Muang, Nonthaburi 11000, Tel.: +66-2-5899850/9 Ext. 2206	Searching for potential medicinal and aromatic plants of medicinal value and R&D for drug formulation from these plants.
The Government Pharmaceutical Organization (GPO)	Ministry of Public Health	Research and Development Institute	75/1 Rama VI Rd., Ratchathevi, Bangkok 10400, Tel.: +66-2-2461179-85 Ext. 101	Finding out precisely the indigenous raw materials available in the country and investigating the possibility of developing bulk drug production utilizing local resources for the country's self-reliance.
Department of Agriculture (DOA)	Ministry of Agriculture and Co-operatives	Agricultural Chemistry Division, Horticultural Research Institute, Field Crops Research Institute	Phahonyothin Rd. Chatuchak, Bangkok 10900, Tel.: +66-2-5790151-8	Investigation on improvement and cultivation of essential oil crops and their products, R&D on essential oil crops including the physical-chemical properties evaluation, marketing and transfer of technology.
Thai Industrial Standard Institute (TISI)	Ministry of Industry	Standard Division 2	Rama VI Rd., Ratchathevi, Bangkok 10400, Tel.: +66-2-2478746 or 2023355	Issue standards of essential oils and their products.
Department of Industrial Promotion (DIP)	Ministry of Industry	Industrial Promotion Centre	86 Mittraphap Rd., Tambon Samran, Amphoe Muang, Khon Kaen 40000, Tel.: +66-43-242047	Promotion of industrial production of essential oils.
Mahidol University (MU)	Ministry of University Affairs	Department of Pharmacognosy, Faculty of Pharmacy	Si Ayutthaya Rd., Bangkok 10400, Tel. +66-2-6448677/91 Ext. 1503	Research on essential oil crops having medicinal properties.
Kasetsart University (KU)	Ministry of University Affairs	Department of Horticulture, Faculty of Agriculture	50 Phahonyothin Rd., Bangkok 10900, Tel.: +66-2-5790113	Research on medicinal and aromatic plants.
Chulalongkorn University (CU)	Ministry of University Affairs	Department of Pharmacognosy, Faculty of Pharmacy	Phayathai Rd., Bangkok 10330	Research on medicinal and aromatic plants.
Chiang Mai University (CMU)	Ministry of University Affairs	Department of Pharmacognosy, Department of Biology	239 Huay Kaew Rd., Chiang Mai 50202 Tel.: +66-53--943004/6	Research on medicinal and aromatic plants.

Government Pharmaceutical Organization (GPO)

The Government Pharmaceutical Organization is a state enterprise operating under the Ministry of Public Health. It was established in 1966 to supply pharmaceuticals and other medicinal products to support health-service activities of the Ministry of Public Health. It manufactures more than 350 pharmaceutical items, in particular drugs, in the National List of Essential Drugs including biological products with annual sale volume of about US$ 150 mn.[15] The Organization performs basic, applied and pilot-scale research which is essential not only for developing the pharmaceutical products but also for complementing and improving existing technologies.

The work plans of the Organization include:

- Finding out precisely the availability of indigenous raw materials in the country;
- Investigating the possibility of developing bulk drugs utilizing local resources for the country's self-reliance;
- Selecting formulations from medicinal plants; extracting and purifying naturally occurring substances of plant origin; and
- Producing and controlling the formulations including crude drugs and their pharmacological, toxicological and clinical evaluation.

All production phases take into consideration the ever more stringent GMP on manufacture and quality assurance. The processing of the raw materials, semi-finished and finished products conforms to the methods and criteria laid down in GMP guidelines. The meticulous attention paid to every stage of production and dispatch means that each preparation reaches the consumer with correct composition, packaging and product information.

Some of the herbal medicinal products, which have been fully investigated as regards of botany, pharmacognosy, phytochemistry, pharmacology, toxicology and clinical study, and manufactured by the Thai Herbal Product Company, a subsidiary company of GPO, are shown in Table 13.[16]

Table 13: Herbal medicinal products of Thai Herbal Product Company

Product	Plant Species	Use(s)/indication(s)
Senna tea	*Cassia angustifolia* Vahl	Constipation
Senna tablet	*Cassia angustifolia* Vahl	Constipation
Ma-Waeng lozenge	*Solanum trilobatum* L.	Cough
Chofibrin capsule	*Allium sativum* L.	To lower blood cholesterol levels
Plygesal cream	*Zingiber purpureum* Roscoe	Muscular pain, bruises, sprains, swelling
Curmin capsule	*Curcuma longa* L.	Dyspepsia
Aloe gel	*Aloe vera* (L.) Burm. f.	Treatment of burn, tissue healing
Fa-Thalai-Chon capsule	*Andrographis paniculata* Nees	Sore throat
Citronella oil mosquito repellent lotion	*Cymbopogon nardus* (L.) Rendle	Malaria
Lingzhi tablet	*Ganoderma lucidum* Karst.	Immunomodulator
Angelisin capsule	*Angelica sinensis* (Olive) Diels	Post-menstrual syndrome (PMS) problems
Flava Soy capsule	*Glycine max* (L.) Merr.	Osteoporosis and phytoestrogen for PMS

Continued

Product	Plant Species	Use(s)/Indication(s)
Cimiraf tablet	*Cimicifuga racemosa* Nutt.	Reduction of hot flashes for PMS
Chofibrin capsule	*Allium sativum* L.	Reduction of cholesterol for PMS
Mem-O-G tablet	*Ginkgo biloba* L.	Memory problems
Kee-Lek tablet	*Cassia siamea* Lam.	Insomnia
Phaya Yo cream	*Clinacanthus nutans* (Burm. f.) Lindau	Herpes infection
Calamine Phaya Yo	*Clinacanthus nutans* (Burm. f.) Lindau	Itchy skin
Phaya Yo glycerine	*Clinacanthus nutans* (Burm. f.) Lindau	Oral wounds with microbial infections
Plugenal	*Piper betle* L.	Microbial infected, inflammatory and itchy skin
Guava fresh	*Psidium guajava* L.	Bad breath, oral inflammation, pain
Guava capsule	*Psidium guajava* L.	Acute diarrhea
Baracol tablet	*Cassia siamea* Lam.	Insomnia
Capsaicin gel	*Capsicum frutescens* L.	Muscular tension and strain
Centella cream	*Centella asiatica* (L.) Urban	Prevention of scar formation
Ginger tablet	*Zingiber officinale* Roscoe	Nausea, vomiting
Orthosiphon tea	*Orthosiphon aristatus* (Blume) Miq.	Diuretic

There are six products for post menopausal (PMS) problems and many more products are in the GPO pipeline. The development of unmodified, plant-derived drugs for pharmaceutical manufacturing consists of various steps as shown in Figure 2.

Development Potential of Small-Scale Aromatic Plant Industry in Thailand

In Thailand, a number of essential oils factories have been established over time at several places for production of essential oils such as citronella (*Cymbopogon mardus* (L.) Rendle), lemon grass (*Cymbopogon citratus* DC. Stapf), eucalyptus (*Eucalyptus* spp.), horapha basil (*Ocimum* spp.), kaphrao (*Ocimum teniflorum* L.), pepper (*Capsicum* spp.) and Japanese mint (*Mentha arvensis* L.), on a commercial scale. However, according to the Thailand Institute of Scientific and Technological Research (TISTR), very few of these now exist. Some of the manufacturers are given as follows:

Natural Flavours and Fragrances Company Limited

The company was established around 1970 in the Muang district of the Kanchanaburi province and has modern facilities for production of several essential oils for export. The most significant was horapha oil, which received great attention from various food industries in Europe and the USA. The cultivation of horapha, kaphro, citronella, lemon grass and turmeric was promoted through contract farming. Owing to the lack of good management and boom in the sugar industry during 1970 to 1975, the factory was closed.

Nan Tobacco Leaf Company Limited

In 1972, the company, which was mainly a tobacco-producing enterprise, signed a contract with the Applied Scientific Research Corporation of Thailand (now Thailand Institute of Scientific and Technological Research - TISTR), to provide technical support in producing Japanese mint *(Mentha arvensis* L.*)* oil in the Nan province of northern

Thailand. During 1972 to 1978, mint was considered an important economic crop in the Nan province and factories for oil extraction were established in almost every district. Some of these possessed twelve distillation units each with 500 kg batch capacity, working on a two-shift basis. The very low price of oil and menthol import from China in 1978 caused a halt in production of mint oil in Thailand, mainly by the Nan Tobacco Leaf Company but also by several small enterprises throughout the country.

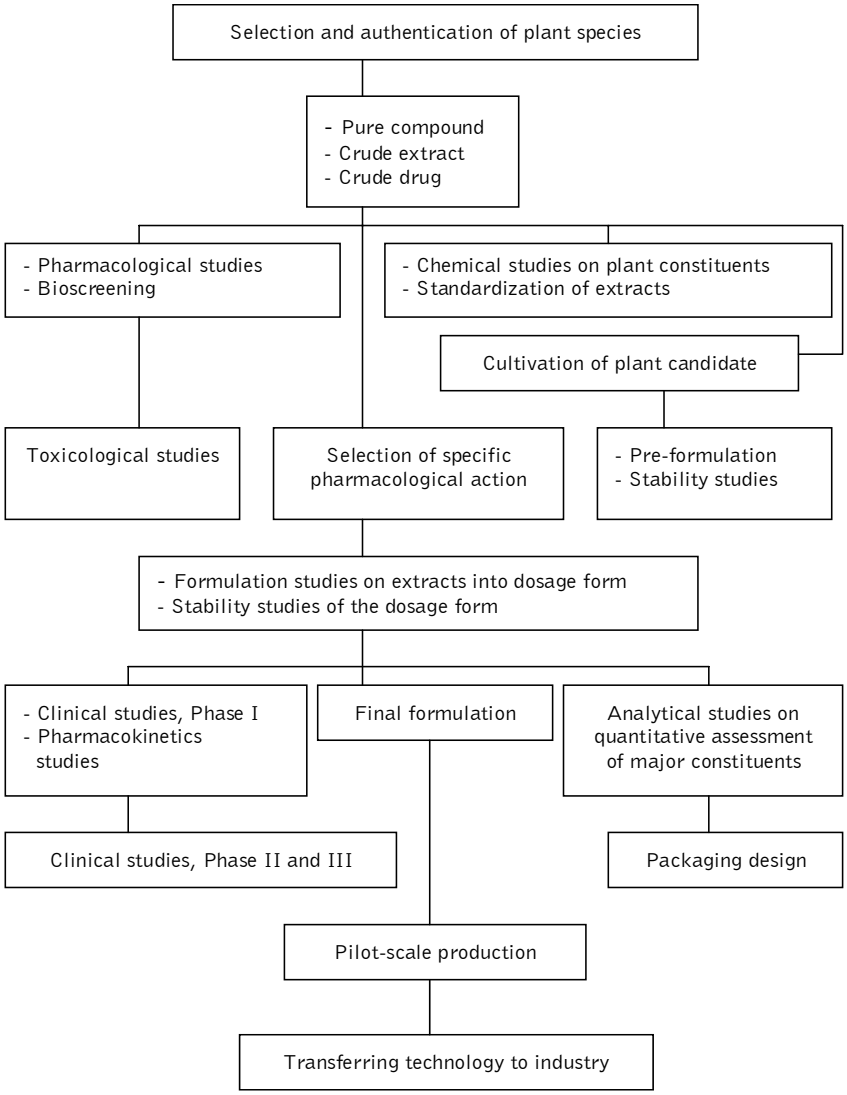

Figure 2: Steps involved in development of plant-derived drugs for pharmaceutical manufacturing

According to the Managing Director of the Nan Tobacco Leaf Company, the possibilty of reviving the mint oil industry still exists in Thailand, provided the price of mint oil is favourable. The planting material which can be mass propagated by large-scale planting within six months is still maintained in the company farms. The company is willing to cooperate with Lao PDR in a joint venture for producing the crop in Lao PDR and processing it in Thailand.

Thai Chemical Products Company Limited

A joint venture company between Thailand's Sri Krung Watana Company and Taiwan's Ming Sheng Chemicals Company Limited (a famous menthol crystal producer) was established in Sam Rong District of Samut Prakan province in 1971, to produce the iceberg brand of menthol from mint oil produced in Thailand. The company had imported modern equipment and high technology for menthol crystallization from Taiwan. The operation was quite successful (output of 50 tonnes of menthol in 1977) until China, in 1978, introduced its products onto the world market, including Thailand, at a price very much lower than production cost for both the oil and menthol, which ultimately led to cessation of its operations.

Menthol Thai Import-Export Company Limited

This was established in 1975, in the Nakhon Chaisri district of the Nakhon Pathom province, with a production target of 300 and 200 tonnes annually for mint oil and menthol, respectively. The raw materials for mint oil were obtained from its own production as well as other sources (e.g. Nan Tobacco Leaf Company). Unfortunately, as discussed earlier, this apparently successful business of mint oil and menthol production was hard hit with the introduction of cheap products from China. However, this company refuses to close its business even to this day and is running at a loss. It still maintains raw material production in the Chanthaburi province, mint oil and menthol production at its factory in Nakhon Chaisri, and imported mint oil as supplement. At present, the import prices of mint oil from China (US$ 9.19 per kg) and menthol from India (US$ 13.79 per kg) is apparently discouraging domestic production of both products.

Thai-China Flavours and Fragances Industry Company Limited (TCFF)

This company is located about 70 km north of Bangkok, in the Lat Bua Luang district of the Ayutthaya province, and is a joint-venture between a Thai enterprise and Guangzhou Bai Hua Flavours and Fragances Company Limited, Guangzhou, China. It was established in 1991 and became fully operational only recently after all equipment and machinery were installed. The factory occupies an area of 5.2 square km and has five main workshops, namely extraction, steam distillation, chemical reaction, flavour compounds and fragance compounds. Its products include essential oils (including concrete, absolute and oil resin); aromatic chemicals; fragrances; food flavours; tobacco flavours; and miscellaneous related products.

The TCFF has a contract with the farmers to supply raw material of jasmine *(Jasminum sambac* L. Aiton*)*, champi *(Michelia xalba.* DC.*)*, champa *(Michelia champaca* L.*)*, citronella grass *(Cymbopogon nardus* (L.) Rendle and *Cymbopogon winterianus* Jowitt*)*, patchouli *(Pogostemon cablin* (Blanco) Benth.*)*, vetiver *(Vetiveria zizanioides* (L.) Nash*)*, clove *(Syzygium aromaticum* (L.) Merr. & L. M. Perry*)*, pepper *(Piper nigrum* L.*)*, phlai *(Zingiber cassumunar* Roxb.*)* and paprika *(Capsicum frutescens* L.*)*. The present capacity of essential oil production is 2.4 tonnes per year. However, the TCFF pays more

attention to other value-added products like aromatic chemicals and flavours and fragrances with annual production potential of 200 tonnes per year and 650 tonnes per year, respectively. All products produced by the TCFF have been made readily available in markets both in Thailand and abroad, mainly Europe, the USA, Southeast Asia, and China.

Constraints and Alleviations

In Thailand, there is a number of constraints in the research and development of medicinal and aromatic plants. The constraints and their alleviations are listed below:

Lack of Multidisciplinary Teams

Most institutes have conducted fragmented research which cannot be readily transferred to industry. The institutional responsibility should be enlarged or should work jointly with other institutes providing complementary mandates should be strengthened.

Lack of Skilled Personnel

Most institutes lack skilled personnel, particularly for R&D on essential oils. Incentives such as training opportunities and facilities for R&D on essential oils as others need to be provided.

Lack of Funds

Insufficient funds are allocated to work on essential oils, considered a minor commodity. Provision of funds from various sources, including private sector through contract research agreement needs to be made.

Lack of Agro-technology and Processing Technologies

Almost none of the technology developed by R&D institutes has been effectively transferred to the private sector. An improved mechanism of technology transfer need to be implemented.

Working on Too Many Crops

It is common practice for R&D institutes to work on a large number of crops and achieve very little. It should be arranged that a number of crops should be limited to a minimum, and work on all aspects should be carried out to obtain high yield and quality.

Lack of Feed-back

The technical feed-back on processing and cultivation technologies developed by R&D institutions is not made available by industry and farmers.

Lack of Price Support

Industry and government do not support the production of raw material. Incentives need to be formulated for promoting cultivation of medicinal and aromatic plants.

Conclusions

Thailand is rich in biodiversity. Its favorable agroclimatic zones can be exploited for the commercial cultivation of exotic plants as well as proven indigenous medicinal and aromatic plants. The production of medicinal and aromatic plants in Thailand is largely confined to mixed home gardens. Their commercial cultivation is being undertaken as an intercrop in coconut and betel nut plantations.

Marketing is a major constraint on the expansion of cultivation. The price stability of the commodities is of vital importance to ensure success in the production of medicinal and aromatic crops.

In order to develop medicinal and aromatic plants, agencies involved in technical assistance, like the United Nations Industrial Development Organization (UNIDO), the Food and Agriculture Organization of the United Nations (FAO) and the Economic and Social Commission for Asia and the Pacific (ESCAP), specialized international agencies under the United Nations (UN) system, could help in promoting the medicinal plant products and essential oil industry in Thailand. ESCAP and the International Trade Centre (ITC) would provide the required information to national research and development institutes. The UN agencies could facilitate the exchange of expertise, materials and germplasm, which is normally difficult through direct contact.

It is expected that consultation among experts in the region would bring a great benefit to all participating countries for the human resources development programme.

The Status of Medicinal and Aromatic Plants in Vietnam

Vietnam is a tropical country with widely varying climatic and geographical features. It has an abundance of diverse natural resources of medicinal and aromatic plants (Table 14). The majority (80%) of its population living in the countryside and a large number of ethnic minority groups scattered in the highlands do not have access to modern medicines. However, Vietnam possesses an age-old traditional system of medicine which has been handed down from generation to generation. The use of traditional medicines is deeply rooted in the society.

Medicinal and aromatic plants and herbal drugs have made a tremendous contribution to national health and development. The Vietnam government has paid great attention to health care since its independence: the health-care system has integrated traditional medicines with modern ones. For a country that soon after its liberation had to face 30 years of atrocious war, the only way to provide health care to all was to mobilize its own resources to produce medicines from indigenous raw materials, since import of drugs was limited. As a result of this policy and renovation efforts, in two decades of post-war era, the state pharmaceutical factories and private companies have served effectively the demand for drugs in Vietnam.

On the basis of success achieved through renovation efforts, the national strategy for protection and raising the standard of public health confirms that by the year 2010, Vietnam will indigenously produce 70% of required medicines. To implement this task, the use of indigenous raw material must be encouraged with the share of herbal and plant-based drugs about 30% of the total value of medicines produced. The annual demand for medicinal plant materials for 20,000 traditional medicine practitioners is at least 3,000 tonnes. Recently, more attention has been paid to the production of cosmetics and fragances from natural materials.

Since 1989, the production of medicinal and aromatic plant material has competed poorly with foreign synthetic drugs. A number of policies have been formulated by the government to protect herbal medicinal products.

Production of Raw Material

In 1985, a survey of genetic resources of medicinal and aromatic plants used in traditional medicines was conducted in 350 districts, provincial capitals and 2,795 villages and quarters. A total of 1,863 species and sub-species (now about 2,000 species) belonging to 238 families, with three-quarters growing wild and distributed throughout, have been reported. About 10,000 herbarium specimens of 1,296 species existing in Vietnam have been collected, and information on flowering and fruiting periods of 1,423 species and nearly 1,000 remedies based on traditional and ethno-experiences have been gathered and catalogued. The leading families of medicinal plants include Asteraceae (105 species), Fabaceae (137 species), Euphorbiaceae (91 species), Rubiaceae (65 species) and Lamiaceae (45 species).[17]

Introduction and Cultivation of Medicinal and Aromatic Plants

The increasing demand of many medicinal and aromatic plants possessing good therapeutic value and extensively used in traditional medicine for centuries cannot be met sustainably from natural regeneration. The Institute of Materia Medica (IMM), in collaboration with provincial stations for medicinal plants research, has carried out agronomical studies in parallel with summarizing popular experiences, to develop cultivation technologies adapted to local needs and provide technical direction to the farmers. The domesticated crops from wild plants have given products of therapeutic importance, which have gradually become familiar and a part of the crop structure. These crops have contributed considerably to the production of drugs and their exportation.

During the 1960s and the beginning of the 1970s, medicinal and aromatic plants enjoyed substantial development, as a result of the issuing of timely instructions and satisfactory investments by the state. The formation of health-care networks from central to local administrative levels created favourable conditions for implementation of the campaign of traditional remedies development in line with the guideline "physicians and drugs on the spot".

Table 14: List of medicinal and aromatic plants of Vietnam

Botanical name	Common name	Botanical family
Abelmoschus esculentus (L.) Moench	Edible hibiscus, gobba	Malvaceae
Abelmoschus moschatus Medic	Musk mallow	Malvaceae
Abrus precatorius L.	Rosary pea, wild liquorice	Fabaceae
Abutilon indicum (L.) Sweet	Malva, country mallow	Malvaceae
Acacia farnesiana (L.) Willd.	Sweet acacia	Fabaceae
Acanthopanax trifoliatus (L.) Voss	-	Araliaceae
Acanthus ilicifolius L.	Sea holly	Acanthaceae
Achyranthes aspera L.	Prickly chaff-flower	Amaranthaceae
Acorus calamus L.	Sweet flag	Araceae
Acorus gramineus Sol. ex Aiton	-	Araceae
Acronychia laurifolia Bl.	Clow flowered laurel	Rutaceae
Adenanthera pavonina L.	Coralwood tree	Fabaceae
Aegle marmelos (L.) Corr.	Bael fruit tree	Rutaceae
Ageratum conyzoides L.	Billy goat weed	Asteraceae
Ailanthus glandulosa Desf.	Ailanto, tree of the gods	Simaroubaceae
Albizia myriophylla Benth.	-	Fabaceae
Aleurites moluccanus (L.) Willd	Belgium walnut	Euphorbiaceae
Amaranthus spinosus L.	Prickly amaranth	Amaranthaceae
Ampelopsis cantoniensis (Hook. & Arn.) Planch.	-	Vitaceae
Ampelopsis heterophylla Sieb.& Zucc. var. *hancei* Planch.	-	Vitaceae
Anamirta cocculus (L.) Wight. & Arn.	Crow killer, fish berry	Menispermaceae
Antiaris toxicaria (Fers.) Lesch. var. *toxicaria*	Upos tree	Moraceae
Aquilaria crassna Pierr.	Agallochum	Thymeleaceae
Aralia armata (Wall.) Seem.	-	Araliaceae
Ardisia sylvestris Pitard	-	Myrsinaceae
Argemone mexicana L.	Mexican poppy	Papaveraceae
Aristolochia indica L.	Indian birthwort	Aristolochiaceae
Aristolochia roxburghiana Klotch.	-	Aristolochiaceae
Artemisia annua L.	-	Asteraceae
Artemisia vulgaris L.	Mugrot, armoise	Asteraceae
Artocarpus heterophyllus Lam.	Jack fruit	Moraceae
Artocarpus integrifolius L. f.	Jack fruit tree	Moraceae
Arundo donax L.	Cane	Poaceae
Asarum maximum Hemsl.	-	Aristolochiaceae
Asclepias curassavica L.	Wild ipecacuanha	Asclepiadaceae
Asparagus cochinchinensis (Lour.) Merr.	Asparagus	Liliaceae
Averrhoa bilimbi L.	Cucumber tree, bilimbi	Oxalidaceae
Averrhoa carambola L.	Carambola apple	Oxalidaceae
Azadirachta indica A. Juss.	Indian lilac	Meliaceae
Baeckea frutescens L.	-	Myrtaceae
Bambusa arundinacea (Retz.) Willd.	Bamboo	Poaceae
Barringtonia acutangula (L.) Gaertn.	-	Lecythidaceae
Bischofia javanica Bl.	Java cedar, vinegarwood	Euphorbiaceae
Blumea balsamifera (L.) DC.	Camphor-plant	Asteraceae
Broussonetia papyrifera (L.) Vent.	Paper mulberry	Moraceae
Brucea javanica (L.) Merr.	Java brucea	Simaroubaceae
Buddleia asiatica Lour.	Asiatic butterfly bush	Scrophulariaceae
Butea monosperma (Lam.) Taub.	Bastard teak, butea gum	Fabaceae
Caesalpinia bonduc Roxb.	Bondux	Fabaceae
Caesalpinia sappan L.	Sappan wood	Fabaceae

Continued

Botanical name	Common name	Botanical family
Calendula officinalis L.	Marigold	Asteraceae
Calophyllum inophyllum L.	Alexander laurel	Clusiaceae
Cannabis sativa L.	Hemp, marijuana	Cannabaceae
Canarium album (Lour.) Raeusch.	-	Burseraceae
Canarium tramdenum C. D. Dai & Yakovlev	Black dammar tree	Burseraceae
Canavalia ensiformis (L.) DC.	Broad bean, sword bean	Fabaceae
Capsicum annuum L.	Bird's eye chilli	Solanaceae
Capsicum frutescens L.	Chili pepper	Solanaceae
Cardiospermum halicacabum L.	Balloon vine, black liquorice	Sapindaceae
Caryota mitis Lour.	Fishtail palm	Arecaceae
Cassia alata L.	Seven golden candlesticks	Fabaceae
Cassia fistula L.	Indian laburnum	Fabaceae
Cassia occidentalis L.	Coffee - senna	Fabaceae
Cassia tora L.	Foetid cassia	Fabaceae
Catharanthus roseus (L.) G. Don	Madagascar periwinkle	Apocynaceae
Ceiba pentandra (L.) Gaertn.	Silk cotton tree	Bombacaceae
Celastrus paniculatus Willd.	Black oil tree	Celastraceae
Celosia argentea L.	Cock's comb	Amaranthaceae
Centella asiatica (L.) Urb.	-	Apiaceae
Ceratopteris thalictroides (Ln.) Brongn.	Water fern	Pteridaceae
Chenopodium ambrosioides L.	American worm seed	Chenopodiaceae
Cibotium barometz (L.) J. Sm.	-	Dicksoniaceae
Cinnamomum iners Reinw.	-	Lauraceae
Cissampelos pareira L.	False pareira brava	Menispermaceae
Citrus grandis (L.) Osb. var. *grandis*	Shaddock, pomelo	Rutaceae
Citrus grandis var. *racemosa* (Roem.) B. C. Stone	Grapefruit	Rutaceae
Citrus medica var. *sarcodactylis* (Hoola Van Nooten) Swingle	Fingered citron	Rutaceae
Citrus medica limon L.	Adam's apple sweet line	Rutaceae
Clematis chinensis Osbeck	-	Ranunculaceae
Clerodendrum indicum (L.) Kuntze	Turban	Lamiaceae
Clerodendrum paniculatum L.	Pagoda	Lamiaceae
Clerodendrum philippinum Schauer.	Whith pagoda flowers	Lamiaceae
Clitoria ternatea L.	Blue pea	Fabaceae
Cocculus sarmentosus Diels	Ink berry	Menispermaceae
Codonopsis javanica (Bl.) Hook. f.	-	Campanulaceae
Combretum quadrangulare Kurz	-	Combretaceae
Coptis chinensis Franch.	Coptis, gold thread	Ranunculaceae
Coptis quinquefolia Miq.	Coptis	Ranunculaceae
Corchorus capsularis L.	White jute, jute	Tiliaceae
Corchorus olitorius L.	Nalt jute, jew's mallow	Tiliaceae
Coscinium fenestratum (Gaertn.) Colebr.	Nalt jute, Jew's mallow	Menispermaceae
Costus speciosus J. (König) Sm.	-	Costaceae
Crescentia cujete L.	West Indian calabash	Bignoniaceae
Crinum asiaticum L.	Grinum	Liliaceae
Crotalaria assamica Benth.	Crotalaria	Fabaceae
Crotalaria bialata Schrank.	Winged bell bean	Fabaceae
Crotalaria juncea L.	Brown hemp, false hemp	Fabaceae
Croton roxburghii N. P. Balaks.	Roxburgh croton	Euphorbiaceae
Croton tiglium L.	True croton	Euphorbiaceae
Cupressaus torulosa D. Don	Cypress	Cupressaceae
Cuscuta hygrophilae Pears.	Dodder	Cuscutaceae

Continued

Botanical name	Common name	Botanical family
Cyclea barbata Miers.	-	Menispermaceae
Cymbopogon citratus (DC.) Stapf.	Lemon grass	Poaceae
Cymbopogon pendulus (Nees ex Steud.) W. Watson	Mana grass, citronella grass	Poaceae
Cyperus rotundus L.	Nutgrass	Cyperaceae
Cyperus stoloniferus Vahl.	Nutgrass of the sea	Cyperaceae
Datura metel L.	Downy datura	Solanaceae
Dendrobium nobile Lind.	-	Orchidaceae
Derris indica (Lam.) Benn.	Pongamia	Fabaceae
Derris scandens (Roxb.) Benth.	Hog creeper	Fabaceae
Derris trifoliata Lour.	-	Fabaceae
Desmodium heterophyllum (Willd.) DC.	Greater clover leaved	Fabaceae
Desmodium styracifolium (Osb.) Merr.	Desmodium	Fabaceae
Desmodium triangulare (Retz.) Merr.	-	Fabaceae
Dichroa febrifuga Lour.	-	Hydrangeaceae
Dillenia indica L.	Elephant apple	Dilleniaceae
Dillenia ovata Wall. ex Hook F. & Thomson	Wampara	Dilleniaceae
Dioscorea bulbifera L.	Air potato, bulbi-bearing yam	Dioscoreaceae
Dioscorea colletii Hook. f.	Collett yam	Dioscoreaceae
Dioscorea deltoidea Wall. ex Griseb.	Yam	Dioscoreaceae
Dioscorea dissimulans Prain & Burkill	Yam	Dioscoreaceae
Dioscorea pentaphylla L.	Fiveleaved yam	Dioscoreaceae
Dioscorea persimilis Prain & Burkill	Yam	Dioscoreaceae
Diospyros castaneana (Craib.) Fletche	Castanea persimon	Ebenaceae
Diospyros decandra Lour.	Persimon	Ebenaceae
Diospyros kaki Thunb.	Kaki, Japanese persimon	Ebenaceae
Dipsacus japonicus Miq.	-	Dipsacaceae
Dipterocarpus tuberculatus Roxb.	Eng tree	Dipterocarpaceae
Disporopsis longifolia Craib.	-	Liliaceae
Disporum calcaratum D. Don var. *rubiflorum* Gagnep.	-	Liliaceae
Docynia indica (Wall.) Decne.	-	Rosaceae
Dracaena angustifolia (Medik.) Roxb.	Baton	Agavaceae
Dracaena cambodiana Pierre ex Gagnep.	Cambodge evergreen	Agavaceae
Drynaria baronii (H. Christ) Diels	-	Polypodiaceae
Drynaria fortunei T. Moore	-	Polypodiaceae
Eclipta prostrata (L.)	-	Asteraceae
Ehretia microphylla Lam.	Ceylon box wood	Boraginaceae
Eichhornia crassipes (Mart.) Solms	Water hyacinth	Pontederiaceae
Elaeocarpus floribundus Bl.	Rugged oil fruit	Elaeocarpaceae
Elephantopus scaber L.	Pickly elephant foot	Asteraceae
Eleusine indica (L.) Gaertn.	Crab-grass, yerd-grass	Poaceae
Embelia ribes Burm. f.	-	Myrsinaceae
Embelia scandens (Lour.) Mez.	-	Myrsinaceae
Emilia sonchifolia (L.) DC.	Cupid's shaving brush	Asteraceae
Eragrostis pilosa (L.) P. Beauv.	Indian love grass	Poaceae
Eriobotrya japonica (Thunb.) Lindl.	Medlar, loquat	Rosaceae
Ervatamia divaricata (L.) Burk.	Wax-flower plant	Apocynaceae
Euonymus japonicus Thunb.	Spindle tree	Celastraceae
Eupatorium fortunei Turcz.	Aya-pana of tonkin	Asteraceae
Eupatorium odoratum L.	Jack in the bush	Asteraceae
Euphorbia antiquorum L.	Malay spurge tree	Euphorbiaceae

Continued

Botanical name	Common name	Botanical family
Euphorbia atoto Furst. f.	Sea-shore spurge	Euphorbiaceae
Euphorbia hirta L.	Hairy spurge	Euphorbiaceae
Euphorbia lathyris L.	Myrtle spurge	Euphorbiaceae
Euphorbia ligularia Roxb.	India spurge tree	Euphorbiaceae
Euphorbia milii Des Moul.	Crow of thorns	Euphorbiaceae
Euphorbia tirucalli L.	Milk bush, finger tree	Euphorbiaceae
Exacum tetragonum Roxb.	Squar-stemmed exacum	Gentianaceae
Excoecaria agallocha L.	Bing-your-eyes	Euphorbiaceae
Fagopyrum esculentum Moench	Buck wheat	Polygonaceae
Polygonum multiflorum Thunb.	-	Polygonoceae
Fibraurea tinctoria Lour.	-	Menispermaceae
Ficus bengalensis L.	Giant banyan tree	Moraceae
Ficus carica L.	Common edible fig	Moraceae
Ficus elastica Roxb. ex. Hornem.	Indian rubber plant	Moraceae
Ficus nervosa Heyne ex Roth.	Mountain fig	Moraceae
Ficus pumila L.	Creeping fig	Moraceae
Ficus racemosa L.	Cluster fig	Moraceae
Ficus religiosa L.	Peepul tree, bodh tree	Moraceae
Flacourtia jangomas (Lour.) Raeusch.	Indian plum	Flacourtiaceae
Garcinia hanburyi Hook. f .	Siamese gamboge tree	Clusiaceae
Gardenia angustifolia (L.) Merr. (Syn. *G. skasminoides* Ellis)	Jasmina	Rubiaceae
Gaultheria fragrantissima Wall.	-	Ericaceae
Gendarussa vulgaris Nees	-	Acanthaceae
Geranium nepalense Sweet	Nepal crane's bill	Geraniaceae
Gleditsia fera (Lour.) Merr.	-	Fabaceae
Gmelina arborea Roxb.	Kashmir tree	Lamiaceae
Gmelina asiatica Linn.	Bristly bush beeth.	Lamiaceae
Gnetum montanum Markgr.	-	Gnetaceae
Harrisonia perforata Merr.	-	Rutaceae
Hedyotis capitellata Wall.	-	Rubiaceae
Hedyotis corymbosa (L.) Lam.	-	Rubiaceae
Hibiscus mutabilis L.	Cotton-rose	Malvaceae
Hodgsonia macrocarpa (Bl.) Cogn.	-	Cucurbitaceae
Holarrhena antidysenterica (Roxb. ex Flem.) Wall. ex A. DC.	Indian kurchi bark	Apocynaceae
Hopea odorata Roxb.	Golden oak	Dipterocarpaceae
Houttuynia cordata Thunb.	-	Saururaceae
Hydnophytum formicarum Jack	-	Rubiaceae
Hypericum japonicum Thunb.	Matted St. John's wort	Clusiaceae
Ilex condorensis Pierre	-	Aquifoliaceae
Ipomoea digitata L.	Giant potato	Convolvulaceae
Ipomoea hederacea Jacq.	Morning glory	Convolvulaceae
Ipomoea pes-caprae (L.) R. Br.	Beach morning	Convolvulaceae
Jasminum subtriplinerve Bl.	-	Oleaceae
Jasminum undulatum Ker-Gawl.	Angel-hair jasmin	Oleaceae
Kaempferia galanga L.	Galanga	Zingiberaceae
Knema globularia Warb.	-	Myristicaceae
Kyllinga nemoralis (J. R. Forst & G. Forst) Dandy ex Hutch. & Dalziel	Poverty grass	Cyperaceae
Lactuca indica L.	Indian lettuce	Asteraceae
Lagerstroemia calyculata Kurz	-	Lythraceae
Lagerstroemia indica L.	Rose of India	Lythraceae
Lantana camara L.	Yellow sage, lantana	Verbenaceae
Laportea crenulata Gaud.	Devil nettle	Urticaceae

Continued

Botanical name	Common name	Botanical family
Lasia spinosa (L.) Thwaites	-	Araceae
Launaea sarmentosa (Will.) Sch. Bip. ex O. Ktze	Pissenlit maritime	Asteraceae
Lawsonia inermis L.	Henna	Lythraceae
Leea rubra Bl.	Lys	Leeaceae
Lindera myrrha (Lour.) Merr.	-	Lauraceae
Liquidambar formosana Hance	Oriental gum	Hamamelidaceae
Lonicera japonica Thunb.	Common honeysuckle	Caprifoliaceae
Lophatherum gracile Brongn.	-	Poaceae
Ludisia discolor (Ker Gawl.) A. Rich.	-	Orchidaceae
Ludwigia adscendens (L.) H. Hara	Water primrose, floating Malayan willow	Onagraceae
Ludwigia octovalvis subsp. *octovalvis* (Jacq.) P. H. Raven	Common willow herb	Onagraceae
Lygodium flexuosum (L.) Sw.	-	Schizaeaceae
Mahonia nepaulensis DC.	Nepal mahonia	Berberidaceae
Maclura cochinchinensis (Lour.) Corner	-	Moraceae
Maesa perlarius (Lour.) Merr.	-	Maesaceae
Mahonia japonica (Thunb.) DC.	Mahonia	Berberidaceae
Mallotus paniculatus (Lam.) Muell. *Arg.*	Turn-in-the-wind	Euphorbiaceae
Mallotus philippensis (Lam.) Muell. Arg.	Kamara, red berry	Euphorbiaceae
Melaleuca cajuputi Powell	Cajeput tree, niaouli	Myrtaceae
Melia azedarach L.	Barbados lilac, bead tree	Meliaceae
Mesua ferrea L.	Ironwood	Clusiaceae
Millettia eberhardtii Gagnep.	-	Fabaceae
Millettia pulchra Benth. ex Baker	-	Fabaceae
Millettia speciosa Champ.	-	Fabaceae
Mimosa pudica L.	-	Fabaceae
Morinda officinalis F. C. How	-	Rubiaceae
Morinda umbellata L.	Common Indian mulberry	Rubiaceae
Moringa oleifera Lam.	Drumstick tree	Moringaceae
Mucuna gigantea (Willd.) DC.	Elephant cowitch	Fabaceae
Mucuna pruriens (L.) DC.	Cowhage plant	Fabaceae
Murraya paniculata (L.) Jack	Curry leaf tree	Rutaceae
Myristica fragrans Houtt.	Common nutmeg	Myristicaceae
Nervilia fordii (Hance) Schltr.	-	Orchidaceae
Oroxylum indicum (L.) Vent.	Indian trumper flaver	Bignoniaceae
Operculina turpethum (L.) Silva Manso	False jalap	Convolvulaceae
Oxalis corniculata L.	Yellow wood sorrel	Oxalidaceae
Oxalis corymbosa DC.	Rose-oxalis	Oxalidaceae
Paederia foetida Linn.	-	Rubiaceae
Paederia scandens (Lour.) Merr.	-	Rubiaceae
Panax bipinnatifidus Seem.	-	Araliaceae
Panax vietnamensis Ha. & Grushv.	-	Araliaceae
Paris polyphylla subsp. *polyphylla* Sm.	-	Liliaceae
*Paris polyphyl*la subsp. *fargesii* (Sm. Franch.) Hara	-	Liliaceae
Passiflora foetida L.	Passion fruit	Passifloraceae
Phyllanthus distichus (L.) Muell. Arg.	The country gooseberry	Euphorbiaceae
Phyllanthus emblica L.	Emblic myrobalan plant	Euphorbiaceae
Phyllanthus niruri L.	-	Euphorbiaceae
Phyllanthus reticulatus Poir.	-	Euphorbiaceae
Piper lolot C. DC.	Pepper	Piperaceae
Plantago major L.	Common plantain	Plantaginaceae
Pluchea indica (L.) Lees	-	Asteraceae

Continued

Botanical name	Common name	Botanical family
Pluchea pteropoda Hemsl.	-	Asteraceae
Podophyllum tonkinense Gagnep.	-	Berberidaceae
Polygala sibirica L.	Japanese senega	Polygalaceae
Polygonatum kingianum Coll. et Hemsl.		Liliaceae
Polygonatum officinale All.	-	Liliaceae
Polygonum hydropiper L.	Water pepper	Polygonaceae
Polygonum tomentosum Willd.	Water smatweed	Polygonaceae
Portulaca oleracea L.	Purslane	Portulacaceae
Psidium guajava L.	Guava	Myrtaceae
Psychotria rubra (Lour.) Poir.	Wild coffee	Rubiaceae
Pteris multifida Poir.	Spider brake	Pteridaceae
Pterocarpus indicus Willd.	Andaman redwood	Fabaceae
Ptenocarya stenoptera C. DC. Van. *tonkinensis* Franch.	-	Juglandaceae
Quassia amara L.	Bitter quassin	Simaroubaceae
Quisqualis indica L.	Rangoon creepper	Combretaceae
Rhaphidophora decursiva Schott	-	Araceae
Rauvolfia cambodiana Pierr. ex Pit.	-	Apocynaceae
Rauvolfia verticillata (Lour.) Baill.	Taiwan devil pepper	Apocynaceae
Rhinacanthus nasutus (L.) Kurz	-	Acanthaceae
Rhodamnia trinervia (Lour.) Bl.	Silver back	Myrtaceae
Rhodomyrtus tomentosa (Ait.) Hassk.	Rose myrtle	Myrtaceae
Rorippa nasturtium-aquaticum Hayek.	Water cress	Brassicaceae
Rosa laevigata Michx.	-	Rosaceae
Rubia cordifolia L.	-	Rubiaceae
Rubus alceifolius Poir.	-	Rosaceae
Rubus cochinchinensis Tratt.	-	Rosaceae
Sageretia theezans (L.) Bron.	Hedge sageretia	Rhamnaceae
Sambucus javanica Reinw. ex Bl.	Elder	Adoxaceae
Sambucus simpsonii Rehder	Elder	Adoxaceae
Sapindus mukorossi Gaertn	Chinese soap-berry	Sapindaceae
Sapium sebiferum (L.) Roxb.	Chinese tallow	Euphorbiaceae
Sandoricum indicum Cav.	Maley red wood	Meliaceae
Schefflera octophylla (Lour.) Harms	-	Araliaceae
Scoparia dulcis L.	Sweet broom weed	Scrophulariaceae
Semecarpus anacardium L. f.	Oriental cashew nut	Anacardiaceae
Severinia monophylla (L.) Tan.	Chinese box orange	Rutaceae
Sida rhombifolia L.	Jelly beaf	Malvaceae
Siegesbeckia orientalis Ln.	Holy herb	Asteraceae
Smilax glabra Roxb.	-	Smilacaceae
Solanum dulcamara L.	Deadly night-wort	Solanaceae
Solanum nigrum L.	Black night-shade	Solanaceae
Solanum procumbens Lour.	-	Solanaceae
Sophora flavescens Ait.	-	Fabaceae
Sophora subprostrata Chun & Chen	-	Fabaceae
Sphaeranthus africanus L.	-	Asteraceae
Spilanthes acmella (L.) L.	Para cress	Asteraceae
Stachytarpheta jamaicensis (L.) Vahl	Devil's coach whip	Verbenaceae
Stemona tuberosa Lour.	-	Stemonaceae
Stephania hernandiifolia (Willd.) Walp.	-	Menispermaceae
Stephania sinica Diels.	-	Menispermaceae
Sterculia foetida L.	Great sterculia	Sterculiaceae
Streptocaulon juventas (Lour.) Merr.	-	Asclepiadaceae

Continued

Botanical name	Common name	Botanical family
Strobilanthes cusia (Nees.) J. B. Imlay	-	Acanthaceae
Strophanthus divaricatus (Lour.) Hook. & Arn.	-	Apocynaceae
Strychnos nux-vomica L.	Nux-vomica tree	Loganiaceae
Strychnos wallichiana Steud. ex A. DC.	Crow fig	Loganiaceae
Symplocos laurina (Retz.) Wall. ex G. Don	-	Symplocaceae
Syzygium cumini (L.) Skeels	Black plum	Myrtaceae
Tacca chantrieri Andr.	-	Dioscoreaceae
Tacca plantaginea (Hance) Drenth	-	Dioscoreaceae
Talinum paniculatum (Jacq.) Gaertn.	Fame flower	Portulacaceae
Tamarindus indica L.	Tamarind	Fabaceae
Terminalia chebula Retz.	Black myroblan	Combretaceae
Tetracera scandens (L.) Merr.	-	Dilleniaceae
Tetrapanax papyrifer (Hook.) K. Koch	-	Araliaceae
Tetrastigma serrulatum (Roxb.) Planch	-	Vitaceae
Thunbergia grandiflora Roxb.	Blue trumpet vine	Acanthaceae
Tinospora tomentosa (Colebr.) Hook. f. & Thoms.	-	Menispermaceae
Tribulus terrestris L.	Calthrops	Zygophyllaceae
Trichosanthes kirilowii Maxim.	-	Cucurbitaceae
Typhonium divaricatum Decne.	-	Araceae
Typhonium trilobatum (L.) Schott	-	Araceae
Uncaria tonkinensis Havil.	-	Pedaliaceae
Verbena officinalis L.	Gambir plant	Verbenaceae
Wikstroemia indica C. A. Mey.	Columbine	Thymelaeaceae
Xanthium strumarium L.	Lambourde	Asteraceae
Zizyphus mauritiana Lam.	Indian jujube	Rhamnaceae

Many medicinal and aromatic plants used in traditional remedies had to be imported in the past. IMM has introduced several medicinal and aromatic plant species from different Asian and European countries by carrying out studies on acclimatization and domestication. To date, 70% of these species have been adapted and grown under climatic conditions of Vietnam, making the country self-sufficient in a great number of valuable and rare medicinal materials which earlier had to be imported. In addition, a thousand tonnes of medicinal and aromatic plants have also been exported.

In the past, efforts for large-scale production of medicinal and aromatic plants in state or collective farms met failures at many sites. Recently, collective efforts of state and farmers through contract cultivation, use of good quality seed material and organized post-harvest processing and extraction using defined technologies have given effective results.

Selection and Breeding of Medicinal and Aromatic Plants

In Vietnam, the application of tissue culture technology for improvement of the strain of *Mentha arvensis* L. and *Costus speciosus* (J. Koenig) Sm. started in the 1980s. Today, this technique is largely applied for the amelioration, multiplication, breeding and conservation of the clones of some selected medicinal plants. The technology of callus culture is applied for the production of biomass of *Panax pseudoginseng* Wall. and *Catharanthus roseus* (L.) G. Don.

The application of the technology of selection and breeding in the field of medicinal and aromatic plants in the country is still at the initial stage of development. The work on selection of high quality planting material has been carried out on *Artemisia annua* L., while improvement and standardization work has been done on the strains of *Angelica acutiloba* (Siebold & Zucc.) Kitag., *Angelica dahurica* (Fisch.) Benth. & Hook. f. ex Franch. & Sav., *Achyranthes bidentata* Bl., *Rehmannia glutinosa* (Gaestn.) Steud. and *Mentha arvensis* L.

Harvesting and Post-harvest Treatment

During the 1980s, state farms used mechanized harvesting of plant material, but the results were not economically encouraging. Therefore, today, the majority of medicinal and aromatic plants are harvested manually.

Among the drying methods, sun drying is the most practiced process in the post-harvest treatment of medicinal and aromatic plants. Recently, some farms and institutions have established small- and medium-scale drying-houses, which use charcoal or electricity as energy. At present, there is a polyvalent drying pilot plant, which can be used for drying of all plant parts.

Processing and Utilization of Medicinal and Aromatic Plants

Medicinal plants are the raw materials for isolation of the pure active compounds for formulation into drugs; as intermediates in the production of semi-synthetic drugs; and for preparation of standardized galenicals. The processes of isolation of active ingredients from plants have been continuously improved to obtain a higher yield and better quality of finished products. Vietnam is now in a position to transfer the technology (technique, equipment and installation) of the extraction process of artemisinin from *Artemisia annua* L., and diosgenin from *Dioscorea* species. Some medicinal and aromatic plant species cultivated in Vietnam are given in Table 15.

The improvement in quality of dosage forms has been made with the application of biopharmacy, bioavailability and pharmacokinetics. Medicines for internal use prepared in the traditional manner have many disadvantages, such as variability of raw material quality, inconvenient bulky dosage forms, poor stability, sensitivity to moisture and vulnerability to microbial contamination. The modernization of traditional dosage forms was carried out by many companies and institutions aiming at applying modern technologies of extraction and formulation to change the large dosage forms of massive water extract and tincture into powder or dried material of active components available for the preparation of capsules or tablets. The Ministry of Health has promulgated the regulations of drug quality control, and a dossier of documents for the clinical trials of new drugs.

A decade ago, Vietnam organized large-scale cultivation of about ten aromatic plants, and exported essential oils rather than the raw material. In recent years, many institutions and companies have established polyvalent pilot plants for processing, improvement

in distillation methods, rectification and fractionation of essential oils. Such pilot plants have also been provided by the United Nations Development Programme (UNDP) and UNIDO. Lately, many companies have restricted cultivation and distillation because of the lack of raw material, degradation of quality of essential oils and lack of investment. Very little use of essential oils is made locally, and some pharmaceutical factories have started the production of fragrances and flavours.

Table 15: Some medicinal and aromatic plants cultivated in Vietnam

Scientific name	Common name	Family
Angelica acutiloba Kita.	Duong qui	Apiaceae
Amomum longiligulare T. L. Wu	-	Zingiberaceae
Amomum villosum Lour. var. *villosum*	-	Zingiberaceae
Amomum xanthioides Wall. ex Baker	-	Zingiberaceae
Aquilaria crassna Pierr. ex Lee.	Aloe wood	Thymeleaceae
Artemisia annua L.	Thanh cao	Asteraceae
Baeckea frutescens L.	Weeping baeckea	Myrtaceae
Catharanthus roseus (L.) G. Don	Madagascar periwinkle	Apocynaceae
Cinchona ledgeriana Moens	Cankina	Rubiaceae
Cinnamomum cassia Bl.	Que	Lauraceae
Cupressus torulosa D. Don	Cypress	Cupressaceae
Cyperus rotundus L.	Nut grass	Cuperaceae
Cyperus stoloniferus Retz.	Nut grass of the sea	Cyperaceae
Cymbopogon citratus Stapf	Lemon grass	Poaceae
Cymbopogon martinii W. Wats.	Sa hoa hong	Poaceae
Cynara scolymus L.	Actiso	Asteraceae
Dacrydium elatum (Roxb) Wall. ex Hook	-	Podocarpaceae
Eucommia ulmoides Oliv.	Do trong	Eucommiaceae
Fokienia hodginsii (Dunn.) A. Henry & H. H. Thoms.	-	Cupressaceae
Geranium nepalense Sweet	Nepal crane's bill	Geraniaceae
Hibiscus sabdariffa L.	Bup dam	Malvaceae
Homalomena aromatica Schott	-	Araceae
Litsea cubeba (Lour.) Pers.	-	Lauraceae
Melaleuca cajuputi Powel	Cajeput tree	Myrtaceae
Melaleuca leucadendron L.	Tram gio	Myrtaceae
Mentha arvensis L.	Bac ha	Lamiaceae
Murraya glabra Guil.	-	Rutaceae
Ocimum gratissimum L.	Huong nhu trang	Lamiaceae
Plantago major L.	Common plantain	Plantaginaceae
Sophora japonica L.	Hoe	Fabaceae
Stevia rebaudiana Bert.	Co ngot	Asteraceae
Vetiveria zizanioides (L.) Nash.	Vetiver grass	Poaceae

Research and Development of Medicinal and Aromatic Plants

Since 1981, the Vietnam government began to reinforce the activities of science and technology by setting up state level research and development programmes for different branches. There were two programmes under the Ministry of Health, one for medicine and the other for pharmacy. So far, four research and devlopment programmes of phar-

macy have been finalized from 1981 to 1985, 1986 to 1990, 1991 to 1995 and 1996 to 2000. These programmes have the task of generating the raw material of medicinal plants to serve traditional medicine and the pharmaceutical industry. The objectives of the programmes include research on synthetic drugs, antibiotics and medicinal and aromatic plants with 50 to 70% research devoted to medicinal and aromatic plants. The research focuses on three thrust areas: cultivation, selection, breeding, protection and preservation of medicinal and aromatic plants for raw materials; the process technology for extraction of active ingredients and essential oils; and the new herbal drugs, plant-based drugs and modernized traditional medicines. The research aimed at the production of raw materials and dosage forms, traditional remedies to treat infectious diseases and those that occurred during the mechanization and modernization processes in the country (cancer, cardiovascular diseases, neurasthenis and mental diseases, diabetes, HIV/AIDS, etc.).

The focus of the five year programme, from 1991 to 1995, was research on *Artemisia annua* L. and artemisinin. From 1993, Vietnam has been producing artemisinin and its derivatives (artesunate, artemether, dihydroartemisinin) in a quantity surplus for local use and exportation. This drug has very significantly decreased the mortality and epidemiology of malaria. The other research result relates to *Panax vietnamensis* Ha & Grushv., one of the world's 18 species of *Panax*. It has been located so far southward, at 15° latitude north, out of the predicted limit of the *Panax* genus. After 21 years of study, the results and value of this wild ginseng have been recognized.

Panax vietnamensis Ha & Grushv. has been investigated for its botany, chemistry, pharmacology, cultivation, tissue culture, pharmaceutical products and clinical evaluation. Out of 49 saponins, 24 new damarane saponins were established based on chemical and spectral methods. The characteristic saponin component makes this species an interesting member of *Panax* genus not only as regards chemotaxonomics, but also from a pharmacological point of view. The evaluation of *Panax vietnamensis* Ha & Grushv. for antistress activity is under way as a part of a cooperative effort between Vietnam and Japan. However, the increasing evidence of usefulness of this species has resulted in shrinkage of its resource-base, as a result of wild collection. Damaging the native land of *Panax vietnamensis* Ha & Grushv. for crops by minority tribes in high mountains has further deteriorated the situation. To date, only one experimental station is attempting to produce semi-wild *Panax vietnamensis* Ha & Grushv. under natural forest canopy at an altitude of 1,800 to 2,000 meters. The introduction of medicinal plant cultivation into farming and forestation in the mountains creates the occasion for environment protection and health-status improvement of the minorities.

Institute of Materia Medica (IMM)

The Institute of Materia Medica was established in 1961 as the main R&D centre of medicinal and aromatic plants. It consists of seven departments, including Medicinal and Material Resources; Phytochemistry; Chemical Analysis and Standardization; Pharmacology and Biochemistry; Formulation; Pilot Plant for Extraction of Active Ingredients from Medicinal and Aromatic Plants; and the Laboratory of Tissue Culture and Callus Culture.

The Institute also comprises two stations for the study of cultivation of medicinal and aromatic plants in Sapa and TamDao, North Vietnam; a research centre for cultivation and processing of medicinal and aromatic plants at the Red River delta; a research centre of Vietnam ginsengs and medicinal and aromatic plants in Ho Chi Minh city; and a centre for selection of medicinal and aromatic plants strains in Dalat city, South Vietnam. In addition, a number of pharmaceutical companies, two faculties of pharmacy in Hanoi and Ho Chi Minh city, the Institute of Natural Products Chemistry and the Institute of Chemistry, are engaged in medicinal and aromatic plant R&D.

Future Directions

Vietnam, a tropical country, has an abundance of natural resource of medicinal material. The country possesses an age-old traditional system of medicine, and plant drugs have contributed tremendously to public health and economic development. However, production and utilization of medicinal and aromatic plants have faced many constraints since 1989, and in the free market these have barely competed with modern medicines.

Overcoming the constraints would mean liberating the potentiality of production of medicines and fragrances from indigenous medicinal and aromatic plant raw material to serve the public health, and to produce raw material from these for pharmaceutical industry and exportation.

Policies to encourage utilization of traditional medicines in the list of national essential drugs, together with measures to protect local plant-based medicines to limit the importation of chemical drugs should be outlined as soon as posible. Exchange of experience and research information on production, processing and trade of medicinal and aromatic plants between Asian and European countries, in particular between member countries of the Asian Network on Medicinal and Aromatic Plants (ANMAP), should be facilitated. Assistance from UN organizations for study and organizing workshops, training courses and symposia should be sought. An international project on screening new active ingredients from plants should be submitted for funding.

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Chapter 2
The Status of Medicinal and Aromatic Plants in India and Nepal

by Karan Vasisht and Maninder Karan

Introduction

The Indian subcontinent is the birthplace of several traditional health-care systems, with the most practised Ayurveda in India and Nepal, and Unani or Tibbi in Pakistan. The Himalayan region is endowed with enormous biodiversity of rare and endangered medicinal plant species of high commercial importance. The enormous variety of flora coupled with developed and documented systems of traditional health care in the region make it an epicentre of activities on medicinal and aromatic plants, which is evident from its international stature, second only to China. India, for example, is the second largest exporter of medicinal plant material onto the international market, while Nepal is a habitat of some rare and extremely valuable medicinal herbs for the world market. The increased demand of plant material in the international market opens an opportunity for these countries to develop their export to sizable extent so as to make significant contributions to their foreign earnings.

The Status of Medicinal Plants in India

India is a land of varied climatic, ethnic, cultural and linguistic zones with population touching one billion. The country is divided into ten bio-geographic zones: Trans-Himalayan, Himalayan, Indian deserts, semi-arid areas, western Ghats, Gangetic plains, northeast India, islands, and coasts. All ranges of climate (alpine to tropical) and altitude (sea level to 6,000 m) are available in the country. The recorded forest area of the country is about 63.73 mn hectares, which is 19.39% of its total area. The region is also one of the places of earliest civilizations known to man. From ancient time, India has been known for its rich resources that have brought about a number of invasions and led to its wealth and knowledge to different parts of the world. The annual per capita consumption of drugs in the country is around US$ 3, which is the lowest in the world, mainly because traditional medicines based on sound ancient system of medicine are still prevalent in the country.[1] In

the context of growing national and international market for medicinal plants, India is well aware of the conservation and sustainable use of its natural resources.

Alternative Systems of Medicine

The rich knowledge that developed in the region is well recorded in the earlier scriptures known as *Vedas*. The earliest references to medicinal plants can be found in *Rig Veda* and *Atharva Veda*, dating back to 5000 B.C. As a result of ancient knowledge and civilizations which flourished in India, that one of the earliest complete systems of health care was developed in the region, known as Ayurveda (*Ayur*-life, *Veda*-knowledge). This system of medicine was taught in ancient universities of India established as early as 700 B.C. (Takshila) and 500 B.C. (Nalanda). The origin of Ayurveda is lost in antiquity, but it matured between 2500 and 500 B.C. Ayurvedic medicine takes a holistic view of a body, and a disease is considered to originate from imbalance of its constituents. The Ayurvedic system of medicine has two well-developed branches, medicine and surgery. Charaka Samhita (~ 900 B.C.) and Sushruta Samhita (~ 600 B.C.) are recorded hallmarks of therapeutics and surgery respectively. The branches of specialization of modern medicine have similar counterparts in Ayurveda, which explains the completeness of the system. Over 2,000 medicinal plants are used in the Ayurvedic system of medicine and the most interesting contribution of Ayurveda to modern medicine is that of the drug reserpine, which revolutionized the treatment of blood pressure.

When the Ayurvedic system was developing in the north of India, another system developed in the South, which is now known as the Siddha system of medicine. Siddhars were the holy persons who practised yoga and saw a great role of environment, age, sex, habit, mental frame and diet in the physical constitution of the body.

The Unani system of medicine is based on Greek philosophy and Hippocrates (460-377 B.C.), the father of modern medicine, was its founder. Later, the Islamic rulers of the Arabian countries adopted this system and it flourished and developed during the Medieval period when development was arrested in Europe. It was introduced in India by Arabs in 1351 A.D.

The homoeopathy system of medicine originated in Germany: Dr. Samuel Hahnemann (1755-1843) was its founder. It entered India in 1839 when Dr. John Martin Honigberger was called to treat Maharaja Ranjit Singh, the ruler of Punjab, for treatment of paralysis of vocal cords. He successfully treated Maharaja Ranjit Singh and demonstrated the efficacy of the system. It is now one of the popular systems of medicine practised in India.

A portion of the population in India on the Indo-China border area follows the Tibetan system of medicine. The Tibetan Medicine and Astrological Institute at Dharmshala in the state of Himachal Pradesh offers a full-fledged six-year degree course in Tibetan medicine. The Institute has 30 branches throughout India and Nepal. Tibetan medicines are mostly derived from herbs.

Ayurveda, Unani, Siddha are well integrated into the national health-care system and are officially recognized by central and state governments. In addition, all ethnic cultures of India have a rich heritage of using medicinal plants to formulate their herbal remedies for common ailments. It is no wonder that the estimated number (about 8,000) of medicinal plants used in unregulated systems of traditional medicines far exceeds the number of plants (estimated between 1,200 to 2,000) used in documented and regulated Indian systems of medicine. The Central Council of Indian Medicine Act of 1970 regulates the teaching, training and registration of practitioners of the Indian system of medicine. The Indian government through the Central Council of Indian Medicine and the Central Council of Homoeopathy is working to strengthen the indigenous systems of medicine, which sank to a status of poor man's medicine during the colonial period.[2]

State Efforts in Development of Indian Systems of Medicine

The Ayurvedic system of medicine is deep-rooted in the culture of India. It received major setback during the medieval period owing to unsettled political conditions. First Mughals and later Britishers patronized their own systems of medicine, but Ayurveda survived solely because of its inherent strength and cultural support. As early as 1920, the Indian National Congress demanded state patronage for Ayurveda from the then British government. The very first conference of Health Ministers of Independent India resolved to develop and strengthen Ayurveda.

In the present sovereign and multiethnic state of India, all alternative systems introduced at different stages coexist with its indigenous systems of medicine. The government of India has given due recognition to all systems and separate department of Indian System of Medicine and Homoeopathy (ISM & H) was established in 1995 to look after the needs of the different systems. Various departments and committees established earlier for the development of Indian systems were moved under the control of this department.[2] The department of ISM & H, under the Ministry of Health and Family Welfare, is responsible for the educational standards, quality control of drugs, availability of raw material for the production of medicine, and R&D activities of these systems. Working committees have been constituted for each of these systems to handle the development activities in the country designed to strengthen these systems. Time-bound research programmes have been initiated in thrust areas, and efficacy of traditional drugs is being assessed using modern standards.

The different activities relating to medicinal plants were formerly under the control of various departments, ministries and state bodies, considering the need to coordinate all activities, a separate National Medicinal Plant Board under the control of the ISM & H was established in the year 2000. This apex body coordinates all aspects of medicinal and aromatic plants and its members are representatives of all relevant government departments, state departments, subject experts, non-governmental organizations (NGOs) and industry. The Board has a further five committees on cultivation and conservation, research, demand and supply, patent/intellectual property rights (IPRs), export and import to address the particular needs of their respective areas.

Each of the Indian systems of medicine has its own strengths. As per a recent report of the Ministry of Health and Family Welfare, 3,841 hospitals, 23,597 dispensaries and 688,802 registered practitioners are available in the country.[3] These figures themselves display the strength and will of the government and public to propagate country's traditional knowledge, also appreciated considering the fact that the country has set up a vast infrastructure to provide modern medicine to its population.

The results of state efforts are positive. The pharmacopoeial standards of crude drugs used in different systems of medicine are nearly complete. The formularies have been published and Good Manufacturing Practices (GMP) have been made applicable for the manufacturing of plant-based drugs. Agro-technologies for 40 medicinal plants have been developed with the help of national and state institutes to facilitate the cultivation of medicinal plants. The country knowledge of ancient texts has been translated and digitalized in the form of a Traditional Knowledge Digital Library to protect IPRs. Three gene banks at the Central Institute of Medicinal and Aromatic Plants, Lucknow; National Bureau of Plant Genetic Resource, New Delhi; and Tropical Botanical Gardens, Trivandrum have been established to preserve genetic material of medicinal plants. Nurseries and exhibition gardens have been established to popularize the use and production of medicinal plants. Conservation programmes in the forests have been taken on a large scale to propagate medicinal plants that cannot be domesticated. R&D activities have been prioritized to facilitate drug discovery from the traditional drugs.

One of the Vision 2020 Reports, *Herbal Products: Current Status, Vision and Action Plan,* developed by the Technology Information, Forecasting & Assessment Council (TIFAC), considering the endemic nature of plants, the volume of domestic and international demand, the endangered nature and the use in traditional system of medicine, has identified 45 medicinal plants for action in cultivation, post-harvest technology, processing, manufacturing, research, patenting and marketing. Seven plants were further short-listed for intense activities during 2001 to 2005.[4] These include *Aloe vera* (L.) Burm. f., *Bacopa monnieri* (L.) Pennell, *Centella asiatica* (L.) Urb., *Rauvolfia serpentina* (L.) Benth. ex Kurz, *Catharanthus roseus* (L.) G. Don, *Taxus baccata* L. and *Artemisia annua* L. The suggested model activities on these plants include the preparation of a plant specific CD-ROM, cultivation and post-harvest protocols and clinical trials.

Medicinal Plants of India

With its varied climatic zones, India possesses one of the largest biodiversities of the world. More than 45,000 plant species are expected to grow in the country. According to all India ethnobiological survey carried out by the Ministry of Environment and Forest, Government of India, there are over 8,000 species of plants used by the people of India.[5] The herbal industry in India uses over 800 medicinal plants and some of the most important are listed in Table 1.[6]

Table 1: Some important medicinal plants used by the Indian industry

Plant name	Common name	Plant part	Estimated consumption (tonnes)
Aconitum heterophyllum Wall. ex Royle	Ativish	Root	20
Acorus calamus L.	Vacha	Rhizome	150
Aloe vera (L.) Burm. f.	Aloes	Leaf	200
Anacyclus pyrethrum (L.) Link	Akkarkara	Fruit	50
Andrographis paniculata (Burm. f.) Wall. ex Nees	Kalmegh	Aerial part	250
Asparagus racemosus Willd.	Shatavari	Root	500
Bacopa monnieri (L.) Pennell	Brahmi	Whole plant	700
Berberis aristata DC.	Daruhaldi	Root	500
Cedrus deodara (Roxb. ex D. Don) G. Don	Deodar	Heart wood	200
Chlorophytum borivilianum L.	Safed musli	Root	25
Cinnamomum zeylanicum Blume	Dalchini	Bark	200-300
Commiphora wightii (Arn.) Bhandari [=*C. mukul* (Hook. ex Stocks) Engl.]	Guggal	Gum resin	500
Crocus sativus L.	Kesar	Stigma	5
Cuminum cyminum L.	Jeera	Fruit	-
Cyperus rotundus L.	Nagar motha	Rhizome	150
Eclipta prostrata (L.) L.	Bhringraj	Aerial parts	500
Elettaria cardamomum (L.) Maton	Cardamon	Seed	60
Embelia ribes Burm. f.	Vidanga	Fruit	200
Glycyrrhiza glabra L.	Mulathi	Root	5000
Hedychium spicatum Buch.-Ham.	Kapurkachri	Rhizome	400
Hemidesmus indicus (L.) W. T. Aiton	Anantmool	Root	200
Holarrhena pubescens Wall. ex G. Don [=*H. antidysenterica* (Roxb. ex Fleming) Wall. ex A. DC.]	Kurchi	Bark	150
Justicia adhatoda L.	Vasaka	Leaf	500
Mucuna pruriens (L.) DC.	Kaunch beej	Seed	200
Myristica fragrans Houtt.	Jaiphal	Fruit	500
Nardostachys grandiflora DC.	Jatamansi	Root	200
Phyllanthus emblica L. [=Emblica *officinalis* Gaertn.]	Amala	Fruit	10000
Picrorhiza kurrooa Royle ex Benth.	Kutki	Root	200
Piper cubeba L. f.	Cubeb (Kankol)	Fruit	150
Piper longum L.	Pipramul, Long pepper	Fruit	200
Piper nigrum L.	Black pepper	Fruit	150
Plumbago zeylanica L.	Chitrak	Root	500
Pueraria tuberosa (Roxb. ex Willd.) DC.	Vidarikanda	Root	200
Saraca indica L.	Ashoka	Bark	1200
Senna alexandrina Mill. [=*Cassia angustifolia* Vahl]	Senna	Leaf, pod	1000
Strychnos nux-vomica L.	Kuchla	Seed	1000
Swertia chirayita (Roxb. ex Fleming) H. Karst. [=*S. chirata* (Wall.) C. B. Clarke]	Kirata or Chirayita	Whole plant	300
Syzygium aromaticum (L.) Merr. & L. M. Perry	Clove or Laung	Flower bud	150
Syzygium cumini (L.) Skeels	Jaman beej	Seed	300
Trachyspermum ammi (L.) Sprague ex Turrill	Ajwain	Fruit	200
Terminalia bellirica (Gaertn.) Roxb.	Bahera	Fruit	500
Terminalia chebula Retz.	Harar	Fruit	500
Tinospora cordifolia (Willd.) Miers	Guduchi	Stem	1000
Valeriana jatamansi Jones [*V. wallichii* DC.]	Tagar	Root & Rhizome	150
Withania somnifera (L.) Dunal	Ashvagandha	Root	500
Zingiber officinale Roscoe	Ginger	Rhizome	500

Ayurveda alone lists uses of some 1,700 plant species. India, with its rich and long culture of using medicinal plants, has discovered herbs for all human ailments. Each ethnic community has its own system of medicine based on medicinal plants, which has resulted in a strongly built-up national knowledge base. It is this knowledge that the government of India is striving to harness and protect from exploitation by foreign agencies.

Around 70% of Indian medicinal plants are distributed in tropical areas while the remainder are found in the temperate and alpine areas.[7] The plants found at the higher altitude include species of very high value and some are rare and region-specific. The majority of medicinal plants are from flowering groups.

The increased industrial activity in the country and industrial dependence on wild collections has resulted in endangering a number of plant species. Around 120 medicinal plants are rare or endangered in India, 35 of which are claimed to be important medicinal plants. Table 2 lists some of the critically endangered species in India.[8]

Table 2: Some critically endangered medicinal plants of India

Aconitum spp.	*Gastrochilus longiflora*
Adhatoda beddomei C. B. Clarke	*Gentiana kurroo* Royle
Angelica glauca Edgew	*Ilex khasiana*
Aquilaria malaccensis Lam.	*Inula racemosa* Hook. f.
Arnebia benthamii (Wall. ex G. Don) Johnston	*Luvunga scandens* (Roxb.) Buch.-Ham. ex Wight
Aristolochia bracteolate Lam.	*Meconopsis aculeata* Royle
Atropa acuminata Royle ex Lindl.	*Nardostachys grandiflora* DC.
Berberis spp.	*Nepenthes khasiana* Hook. f.
Chlorophytum spp.	*Nothapodytes nimmoniana* (J. Graham) Mabb (= *Nothapodytes foetida* (Wight) Sleumer)
Colchicum luteum Baker	
Commiphora wightii (Arn.) Bhandari (= *C. mukul* (Hook. ex Stocks) Engl.	*Panax pseudoginseng* Wall.
Coptis teeta Wall.	*Przewalskia tangutica* Maxim.
Crateriostigma plantagineum Hochst.	*Picrorhiza kurrooa* Royle ex Benth.
C*urcuma caesia* Roxb.	*Podophyllum hexandrum* Royle
Dactylorhiza hatagirea D.Don	*Rauvolfia serpentina* Benth. ex Kurz.
Delphinium denudatum Wall. ex Hook. f. &Thomson	*Saussurea costus* (Falc.)=Lipsch
Dioscorea deltoidea Wall. ex Griseb.	*Saussurea gossypiphora* D.Don
Ephedra gerardiana Wall. ex Stapf	*Swertia chirayita* (Roxb. ex Fleming) H. Karst. (= *S. chirata* (Wall.) C. B. Clarke
Ferula jaeschkeana Vatke	*Taxus wallichiana* Zucc.
Fritillaria roylei Hook.	*Valeriana jatamansi* Jones

Production and Utilization of Medicinal Plants

India is one of the largest users of crude drugs in the world. Most of the plant material collected in the country is indigenously used by more than 9,000 manufacturing units.[1] About 50 manufacturing units are of large-scale, 200 of medium-scale and remaining are of small-scale. The plant material is also used for the preparation of home remedies. As a result, despite collection of huge volumes of crude drugs, only a small volume is made available for export. It is difficult to obtain realistic data of volume of

local consumption and export as the trade operates through a complex chain comprising village collectors, small merchants near collection points, middlemen and large trading houses at regional and international markets. In a number of instances, the collection of medicinal plant from the forests is either restricted, prohibited or required to take place through state forest departments, which promotes illegal trade. As a result, traders and companies remain hesitant in divulging true figures of trade or consumption. The origin of crude drugs sold at the main markets of the country, most of the time, is untraceable. The practice is in contrast with the required standards of GMP of herbal medicinal products, which requires the company to maintain detailed history sheets of the raw material, beginning from its point of origin to type of treatments that it has undergone during periods of shipment and storage. The total domestic market of Ayurvedic medicine is about US$ 1 bn.

More than 90% of medicinal plants used by the industry are collected from the wild. While about 800 species are used in production by industry, less than 20 species of plants are produced by cultivation.[9] This is despite the fact that for a number of plants the cultivation technology is available in the country. Table 3 lists some important plants cultivated in India, while Table 4 lists some significant plants for which technology for cultivation and processing is available in India. The report of the Task Force on Conservation and Sustainable Use of Medicinal Plants, submitted to the Planning Commission, Government of India in March 2000, recommended cultivation of 25 species (Table 5) which are in great demand along with relevant information for undertaking cultivation.[6] The main report of the working group on horticulture development for the tenth five-year plan submitted to the Planning Commission, Government of India in June 2001, identified 24 medicinal plants for cultivation and development. The list is similar to one of Table 5, except that *Bacopa monnieri* (L.) Pennell, *Convolvulus pluricaulis* Choisy and *Embelia ribes* Burm. f. do not figure in this list and new names of *Gloriosa superba* L. and *Phyllanthus niruri* L. have been added.[10]

Over 70% of wild collections are destructive as they involve root, rhizome, whole plant, bark, wood or stem.[11] An interesting example demonstrates how even a most abundant resource can become exhausted by simply not following good collection practice, but to speak of over-collection, which certainly endangers the survival of species. *Phyllanthus emblica* L. [= *Emblica officinalis* Gaertn.] fruit is extensively used in the Indian system of medicine. The plant was commonly and abundantly available in the forests of Madhya Pradesh (a state of Central India). Instead of picking fruits, collectors sometimes chopped off branches or even felled trees to make quick collection. This resulted in reduction of plant population to an extent that it was declared endangered in the state.[12]

Collection from the forests is regulated by Indian Forest Act, 1927. Different states of India can make their own amendments to include medicinal and aromatic plants of the region in their list to regulate collection of the raw material from the forests, e.g. *Rauvolfia serpentina* Benth. ex Kurz. in the states of Gujarat and Maharashtra; *Santalum album* L. in the states of Tamil Nadu, Karnataka, Orissa and Kerala.

Table 3: Some important medicinal plants cultivated in India

Aloe vera (L.) Burm. f.	*Mucuna pruriens* (L.) DC.
Asparagus racemosus Willd. & A. adscendens Roxb.	*Papaver somniferum* L.
Bacopa monnieri (L.) Pennell	*Phyllanthus emblica* L. [= *Emblica officinalis* Gaertn.]
Catharanthus roseus (L.) G. Don	*Piper nigrum* L.
Centella asiatica (L.) Urb.	*Plantago ovata* Forssk.
Cephaelis ipecacuanha (Brot.) Tussac	*Saussurea costus* (Falc.) Lipsch. [= *S. lappa* (Decne.) C. B. Clarke]
Chlorophytum spp.	
Cinchona ledgeriana (Howard) Bern. Moens ex Trimen	*Senna alexandrina* Mill. [= *Cassia angustifolia* Vahl]
Crocus sativus L.	*Solanum khasianum* C. B. Clarke
Mentha spp.	*Withania somnifera* (L.) Dunal

Table 4: Technology sources of some medicinal plants in India

Plant source	Product	Technology source
Solanum khasianum C. B. Clarke	Solasodine	RRL-Bhu, RRL-Jmu, RRL-Jor
Dioscorea composita Hemsl.	Diosgenin	RRL-Jmu, RRL-Jor
Dioscorea floribunda M. Martens & Galeotti		
Catharanthus roseus Inn. G. Don	Vinca alkaloids	CIMAP-Lkw
Artemisia annua L.	Artemisinin	CIMAP-Lkw,RRL-Jmu, Cx- Pal
Eucalyptus youmanii Blakely & McKie *& Eucalyptus macrorhyncha* F. Muell. ex Benth.	Rutin	RRL-Jmu
Ammi majus L.	Xanthotoxin	CIMAP-Lkw
Tanacetum cinerariifolium (Trevir.) Sch. Bip. [Pyrethrum]	Pyrethrum	CIMAP-Lkw
Hyoscyamus muticus L.	Hyoscine	CIMAP-Lkw
Duboisia myoporoides R. Br.	Tropane alkaloids	CIMAP-Lkw
Atropa acuminata Royle ex Lindl	Atropine	CIMAP-Lkw
Matricaria recutita L.	Chamomile oil	NBRI-Lkw, CIMAP-Lkw
Taxus baccata L.	Taxol	RRL-Jmu
Claviceps purpurea Tul.	Ergot alkaloids	CIMAP-Lkw, RRL-Jmu

RRL-Jmu: *Regional Research Laboratory, Council of Scientific & Industrial Research (CSIR), Jammu, Jammu & Kashmir*
RRL-Jor: *Regional Research Laboratory, CSIR, Jorhat, Assam*
RRL-Bhu: *Regional Research Laboratory, CSIR, Bhuvaneshwar, Orissa*
CIMAP-Lkw: *Central Institute of Medicinal and Aromatic Plants, CSIR, Lucknow*
NBRI-Lkw: *National Botanical Research Institute, CSIR, Lucknow*

The demand pressure of medicinal plant material for local consumption and export has endangered the existence of a number of plant species in the wild, e.g. 112 species are considered endangered, near threatened or vulnerable in South India. The biodiversity Conservation Prioritization Project in India, in collaboration with the Forest Department of Uttar Pradesh, held a workshop in 1997 for conservation assessment of selected medicinal plants of northern, northeastern and central India. The workshop considered 75 plants, selected on the basis of importance and the results were alarming. Out of 75 plants, 33 were designated critically endangered (based on accepted criteria of risk assessment) and 17 endangered.

Table 5: Medicinal plants recommended for large-scale cultivation in India

Aconitum heterophyllum Wall.	*Gymnema sylvestre* (Retz.) Schult.
Aegle marmelos (L.) Corrêa	*Nardostachys grandiflora* DC.
Andrographis paniculata (Burm. f.) Wall. ex Nees	*Phyllanthus emblica* L. [= *Emblica officinalis* Gaertn.]
Asparagus racemosus Willd.	*Picrorhiza kurrooa* Royle ex Benth.
Bacopa monnieri (L.) Pennell	*Piper longum* L.
Berberis aristata DC.	*Plantago ovata* Forssk.
Chlorophytum borivilianum L.	*Santalum album* L.
Commiphora wightii (Arn.) Bhandari [= *C. mukul* (Hook. ex Stocks) Engl.]	*Saraca asoca* (Roxb.) W. J. de Wilde
Convolvulus prostratus Forssk. [= *C. pluricaulis* Choisy]	*Saussurea costus* (Falc.) Lipsch.[= *S. lappa* (Decne.) C. B. Clarke]
Embelia ribes Burm. f.	*Senna alexandrina* Mill. [= *Cassia angustifolia* Vahl]
Garcinia indica (Thouars) Choisy	*Swertia chirayita* (Roxb. ex Fleming) H. Karst. [= *S. chirata* (Wall.) C. B. Clarke]
Glycyrrhiza glabra L.	*Tinospora cordifolia* (Willd.) Miers
	Withania somnifera (L.) Dunal

Export and Import of Medicinal Plants

Most of the raw material produced in the country is locally used. However, with introduction of cultivation of high-demand plants the export is expected to rise in the future years. The present export volume of crude drugs from India stands at 36,200 tonnes valued around US$ 24 mn.[13] The figure touches US$ 92 mn (IRS 446.3 crores) if the plant products are included in the list. A quantum jump of 5 to 7 times is expected by 2005 considering the rising international demand and potential of India. The global market of herbal medicinal products is estimated at around US$ 60 bn.[4] India expects to achieve export figures of US$ 850 and 2,000 mn by 2005 and 2010, respectively.[6] Plantago seed and husk and senna are the main export items from India. During 1998-99, India exported plantago worth US$ 16 mn. India also exports finished Ayurvedic and Unani medicines and during the year 2000-01, it exported medicines worth US$ 127 mn to various countries including the USA, Germany, Russia, the UK, Hong Kong and Malaysia.

India, besides promoting export of medicinal and aromatic plants, is also aware of possible impact on the biodiversity. India is signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and considering plants banned from international trade by CITES and national interest, had released a list of 52 plants (Notification no. 47, (PN)/92-97, dated 30 March 1994) for ban from export. The list was later reviewed and the present list (Notification no. 2, (RE-98)/1997-2002, dated 13 April 1998) prohibits the export of 29 plant materials (Table 6).[14] Some new plants were added in the fresh list while others were removed from the previous list (Table 7).[4, 14]

Despite the potential for producing raw material within the country, it imports some crude drugs from other countries: the most prominent are *Glycyrrhiza glabra* L. from Pakistan, Iran and Afghanistan; *Atropa belladonna* L. from Germany; *Heydichium spicatum* from China; *Commiphora wightii* (Arn.) Bhandari Engl. from Pakistan; and *Swertia chirayita* (Roxb. ex Fleming) H. Karst. from Nepal.

Table 6: List of medicinal plants banned from export from India

Plant name	CITES Appendix
Aconitum spp.	-
Aquilaria malaccensis Lam	Appendix II
Ceropegia spp.	-
Coptis teeta Wall.	-
Coscinium fenestratum (Gaertn.) Colebr.	-
Cyathea spp.	-
Cycas beddomei Dyer	Appendix I
Dactylorhiza hatagirea (D. Don) Soo.	-
Dioscorea deltoidea Wall. ex Griseb.	Appendix II
Euphorbia spp.	-
Frerea indica Dalzell	-
Gentiana kurroo Royle	-
Gnetum spp.	-
Kaempferia galanga L.	-
Nardostachys grandiflora DC.	Appendix II
Nepenthes khasiana Hook. f.	Appendix I
Orchids	-
Panax pseudoginseng Wall.	-
Paphiopedilum spp.	-
Picrorhiza kurrooa Royle ex Benth.	Appendix II
Podophyllum hexandrum Royle	Appendix II
Pterocarpus santalinus L. f.	Appendix II
Rauvolfia serpentina (L.) Benth. ex Kurz	Appendix II
Renanthera imschootiana Rolfe	Appendix I
Saussurea costus (Falc.) Lipsch. [= *S. lappa* (Decne.) C. B. Clarke]	Appendix I
Swertia chirayita (Roxb. ex Fleming) H. Karst.	-
Taxus wallichiana Zucc.	Appendix II
Tree ferns	-
Vanda coerulea Griff. ex Lindl	Appendix I

Appendix I *of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora now ratified by 158 countries) lists species for which the international trade is generally prohibited; however, under special circumstances international transfer requires permits both for importer and exporter.* ***Appendix II*** *species require only export permit or re-export certificate for international trade.*

Research Activities in Medicinal Plants

Research activities on medicinal plants are led by the Council of Scientific and Industrial Research (CSIR), a leading research organization in India. CSIR has 40 laboratories spread throughout the country. Each laboratory specializes in research in a particular field, according to the needs of the country. The location and specialization of these laboratories has been carefully planned, keeping in view the availability of resources and needs of the region. Research on medicinal plants is carried out at nearly one quarter of these laboratories. The Indian Council of Agricultural Research (ICAR) and agricultural universities of various states have made significant contributions in developing agrotechniques for fostering cultivation of medicinal plants in the country. The Defence Research and Development Organization (DRDO) and Central Council of Research in Ayurveda and Siddha (CCRAS) are other national organizations involved in medicinal plant R&D.

The Indian Council of Medical Research (ICMR) has conducted clinical investigations of Indian drugs. The ICMR and the Department of Indian Systems of Medicine & Homoeopathy (ISM&H) are involved in developing standards for medicinal plants of India through the network of eminent laboratories. The newly constituted National Medicinal Plant Board is expected to accelerate applied research in the area of medicinal plants. All universities and leading pharmaceutical institutes carry out research on medicinal plants and the major herbal drug industries of the country are equipped with state-of-the-art facilities for conducting research on medicinal plants.

Table 7: Comparison of medicinal plant species prohibited for export under present and past notification

Deletions from the previous notification	
Acorus spp.	*Aloe vera* (L.) Burm. f.
Angiopteris spp.	*Araucaria imbricata* Pav. [=*A. araucana* (Molina) K.Koch]
Aristolochia spp.	*Artemisia* spp.
Atropa spp.	*Balanophora* spp.
Berberis aristata DC	Plants of family Cactaceae
Chimonobambusa jaunsarensis (Gamble) Bahadur& Naithani	*Colchicum luteum* Baker
Commiphora wightii (Arn.) Bhandari	*Costus speciosus* (J. König) Sm.
Didymocarpus pedicellata R. Br.	*Dolomiaea cooperi* Ling [=*Jurinea cooperi* C. Shih]
Drosera spp.	*Ephedra* spp.
Gloriosa superba L.	*Gynocardia odorata* R. Br.
Hydnocarpus spp.	*Hyoscyamus niger* L.
Iphigenia indica (L.) A. Gray ex Kunth	*Meconopsis betonaefolia* Franch.
Osmunda spp.	*Physochlaina praealta* (Decne.) Miers
Pratia montana (*Paltia surpunila*)	*Rheum emodi* Wall. ex Meisn. (=*R. australe* D. Don)
Rhododenron spp.	*Strychnos potatorum* L. f.
Urginea spp.	
Additions in the present notification	
Cycas beddomei Dyer	*Dactylorhiza hatagirea* (D. Don) Soo
Kaempferia galanga L.	*Panax pseudoginseng* Wall.
Picrorhiza kurrooa Royle ex Benth.	*Renanthera imschootiana* Rolfe
All orchids	Tree ferns

Conservation of Medicinal Plants Resources

The herbal drug industry is poised to make great jumps in coming years as a result of booming international demand and rise of green consumerism. Though this opens opportunities for the developing countries to benefit from the situation, at the same time it exposes their vulnerability to resort to unsustainable exploitation of their biodiversity and presents the risk of inflicting irreparable damage. This situation calls for immediate measures to impose sustainable use of natural resources. The amount of raw material required in the country for domestic and international market cannot be obtained through sustainable harvest from the wild. Thus a clear threat of damage to the biodiversity is anticipated from the present practice of obtaining over 90% of raw material from the forests. The pressure on some species is very high and if remedial actions are not launched immediately, there is a danger of these species becoming extinct.

The country possesses unique biodiversity in the Himalayan region, where some rare and very valuable plant species are found. It is necessary to promote the cultivation of these rare species to protect them from extinction. Economic considerations prevent industry from cultivating medicinal plants, and wild collections are continued as they are economically more attractive. In a situation when collection exceeds the sustainable quantity available from the forests, the state should exert its authority to force industry to cultivate.

There is a clear need to augment the conservation strategies in the country. The conservation efforts involve ecological, technical, social, economic, legal and political issues. On the ecological front, it involves understanding of complex ecosystems; the technical aspect entails development of appropriate harvesting, processing and cultivation technologies; the social front requires understanding of cultural beliefs, social values, attitudes, ethics and aspirations of local people who are the first users of biodiversity; the economic aspects need to maximize benefits derived from a biodiversity resource; and finally the whole process requires the political will to accomplish the task.

The government of India is aware of the urgency for conserving national biodiversity of medicinal plants, and steps have already been initiated at national and state level to alleviate the pressure of demand on the forests. Many international agencies, research institutes and NGOs have played an active role in promoting sustainable use of biodiversity resources of medicinal and aromatic plants. Initiatives have already been taken in the country for public awareness, development of technologies for efficient utilization of resources and species cultivation, efficient management of local resources, creation of reserve forests for monitoring biodiversity change, and regular review of requirements of conservation plans. For example, the state forest departments of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu have 54 protected areas covering different types of forests, known as Medicinal Plant Conservation Areas (MPCAs). They are accorded with enhanced fire protection and harvest restrictions. The Foundation for Revitalization of Local Health Traditions (FRLHT) has made significant contributions to the state efforts of conservation in South India.

The government of India has implemented several projects to develop agro-technologies to successfully introduce cultivation of endangered medicinal plants and has established gene banks to preserve the germplasm. It has ambitious plans to create more MPCAs covering all ecosystems, attempt *ex situ* conservation of rare species in established gardens, create *Vanaspati Vans* for production of medicinal plants in degraded forest lands, establish herbal gardens and nurseries for medicinal plants, and promote contact farming to encourage cultivation.

Production of Spices in India

India is the land of spices and has a long tradition and reputation of producing a rich variety of spices. More than 50 different kinds of spices are produced in India, some of them in huge quantities. The country's consumption of spices ranks among the highest in

the world, and more than 90% of domestic production is locally used (Figure 1). Only about 8 to 10% is exported, to more than 150 countries.

India accounts for 46% of world trade in spices. The world's total spice production is estimated at 500,000 tonnes per annum valued at US$ 1.5 to 2 bn.[15] The main spices produced in India include chillies, turmeric, garlic, coriander, ginger, cummin, fenugreek, pepper, fennel and cardamom, in decreasing volume of production. The estimated export during 2000-01, in tonnes, was the highest for chillies (61,000) followed by turmeric (34,500), pepper (19,250), cummin (13,800), coriander (11,700), garlic (11,000) and fenugreek (9,050). However in value terms, in billion IRS, pepper had the largest share (3.26) followed by chillies (1.95), cumin (1.17), turmeric (0.91) and cardamom (0.56). The country has strengthened its position in the export of value-added products, which have shown continuous rise in the export. During the year 2000-01, the country exported spice oils and oleoresins worth IRS 3.64 bn. The yearly export figures from India from 1996-97 to 1999-2000 are 346.97, 394.45, 428.77 and 468.12 tonnes respectively[16] (Figure 2). The country is the main producer of turmeric, ginger and pepper controlling 90, 35 and 30%, respectively of their world market.

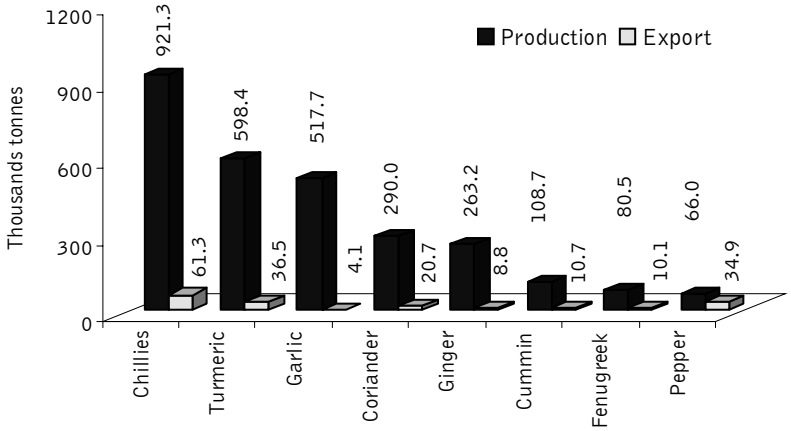

Figure 1: Indian production and export of spices

Essential Oils

A number of essential-oil-bearing plants are cultivated or collected from the wild in the country. Brazil, Indonesia, China and India are the leading world producers of essential oils. The local consumption of essential oils in the country is very high and as a result very little volumes are made available for the export. The most significant export is of sandal wood oil, for which the country is the major world producer, exporting 50 to 60 tonnes to the world market, estimated at around 80 tonnes. India is leader in production of menthol as mentha oil production in the country has steadily expanded in the last decade. During the year 2000-01, India exported 3,875 tonnes of mint oil valued at IRS 1.26 bn.[15]

Lemon grass, citronella, palmrosa, vetiver and rose oils are the main essential oils produced in the country. India also produces jasmine concrete, which is a high-value product in the perfumery. The country has a very old cottage industry involved in the production of high-value perfumes (attars) for the world market.

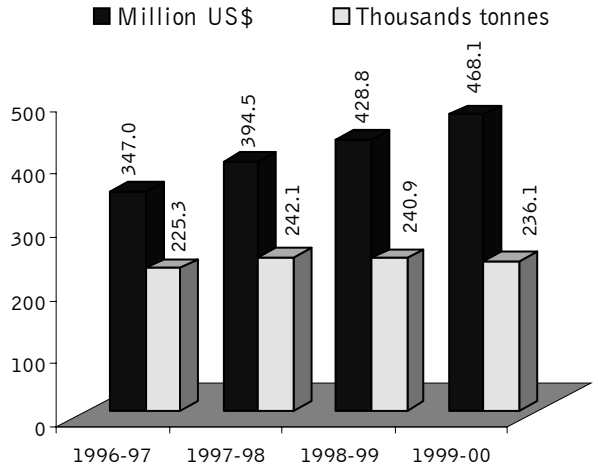

Figure 2: The export of spices from India

The Status of Medicinal Plants in Nepal

Nepal lies between China on the north and India on the east, south and west. The country has a rectangular shape and land area of 1,47,181 square km. It has a population of more than 23 mn (1999) people of different races with diverse cultures, languages and dialects. The country has the distinction of possessing Mount Everest, the highest mountain peak of the world. The topography of Nepal varies from an altitude range of about 70 to 8,848 meters. It enjoys all the climates of alpine, temperate and tropical lowland. It has a biodiversity of 6 phytogeographical provinces, 10 bioclimatic zones, 35 forest types and 75 vegetation types.[17] The beauty of the ecosystem of Nepal is that within a very short distance of about 200 km, it offers dense tropical monsoon forests (Terai in the south) and alpine pastures and snow-covered Himalayas (in the north). Forests contribute significantly to the economy of what is otherwise one of the poorest nations of the world.

About 7,000 species of flowering plants have been reported from the country and 246 are endemic. At a global scale, the country stands 27th in number of flowering plants. The list of recorded identified medicinal plants used in Nepal has grown from 70 species in a 1968 survey to 1,463 in 1997.[18] This increasing number over the years clearly reflects that still the total number of species used as medicine in the country is not known. A land area of 14% is under protection in Nepal.

Traditional Systems of Medicine

Ayurvedic, Tibetan, Amchi (local version of Tibetan) and folk medicines are the practised alternative systems in Nepal. The population of Nepal is largely dependent on indigenous medicine, especially folk herbal remedies, which have been used and appreciated since prehistoric times. About 85% of the rural population is dependent on indigenous medicine.

Nepal is known to possess some of the rare medicinally important plant species of the world. The collection of wild herbs dates back to ancient times and trade of medicinal herbs from Nepal was described by holy men as early as 3,000 years ago.

The use of medicinal herbs in Nepal's traditional medical system dates back to at least 500 A.D. Traditional medicines, although with low profile, are an integral part of the national health system. Parallel to the allopathic system, traditional medicines are encouraged in all spheres because of their efficacy, availability, and affordability when compared to allopathic drugs.[19]

The Ayurvedic system of medicine is widely practised in Nepal and is the national medical system. More than 75% of the population use Ayurvedic medicines. There are 141 Ayurvedic dispensaries, 14 zonal dispensaries, 15 district Ayurvedic health centres, and two Ayurvedic hospitals. One of these hospitals is centrally located in Naradevi, Kathmandu, and the other is regionally located in Dang. There are 623 institutionally qualified practitioners of Ayurveda and about 4,000 traditionally trained practitioners. Homoeopathy has recently been introduced in Nepal.[20]

State Efforts in Development of Traditional Medicine

The policy of the government,[21] based on five-year plans, involves a system of integrated health services in which both allopathic and Ayurvedic medicines are used. Ayurvedic clinics are considered to be part of the basic health services, and there is a department responsible for Ayurvedic medicine in the Office of the Director General of Health Services. The Ayurvedic Governmental Pharmaceutical Unit works to provide inexpensive medicaments. The Ayurvedic Medical Council was created through legislation passed in 1988.[22] Section 2.1 of this Act gives the Council's mandate as, among other things, steering the Ayurvedic medical system efficiently and registering suitably qualified physicians to practise Ayurvedic medicine. In Section 4, the legislation sets out provisions for registration that classify applicant practitioners into four groups according to their qualifications and experience in Ayurvedic science. Section 5.2.2 determines the range of Ayurvedic medicines that a practitioner is permitted to prescribe. Direct or indirect practice of Ayurvedic medicine by unregistered practitioners is forbidden by Section 5.1.1. Registered Ayurvedic practitioners are eligible to issue certificates concerning a patient's physical and mental fitness.

Formal education in the Ayurvedic system falls under the supervision of the Institute of Medicine of Tribhuvon University.[23] The Auxiliary Ayurveda Worker training programme

is run by the Department of Ayurveda under the Council for Technical Training and Vocational Education.[21]

Manufacturing of Herbal Medicinal Products

There are some 20 manufacturers of plant-based medicine.

Herbs Production and Processing Company Limited (HPPCL)

The HPPCL, established in 1981, has pioneered the work on medicinal plants in Nepal. It is one of the main herbal drug industries of Nepal and extends support to over 20 small manufacturers at district level. The company has its own research and extension activities.

Singha Darbar Vaidyakhana

This company was established especially for the Royal family and top dignitaries of the country about 300 years ago. It was later opened for the public. After the implementation of the Ayurvedic Policy of Nepal, it was transferred to the Development Board so that it can produce more valuable products for the country. About 100 types of its products are on the market.

Dabur Nepal

Dabur Nepal is a sister organization of Dabur India Company Limited. The company has made heavy investment to secure long-term supply of medicinal plant material. The company has a high-technology nursery in Kathmandu, where it is propagating 20 plants for cultivation. The company encourages contract farming and sells seedlings to farmers at a very nominal price.

Other herb processing units in Nepal include Gorkha Ayurved Company Limited, Gorkha; Vaidyakhana Vikas Samitee, Kathmandu; Natural Products Industries (NPI), Kapilbastu; Himalayan Ginger Company, Khairenitar; Arogya Bhawan, Kathmandu and around 20 small herbal enterprises located at different districts of the country supported by the HPPCL. Twenty-six private companies produce about 200 different brands of Ayurvedic drugs in Nepal. More than 150 Indian Ayurvedic drug companies supply Ayurvedic medicines to Nepal.

Research and Development of Medicinal Plants

Royal Nepal Academy of Science & Technology (RONAST)

The RONAST was established in 1982 to develop scientific capacity in the country. The RONAST natural products laboratory works on the isolation of useful phytopharmaceuticals. The various programmes of the academy include collection and preservation of germplasms of medicinal and aromatic plants, propagation and cultivation techniques and sustainable use of natural resources.

Department of Plant Resources

The Department of Plant Resources (formerly Department of Forestry and Plant Resources, Department of Medicinal Plants) falls under the Ministry of Forest and Soil Conservation, and looks after R&D activities on medicinal plants. The department was established in 1959 to collect and maintain herbarium specimens, conduct phytochemical and pharmacological screening and develop techniques for cultivation of important medicinal and economic plants.

Herbs Production and Processing Company Limited

This also falls under the Ministry of Forest and Soil Conservation and undertakes processing and R&D activities on medicinal plants. Besides processing plant material, it has carried out several extension programmes. The HPPCL has an area of about 300 hectares for commercial cultivation of aromatic plants. It has successfully introduced the cultivation of a number of aromatic plants and has worked for domestication of important herbs such as *Nardostachys grandiflora* DC., *Valeriana jatamansi* Jones and *Swertia chirayita* (Roxb. ex Fleming) H. Karst.

Royal Drug Research Laboratory

The Royal Drug Research Laboratory under the Department of Drug Administration is authorized to conduct analysis of Ayurvedic and other herbal drugs for granting approval to manufacture. More than 300 species have been screened and studied for their active constitutents in the laboratory.

Trade

Around 95% of medicinal plant material is collected by local people from the forests, who sell it to rural middlemen. An estimated 470,000 households are involved in the collection of plant material. Some community collections are also made. Rural middlemen sell the material to herb traders located at road head or districts. The material from them reaches wholesalers who are located mostly in the Terai region. The wholesalers sell the material either to local consumers or export it to other countries, mainly India. The Nepalese government started efforts to improve export of crude herbs as early as 1937; an organized department, the Department of Medicinal Plants, was established in 1959 to manage the activities on medicinal plants.

Legislation concerning the commercial collection of medicinal and aromatic plants has become increasingly restrictive with the implementation of Forest Act (1993) and accompanying Forest Rules of 1995. The collection is authorized by permits issued by District Forest Offices. A "release order" for herb is required to transport harvested plants out of the district of origin.

The collection of endangered species such as *Dactylorhiza hatagirea* (D. Don) Soo. (an orchid commonly known as salampanja) and *Cordyceps sinensis* (Berk) Sacc. (cater-

pillar fungus - Yarsagumba) was officially banned in 1996. A number of plant species have been banned for unprocessed export, including *Nardostachys grandiflora* DC., *Valeriana jatamansi* Jones, *Cinnamomum glaucescens* Nees, *Rauvolfia serpentina* (L.) Benth. ex Kurz, Jhyau consisting of several species of Lichens and the mineral product Silajit. The ban on collection of yarsagumba was lifted in 2001 and a royalty rate of NRS 500 per piece was fixed (3,000 to 5,000 pieces make one kilogram). A kilogram now costs NRS 1,625,000 (US$ 21,300).[24] Since this revenue is high, it will naturally encourage illegal trade.

The private sector handles over 95% of trade and 99% of export is to India, where used by the local industry or exported to international market.[25, 26] The Nepal Non-timber Forest Products Network (NNN), established in 1995, encourages community participation, and representatives from stakeholders, environment and government work together to promote sustainable use of non-timber forest products (NTFPs). Useful information such as prevailing price of crude drugs can be obtained through e-mail by interested individuals, traders and organizations.

About 100 medicinal plants are reported to be collected in Nepal for use by the herbal drug industry.[26] Some of the most important medicinal plants, whose annual collection exceeds 100 tonnes are *Asparagus racemosus* Willd., *Bergenia ciliata* (Haw.) Sternb., *Cinnamomum glaucescens* Nees, *Picrorhiza scrophulariiflora* Pennell, *Swertia chirayita* (Roxb. ex Fleming) H. Karst., *Sapindus mukorossi* Gaertn. and *Zanthoxylum armatum* DC. Some others plants such as *Acorus calamus* L., *Piper* spp., *Rheum australe* D. Don, *Rubia cordifolia* L. and *Valeriana jatamansi* Jones also show similar trend in demand and distribution.[25] Although their total collected quantities are smaller, their utility value is higher than the former group.

The export quantities of medicinal plant material amounted to 4,000 tonnes during the mid-1970s but the trend declined sharply during the 1980s.[27] It increased during the first half of the 1990s and after a year of decline in 1997-98, increased again during following two years (Table 8).[28] The export of essential oil increased from US$ 76.62 mn in 1996 to 126.06 in 1999-2000.

Cultivation of important aromatic plants (palmrosa, chamomile, basil, mentha) is undertaken in the Terai region on contact farming.

Table 8: Export of crude drugs

Year	Quantity (kg)	Value NRs '000	Value US$ '000
1995-96	57,197	8,362	122.97
1996-97	69,711	12,051	177.22
1997-98	37,756	12,024	176.82
1998-99	-	31,400*	411.58
1999-00	-	43,100*	564.95

** Export only to India*

Conclusions

The region has very strong and prevalent practice of use of alternative systems of medicine, including Ayurveda, Unani, Siddha, homoeopathy and Tibetan. Medicinal and aromatic plants are widely used to prepare medicines for these systems. India is one of the largest producers of plant-based drugs used in Ayurveda, Unani and Siddha systems of medicine. The country has huge domestic demand of medicinal plant raw material, met largely from wild collections and partly through import from the neighbouring countries. Despite large domestic consumption, its export to international market is second only to China. The country is also one of the major producers of spices and again, only about 10% of production is available for export. The country has a tremendous potential to undertake cultivation of medicinal plants for both domestic consumption and international market. The varied agro-climatic conditions of the country can be exploited to undertake the cultivation of medicinal plants specifically for demand on the international market.

Nepal has a rich biodiversity, which allows ample scope for the development and sustainable utilization of medicinal and aromatic plants. The favourable conditions are underexploited for commercial cultivation of exotic as well as high-value industrially important medicinal plants that can only be grown in this country. The development of medicinal and aromatic plants business has been constrained owing to lack of planning and policies in R&D, pricing, marketing and resource management in the past. However, the recent trend demonstrates the high priority of state governments, not only to promote the alternative systems but also to introduce cultivation of species that are endangered or commercially important.

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Chapter 3
The Status of Medicinal and Aromatic Plants in Pakistan

by Farzana Shaheen, Atta-ur-Rahman, Karan Vasisht and M. Iqbal Choudhary

Introduction

Pakistan is a developing country of South Asia with a total area of 87.98 mn hectares, of which 88% is arid and semi-arid and only 12% is humid and sub-humid located in Himalayan ranges. It is the ninth most densely populated country in the world. According to the latest estimates, the population of the country is over 140 mn. The state-owned forest area, under the control of the Forest Department is 5.2% of the total land area of Pakistan.[1] It shares a long border with India and enjoys varied climatic conditions, from arid to Mediterranean type and from coastal to alpine zones. As a result, diverse flora of indigenous and alien species are found in Pakistan. The country has 5,700 to 6,000 species of vascular plants.[2] The flora of Pakistan has not been completely documented, e.g. the 209 volumes of the *Flora of Pakistan* does not cover the largest family Asteraceae. The diversity of the various mountain ranges in the North has contributed to a uniquely rich flora with 350 to 400 endemic species mainly confined to the northern and western dry mountains.[3]

Traditional Systems of Medicine

The knowledge of medicinal herbs is confined to rural areas and more than 55,000 Traditional Medical Practitioners (TMPs) serve over 70 to 80% of the population using their own prescriptions dispensed for patients.[4] The Unani system of medicine (Hikmat or Greco-Arab or Tibbi) is the prevalent alternative system of medicine, and uses both raw and semi-processed plant material. The Tibbi Pharmacopoeia of Pakistan (Pharmacopoeia of Traditional Drugs compiled by the Tibbi Board) has listed around 900 single drugs and 500 compound preparations made from medicinal plants. Nearly 360 *tibb* dispensaries and clinics provide health care to the public under the control of the health departments of provincial governments. About 95 dispensaries have been established under provincial departments of Local Bodies and Rural Development, and one *tibb* clinic is working under the Provincial Department of Auqaf. A separate Directorate of Hakims has been established under the Federal Ministry of Population Welfare Programme.

Unani, Tibb, Ayurveda, and homoeopathy have been accepted and integrated into the national health-care system. The Board of Unani and Ayurvedic Systems of Medicine and the Board of Homoeopathic Systems of Medicine are responsible for maintaining adequate standards at recognized institutions and conducting research in traditional medicines in the country, and for the registration of TMPs. The Ministry of Health, through the National Council for Tibb, oversees the qualifications and registration of practitioners and manage the educational institutions imparting education in Unani and Ayurvedic systems of medicine. Twenty-six colleges in the private sector and one in the public sector offer four-year diploma courses in traditional systems of medicine.

Medicinal Plants of Pakistan

In Pakistan, there are about 2,000 estimated species of medicinal plants of which 400 are extensively used in traditional medicine.[3,4] Commercially exploited medicinal plants occur mainly in alpine and high-altitude regions, temperate montane forests, subtropical foothill forests and semi-arid scrub lands in the country (Table 1).[5]

Table 1: Some medicinal plant species of commercial importance in Pakistan

Region	Botanical name	Conservation status
Alpine and high altitude areas	*Aconitum heterophyllum* Wall ex. Royle	Endangered
	Corydalis spp.	
	Picrorhiza kurrooa Royle ec Benth. Benth.	
	Podophyllum hexandrum Royle	
	Saussurea costus (Falc.) Lipsch	
Temperate montane forests	*Angelica glauca* Edgew.	Common
	Artemisia spp.	
	Atropa acuminata Royle ex Lindl.	
	Ephedra spp.	
	Geranium wallichianum D. Don ex Sweet	
	Glycyrrhiza glabra L.	
	Paeonia emodi Wall.	
Sub-tropical foothill forests	*Butea monosperma* (Lam.) Ktze.	Common
	Mallotus philippensis (Lam.) Müll. Arg.	
	Phyllanthus emblica L. [=Emblica officinalis Gaertn.]	
	Terminalis spp.	
Arid and semi-arid areas	*Artemisia* spp.	Common
	Bunium persicum (Boiss.) Fedtsch.	
	Ephedra gerardiana Wall.	
	Ephedra procera Fisch. & Mey.	

A number of botanical explorations have been conducted under the auspices of several authorities such as the Pakistan Agricultural Research Council (PARC) in Sindh; the Pakistan Science Foundation (PSF) in Balochistan; and the Pakistan Association of Advancement of Science (PAAS) in Kashmir. The Pakistan Forest Institute (PFI) has also published a number of booklets and market surveys on medicinal plants.

Over 85% of the medicinal plants demand is met from wild collections especially from moist alpine and high-altitude areas in the northwestern part of the country and dry montane areas of Karakoram and Hindukush ranges.[6] The sub-tropical foothill forests are most important for species diversity and forest density. Most of the medicinal plant material is produced in the Hazara and Malakand regions (500 tonnes) followed by Azad Jammu and Kashmir province (38 tonnes), northern areas (24 tonnes) and Murri Hills (16 tonnes).[1] Approximately 5,000 poor families, residing in remote hilly areas are engaged in the collection of medicinal plants during the summer months in the North-west Frontier province.

In areas bordering Kashmir, the most valuable medicinal plant is *Saussurea costus* (Falc.) Lipsch. The cultivation of medicinal plants is undertaken in Punjab, Sindh and Balochistan provinces. Some important cultivated species are *Crocus sativus* L., *Ocimum sanctum* L., *Plantago ovata* Forssk., and *Nigella sativa* L. The medicinal plant material from cultivation satisfies only a very small portion of the market. Unfortunately, no attention is paid to the systematic cultivation, propagation and collection of medicinal plants nor is any authentic data available, except for some limited information published in the Pakistan Journal of Forest Department.

There are a number of medicinal plants that can be cultivated; these have established demand for their raw material or their active constituents in the international market. These plants are: *Acorus calamus* L., *Aconitum* spp., *Justicia adhatoda* L., *Aloe vera* (L.) Burm. f., *Ammi majus* L., *Atropa acuminata* Royle ex Lindl., *Berberis aristata* DC., *Carica papaya* L., *Catharanthus roseus* (L.) G. Don f., *Senna alexandrina* Mill., *Cephaelis ipecacuanha* (Brot.) A. Rich., *Cinchona* spp., *Colchicum* spp., *Datura metel* L., *Digitalis* spp., *Dioscorea* spp., *Glycyrrhiza glabra* L., *Hedychium spicatum* Buch.-Ham., *Heracleum candicans* Wall. ex DC., *Hyoscyamus* spp., *Inula racemosa* Hook. f., *Juglans regia* L., *Juniperus* spp., *Matricaria recutita* L., *Papaver somniferum* L., *Plantago ovata* Forssk., *Podophyllum hexandrum* Royle, *Rauvolfia serpentina* (L.) Benth. ex Kurz., *Rheum emodi* Wall. ex Meisn., *Saussurea costus* (Falc.) Lipsch., *Swertia chirayita* (Roxb. ex Fleming) H. Karst., *Urginea indica* Kunth, *Valeriana jatamansi* Jones and *Zingiber officinale* Roscoe.

The survival of many species of medicinal value has been threatened through over harvesting and habitat destruction. The most prominent include *Saussurea costus* (Falc.) Lipsch., *Podophyllum hexandrum* Royle, *Dioscorea deltoidea* Wall. ex Kunth, *Valeriana jatamansi* Jones (Table 2).

Herbal Drug Manufacturing Companies in Pakistan

There are about 27 large herbal manufacturing companies in Pakistan, which produce Unani medicines on commercial scale and hundreds of herbal medicine manufacturers in non-organized sectors.[4] Herbal sections of national and multinational pharmaceutical companies also utilize indigenous herbal resources. The actual demand of herbs and medicinal plants is in the range of 20,000 tonnes per annum. In an estimate, about 14,000 tonnes of plant material were imported in 1989-1990 and 106 tonnes exported in the same year.[1]

Table 2: Endangered and vulnerable medicinal plant species of Pakistan

Botanical name	Local name	Annual demand (tonnes)	Ecological region	Conservation status
Aconitum heterophyllum Wall. ex Royle	Atees	4-5	Temperate Himalayas	Endangered
Acorus calamus L.	Warch, gorbach	20-30	Temperate Himalayas	Vulnerable
Adiantum capillus-veneris L.	Parsiyawshan	80-100	Temperate Himalayas	Vulnerable
Artemisia spp.	Afsantin	100-150	Hindukush Himalayas	Vulnerable
Atropa acuminata Royle ex Lindl.	Angoor-shafa	15	Temperate Himalayas	Endangered
Berberis lycium Royle	Dardald	300-400	Hidukush, Himalayas	Vulnerable
Bergenia ciliata Sternb.	Zakhme-e-Hayat	15-20	Temperate Himalayas	Vulnerable
Citrullus colocynthis (L.) Schrad.	Tumba, hanzil	40-50	Deserts	Vulnerable
Colchicum luteum Bak.	Suranjan Talkh	5-8	Sub-tropical Himalayas	Vulnerable
Commiphora wightii (Arn.) Bhandari	Guggul	25-50	Deserts	Endangered
Dioscorea deltoidea Wall. ex Kunth	Kanis	30-60	Temperate Himalayas	Endangered
Glycyrrhiza glabra L.	Mulathi	>200	Hindukush, Karakoram	Vulnerable
Mallotus philippensis (Lam.) Muell.	Kamila	5-10	Sub-tropical Himalayas	Vulnerable
Onosma echioides L.	Ratanjot	5-10	Cold dry mountain	Endangered
Paeonia emodi Wall.	Mamekh	10-20	Temperate Himalayas	Endangered
Picrorhiza kurrooa Royle ex Benth.	Kutki	10-15	Alpine Himalayas	Endangered
Pistacia integerrima Stew.	Kakarsinghi	2-3	Sub-tropical Himalayas	Vulnerable
Plantago ovata Forssk.	Isabagol	30-40	Cold arid hills	Vulnerable
Podophyllum hexandrum Royle	Bankakri	30-40	Temperate Himalayas	Endangered
Polygonum amplexicaule D. Don	Anjabar	15-20	Temperate Himalayas	Endangered
Rheum emodi Wall.	Revand-chini	30-40	Temperate Himalayas, Hindukush	Endangered
Saussurea costus (Falc.) Lipsch.	Kuth	5-8	Alpine Himalayas	Endangered
Valeriana jatamansi Jones.	Mushkbala	30-50	Temperate Himalayas	Endangered
Ziziphus sativa Gaertn.	Unab	50-100	Sub-tropical Himalayas	Vulnerable

Although a good deal of work has been carried out on natural products, but little attention has been paid to the demand of the herbal industry and integration of alternative medicine in the health-care system of the nation. Most of the industrial requirement is met through import. Medicinal plants collected from wild sources are largely used in the manufacture of traditional medicines, natural cosmetics, health foods, culinary, spices, raw material for the extraction of phytopharmaceuticals and essential oils for pharmaceutical industry. The supply is erratic, resulting in similar trends in price. The full potential of natural reserves is yet to be exploited. Cultivation of plants has been undertaken only for plants with ready demand in good quantities.

The pharmaceutical industry in the country concentrates on no more than about 20 herbs. A large part of the world's supply of ephedrine once originated from the processing of *Ephedra procera* Fisch. & C. A. Mey., sourced from Balochistan. Plants such as *Digitalis purpurea* L., *Atropa belladonna* Royle ex Lindl., *Colchicum luteum* Bak. used in the isolation of valuable phytopharmaceuticals have been over-exploited and many more are depleted from the natural resources. Some of the most important medicinal plant species of North-west Frontier province and Balochistan are given in Table 3.

Table 3: Important medicinal plant species of Kashmir forests, North-west Frontier province and Balochistan

Plant name	Part(s) used	Approximate annual yield (tonnes)
Aconitum chasmanthum Stapf	Root	5
Aconitum heterophyllum Wall. ex Royle	Root	1
Adiantum capillus-veneris L.	Whole plant	120
Angelica glauca Edgew.	Root	7
Artemisia vulgaris L.	Leaf, shoot	148
Atropa acuminata Royle ex Lindl.	Root	74
Berberis lycium Royle	Root	300
Dioscorea deltoidea Wall. ex Kunth	Rhizome	148
Geranium wallichianum D. Don ex Sweet	Root	18
Myrtus communis L.	Fruit	45
Paeonia emodi Wall.	Rhizome	99
Podophyllum hexandrum Royle	Rhizome	55
Polygonum amplexicaule D. Don	Root	27
Rheum emodi Wall.	Root	259
Saxifraga ciliata Royle	Root	37
Thymus serphyllum L.	Leaf	7
Valeriana jatamansi Jones	Rhizome	148

Marketing and Trade

Medicinal and aromatic plants have a market of considerable size both nationally and internationally. Crude plant-based drugs worth over US$ 130 mn are used annually in Pakistan. The Pakistan Forest Institute in Peshawar has conducted a number of market surveys of herbal markets of Pakistan. A survey of Punjab and Sindh province showed that 75 items of crude herbal drugs are extensively used and traded in Pakistan (Table 4). Trade of crude drugs is very erratic and prices fluctuate greatly due to variation in demand within and outside the country. Traders frequently underpay the collectors and sell their products at huge profit. The availability of crude drugs remains unstable and market trends cannot easily be determined. Export of medicinal plants and plant products through documented channels is relatively low compared to many other countries of Asia, and there is good potential for expansion.

The main markets of crude herbal drugs are in Mingora, Dir, Peshawar, Rawalpindi, Bahawalpur, Lahore, Faisalabad, Multan, Sukkar, Hyderabad and Karachi. The Peshawar market acts as a supply centre of herbal drugs to various markets in Pakistan. This market procures herbal material not only from Pakistan but also from Afghanistan and other Central Asian Republics. On the other hand, Karachi herbal market is the main hub export-based trade of medicinal herbs.

Pakistan exports a significant volume of medicinal plants to the world market. Crude drugs exported from Pakistan are given in Table 5. Pakistan also imports medicinal plant material from India, China, Thailand, Indonesia, Iran and Afghanistan (Table 6). The import of herbal material as a whole is worth over US$ 130 mn and has increased over the last ten years. Investigations have reported that about 60% of the medicinal plant species imported actually grow wild in the northern areas of Pakistan.

These plants have not been thoroughly explored and investigated, e.g. *Cichorium intybus* L. imported from India to the tune of 14.8 tonnes is abundantly available. The survey conducted in 1999 on women's indigenous knowledge of folk medicines indicated that the knowledge of known medicinal plants gives valuable information about the characteristics of habitat and also about unexplored medicinal plants of the region. For instance, *Plantago major* L., *Carum copticum* (L.) C. B. Clarke, *Crocus sativus* L. and others can easily be cultivated as a cash crop in the area, which would save foreign revenue and provide employment to people of the area.

Table 4: Medicinal and aromatic plants collected and traded from Punjab and Sindh provinces of Pakistan

Category	Plant species	Quantity traded (tonnes)
Category A	*Borago officinalis* L.	>200
	Bunium bulbocastamum L.	
	Carum copticum (L.) C. B. Clarke	
	Cassia fistula L.	
	Coriandrum sativum L.	
	Cuminum cyminum L.	
	Foeniculum vulgare Mill.	
	Glycyrrhiza glabra L.	
	Lawsonia inermis L.	
	Mentha longifolia (L.) Huds.	
	Plantago ovata Forssk.	
	Punica granatum L.	
	Rosa damascena Mill.	
	Valeriana jatamansi Jones	
	Ziziphus jujuba Mill.	
Category B	*Adiantum capillus-veneris* L.	101-200
	Centaurea behen L.	
	Phyllanthus emblica L.	
	Ferula foetida (Bunge) Regel	
	Myrtus communis L.	
	Polygonum amplexicaule D. Don	
	Rheu australe D. Don	
	Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	
	Terminalia chebula Retz.	
	Viola pilosa Blume	
Category C	*Aretmisia maritime* L.	51-100
	Senna alexandrina Mill. [= *Cassia angustifolia* Vahl]	
	Cichorium intybus L.	
	Commiphora wightii (Arn.) Bhandari	
	Cordia latifolia	
	Lallemantia royleana (Benth.) Benth.	
	Mallotus philippensis (Lam.) Muell. Arg.	
	Malva sylvestris L.	
	Nigella sativa L.	
	Peganum harmala L.	
	Salvia haemotodes	
	Saussurea costus (Falc.) Lipsch.	
	Sisymbrium irio L.	
	Zingiber zerumbet (L.) Sm.	

Continued

Category	Plant species	Quantity traded (tonnes)
Category D	*Acorus calamus* L.	2-50
	Achillea millefolium L.	
	Aconitum napellus L.	
	Aloe vera (L.) Burm. f.	
	Alpinia galanga (L.) Sw.	
	Althaea officinalis L.	
	Berberis lycium Royle	
	Carthamus tinctorius L.	
	Cassia absus L. (=Chamaecrista absus (L.) H. S. Irwin & Barneby)	
	Centella asiatica (L.) Urb.	
	Colchicum luteum Baker	
	Cuscuta reflexa Roxb.	
	Fumaria indica (Hausskn.) Pugsley	
	Hygrophila spinosa And.	
	Hyoscyamus niger L.	
	Lactuca sativa L.	
	Lavandula stoechas L.	
	Merendera persica Boiss	
	Nepeta ruderalis Hamilt.	
	Nymphaea lotus L.	
	Ocimum basilicum L.	
	O. americanum var. *pilosum* (Willd.) A. J. Paton	
	Pimpinella anisum L.	
	Plumbago zeylanica L.	
	Pongamia glabra Vent.	
	Prunus cydonia	
	Rubia cordifolia L.	
	Salvia spinosa L.	
	Swertia chirayita (Roxb. ex Fleming) H. Karst.	
	Trapa bispinosa Roxb.	
	Tribulus terrestris L.	
	Vetiveria zizanioides (L.) Nash	
	Withania somnifera (L.) Dunal	
	Zanthoxylum alatum Roxb.	

Table 5: Crude drugs exported from Pakistan

Botanical name	Part used	Voulme (tonnes)	Value US$ '000
Acacia nilotica (L.) Del.	Gum	857.07	52.84
Carum copticum L.	Fruit	9.90	0.06
Cuminum cyminum L.	Fruit	687.95	92.05
Ephedra spp.	Twig	64.95	4.87
Foeniculum vulgare Mill.	Fruit	316.65	67.09
Papaver somniferum L.	Seed	731.20	33.43
Rheum australe D. Don	Root	143.00	3.80
Ricinus communis L.	Seed	693.70	445.28
Valeriana jatamansi Jones	Rhizome	346.32	67.72

Table 6: Medicinal plants imported despite their availability

Botanical name	Part used	Quantity imported per annum (tonnes)	Country	Availability source in Pakistan
Asparagus adscendens Roxb.	Root	7.5	India, Thailand	Swat, Dir
Asparagus racemosus Willd.	Root	8.0	India	Swat, Buner
Carum copticum (L.) C. B. Clarke	Fruit	21.0	India, China	Swat, Chitral
Senna alexandrina Mill. (= *Cassia aungustifolia* Vahl)	Fruit	3.7	India, China	Cultivated
Cichorium intybus L.	Seed	14.8	India, Indonesia	Swat, Dir, Buner
Colchicum autumnale L.	Root	3.7	India, China	Kashmir
Cuminum cyminum L.	Fruit	4.6	India	Swat, Dir
Ferula foetida (Bunge) Regel	Gum	3.8	Afghanistan	Chitral
Glycyrrhiza glabra L.	Root	1.2	China	Chitral
Lavandula stoechas L.	Root	1.2	India	Swat
Myristica fragrans Houtt.	Root	4.0	India	Swat
Plantago major L.	Seed	11.1	India, China	Cultivated
Polygonatum multiflorum (L.) All.	Root	8.5	Afghanistan	Swat, Chitral
Quercus infectoria Olivier	Seed	4.1	Iran	Not available
Withania somnifera (L.) Dunal	Seed	3.8	China, India	Swat, Buner
Ziziphus jujuba Mill.	Fruit	4.0	India	Swat, Buner

Essential Oils and Spices

Consumption of essential oils has been estimated at 86,000 kg/year. Anise, caraway, coriander, fennel, lavender, spearmint, peppermint, rosemary, eucalyptus, lemon and orange oil are used in significant quantities. Pakistan is also a prominent user of spices and in 1998 imported 22,336 tonnes of spices valued over US$ 22.39 mn.[1]

Public Awareness and Information

Efforts have been initiated to identify the ethnomedical use of medicinal plants and to popularize them. In 1997, the UNDP sponsored the Baltistan Herbal, Medicinal and Aromatic Plants Project through an NGO to record the use of medicinal plants in the northern areas of Pakistan.[8] Three postage stamps carrying images of *Datura stramonium* L., *Plantago ovata* Forssk. and *Glycyrrhiza glabra* L. indicate the will of the government of Pakistan to popularize the use of medicinal plants and create awareness among the general public.[9]

Pakistan has recently imposed a quantitative ban on the import of Unani, Ayurvedic and other herbal drugs in order to encourage their indigenous production. To ensure quality and safety of herbal drugs, action was taken against a number of manufacturing units for non-compliance with good manufacturing practices.

Research on Medicinal Plants in Pakistan

A number of national institutes, departments, universities and laboratories are involved in the research projects on medicinal plants. The International Centre for Chemical Sciences (HEJ) Research Institute of Chemistry, University of Karachi; the Pakistan Council of Scientific and Industrial Research (PCSIR) Laboratories at Peshawar, Lahore and Karachi; the National Institute of Health; the Pakistan Forest Institute, Peshawar; the National Agricultural Research Center, Islamabad (Plant Genetic Research Center and National Herbarium); the Pakistan Agricultural Research Council, Hamdard University, Karachi; and the chemistry, pharmacy and botany departments of various universities have actively contributed to the R&D projects. The Pakistan Council of Scientific and Industrial Research has undertaken standardization of herbal drugs and 135 commonly used drugs have been analyzed for various parameters. A database is in an advanced stage of compilation at the National Agricultural Research Centre, Islamabad for dissemination of information on medicinal plants. *In situ* conservation of medicinal and aromatic plants seeds have recently been initiated at the Plant Genetic Resource Institute (PGRI), National Agricultural Centre, Islamabad. A special chamber, the Hakim Mohammad Saied Chamber, has been established for preservation of the germplasm.

Significant research leads have been obtained with respect to processing, agro-technology and product development from *Andrographis paniculata* (Burm. f.) Wall. ex Nees, *Artemisia annua* L., *Boswellia serrata* Roxb. ex Colebr., *Centella asiatica* (L.) Urb., *Coleus forskohlii* (Poir.) Briquet, *Commiphora wightii* (Arn.) Bhandari, *Curcuma longa* L., *Phyllanthus amarus* Schu. & Thonn., *Picrorhiza kurrooa* Royle ex Benth., *Sida rhombifolia* L., *Taxus baccata* L. and *Withania somnifera* (L.) Dunal. The propagation techniques for *Acorus calamus* L., *Atropa acuminata* Royle ex Lindl., *Digitalis lanata* Ehrh., *Digitalis purpurea* L., *Dioscorea deltoidea* Wall. ex Griseb., *Podophyllum hexandrum* Royle, *Rheum australe* D. Don, *Saussurea costus* (Falc.) Lipsch. and *Valeriana jatamansi* Jones have also been developed in the country. Further research efforts for propagation, cultivation, processing and marketing techniques for more plants are under way.

Problems and Constraints

In Pakistan, the complete inventory of the flora has not yet been completed. Most of the medicinal plant material is collected from the wild and cultivation satisfies only a very small portion of the market. No attention is being paid to the systematic cultivation and collection of medicinal plants, and no authentic data is available on trade, etc. Many of the medicinal plant species of commercial importance are becoming extinct due to over-harvesting and extensive destruction of plant-rich habitats. The local communities do not have active involvement in genetic resources management. Indigenous knowledge on identity, efficacy and utility of medicinal plants is dying out and no systematic documentation of ethnobotanic information exists. There is a lack of reliable data on species of medicinal plants that need conservation. Many conservation efforts have been carried out but poor management and enforcement have led to continuation of over-harvesting of medicinal plant species under threat. *Ex situ* conservation of medicinal plant resources

does not exist, while *in situ* conservation is still in infancy. Most R&D institutes are either inadequately equipped or do not have sufficient human or financial resources.

Conclusions

Pakistan has great potential to increase its share in both national as well as international markets through sustainable harvesting of medicinal plant resources and value addition to their products. The documentation, developing electronic database, holding information on collection, trade and conservation status and establishment of a National Herbarium of economically important plants can solve the problems of loss of biodiversity and ethno-medical information. There is an urgent need for training of collectors of medicinal plant material in both sustainable harvesting and post-harvest care of the produce. Suitable monitoring to control over-harvesting of resources, trade monopolies and unethical practices in trade can play an important role in the promotion of medicinal plant sector in the country. Public awareness and educational material should be developed in local languages to inform communities and collectors about the occurrence of medicinal plants, their market values, medicinal importance, threat faced by specific medicinal plant species and the legal status of their collection and uses. There should be community participation in resource management.

The cost-effective appropriate agro-technologies should be developed for value addition and manufacture of finished products. Small processing units should be established in areas where wild medicinal plant resources are abundant.

For sustainable production in the medicinal plants sector, it is important to consolidate information bases, assess international and national markets and supply resources of the country, implement large-scale cultivation projects, and save the priority species of medicinal plants. The country needs an extension of research efforts into plantation and production, and development of a system of institutional linkages amongst R&D organizations working in the medicinal and aromatic crop sector.

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Chapter 4
The Status of Medicinal and Aromatic Plants in Indonesia

by Bambang Mursito, Karan Vasisht and Vishavjit Kumar

Introduction

Indonesia is an unique country of 17,000 islands. It is the world's second largest megacentre of biodiversity after Brazil and home for about 90% of medicinal plant species found in Asia. Indonesian traditional medicine is the two-fold result of biodiversity and cultural diversity. The country population mainly relies on traditional medicine for their health-care needs. The rich biodiversity provides a sound base for future export development of medicinal plants and their products. The Indonesian government is promoting sustainable utilization of its medicinal plant resources both to provide better health care for its people and to promote export.

Traditional Systems of Medicine

There are many different varieties of traditional medicine practised in Indonesia, all associated to a greater or lesser extent with the different ethnic groups and the historical developments that have shaped the nation. Traditional medicine provides an important source for self-care within the health services. In general, about 40% of Indonesians use herbal drugs for different purposes. There were 281,492 practitioners of traditional medicine in 1995, and about 96% of them made use of traditional Indonesian methods of treatment.[1,2]

The Indonesian Health Law Act of 1992 emphasizes the need for supervision of traditional medicine to ensure safety and efficacy. It also supports the development and improvement of traditional medicine in order to fulfil the goal of providing good health to its people. The Act classifies traditional medicine into two groups.

The first group comprises Jamu medicines, which include the natural medicines constituting either crude drugs or galenical preparations, whose efficacy is entirely based on experiences but does not comply with the formal minimum requirements. Jamu medicines are produced by individual persons or by households. These medicines need not be registered, labelled or marked except with the empirical name. The Ministry of Health is

giving assistance to producers of these medicines to ensure product quality. It is the oldest, most widespread and best-understood system of traditional medicine in the country, known to have originated in Java, and probably dating back to the late eighth or early ninth century.[3] Over the course of time, the use of Jamu medicines spread to the whole island of Java, Bali and many neighboring islands. This dissemination was greatly furthered by the policy of resettlement, which dates back to the period of Dutch colonial rule. Today, the Jamu system of medicine plays a decisive role in national health care and is its important constitutent. It also plays a major role in the economy of the rural people. Some medicinal and aromatic plant species approved for use in the Jamu system are given in Table 1.[4]

The second group is phytopharmaca, which includes natural medicines, constituting either crude drugs or galenical preparations, with guaranteed safety and efficacy. Their efficacy is tested and quality parameters comply with the specified standards. The Ministry of Health has distributed a publication on "Guidance for Clinical Trial of Traditional Drug" to help the manufacturers fulfil these requirements. Guidelines for Good Manufacturing Practice (GMP) for herbal medicine, extraction of plants and performance of clinical tests on herbal medicine have also been issued in Indonesia. Some medicinal and aromatic plant species approved for development as phytopharmaca are given in Table 2.[4]

Table 1: Some medicinal and aromatic plant species approved for use in Jamu medicine

Botanical name	Family	Common name	Part(s) used
Abelmoschus moschatus Medik.	Malvaceae	Musk mallow	Root
Abrus precatorius L.	Fabaceae	Indian licorice	Leaf
Achillea millefolium L.	Asteraceae	Yarrow	Leaf
Acorus calamus L.	Acoraceae	Sweet flag	Rhizome
Aegle marmelos (L.) Corr.	Rutaceae	Bael tree	Leaf
Aglaia odorata Lour.	Meliaceae	Chulan	Leaf
Aleurites moluccanus (L.) Willd.	Euphorbiaceae	Candle nut	Seed
Allium cepa L.	Liliaceae	Onion	Bulb
Allium sativum L.	Liliaceae	Garlic	Bulb
Aloe vera (L.) Burm. f.	Liliaceae	Aloe	Stem
Alstonia scholaris (L.) R. Br.	Apocynaceae	Milky pine	Bark
Alyxia reinwardtii Bl.	Apocynaceae	Pulasari	Bark
Amomum cardamomum L.	Zingiberaceae	Kapol	Fruit
Anacardium occidentale L.	Anacardiaceae	Cashew	Leaf
Andrographis paniculata (Burm. f.) Wall. ex Nees	Acanthaceae	King of bitters	Whole herb
Anisum vulgare Gaertn.	Apiaceae	Anise	Fruit
Annona muricata L.	Annonaceae	Soursop	Leaf
Apium graveolens L.	Apiaceae	Celery	Fruit
Aquilaria malaccensis Lam.	Thymelaeaceae	Agarwood	Wood
Arcangelisia flava (L.) Merr.	Meispermiaceae	Kikoneng (liana)	Leaf, stem, flower
Areca catechu L.	Arecaceae	Betel nut palm	Seed
Artemisia vulgaris L.	Asteraceae	Mother wort	Whole herb
Averrhoa bilimbi L.	Oxalidaceae	Cucumber tree	Leaf
Averrhoa carambola L.	Oxalidaceae	Goose berry	Flower
Baeckea frutescens L.	Myrtaceae	False ru	Fruit

Continued

Botanical name	Family	Common name	Part(s) used
Blumea balsamifera (L.) DC.	Asteraceae	Blumea camphor	Leaf
Boesenbergia pandurata (Roxb.) Schltr.	Zingiberaceae	Black gallingale	Rhizome
Brassica alba (L.) Rabenh.	Brassicaceae	-	Seed
Caesalpinia sappan L.	Fabaceae	Sappan wood	Wood
Cananga odorata Hook. f. & Th.	Annonaceae	Ylang-ylang	Flower
Capsicum annuum L.	Solanaceae	Chilli	Fruit
Carica papaya L.	Caricaceae	Papaya	Leaf
Carthamus tinctorius L.	Asteraceae	Safflower	Flower
Carum copticum (L.) C.B. Clarke	Apiaceae	Ajowan	Fruit
Cassia alata L.	Fabaceae	-	Leaf
Cassia angustifolia Vahl	Fabaceae	Senna	Leaf
Centella asiatica (L.) Urb.	Apiaceae	Gotu kola	Whole herb
Cinchona calisaya Wedd.	Rubiaceae	Cinchona tree	Bark
Cinnamomum burmanni (Nees & T. Nees) Bl.	Lauraceae	Cinnamon	Bark
Cinnamomum sintoc Bl.	Lauraceae	Sintok	Bark
Cinnamomum zeylanicum Bl.	Lauraceae	-	Bark
Citrus aurantiifolia (Christm.) Swingle	Rutaceae	Sour lime	Fruit
Citrus hystrix DC.	Rutaceae	Kaffir lime	Fruit
Cocos nucifera L.	Arecaceae	Coconut	Oil
Cola nitida (Vent.) Schott & Endl.	Sterculiaceae	Kola	Seed
Coleus atropurpureus L.	Lamiaceae	Ati-ati	Leaf
Coriandrum sativum L.	Apiaceae	Coriander	Fruit
Cucurbita moschata Duch.	Cucurbitaceae	Pumpkin	Seed
Curcuma aeruginosa Roxb.	Zingiberaceae	Temu hitam	Rhizome
Curcuma domestica Vahl	Zingiberaceae	Turmeric	Rhizome
Curcuma heyneana Vahl & Zyp.	Zingiberaceae	Temu giring	Rhizome
Curcuma xanthorrhiza Roxb.	Zingiberaceae	Javanese turmeric	Rhizome
Cymbopogon citratus (DC.) Stapf	Poaceae	Lemon grass	Leaf
Cyperus rotundus L.	Cyperaceae	Nutgrass	Rhizome
Datura metel L.	Solanaceae	Thorn apple	Leaf
Desmodium triquetrum (L.) DC.	Papilionaceae	Daun duduk	Leaf
Dioscorea hispida Dennst.	Dioscoreaceae	Asiatic bitter yam	Rhizome
Elaeocarpus grandiflorus Smith.	Elaeocarpaceae	Anyang-anyang	Fruit
Elephantopus scaber L.	Asteraceae	Prickly leaved elephants foot	Leaf
Elettaria cardamomum (L.) Maton	Zingiberaceae	Cardamom	Fruit
Equisetum debile Roxb. ex Vaucher	Equisetaceae	Geges otot	Whole herb
Euchresta horsfieldii Bennett	Fabaceae	-	Seed
Eugenia cumini (L.) Druce	Myrtaceae	Java plum	Fruit
Euphorbia hirta L.	Euphorbiaceae	Australian asthma weed	Whole herb
Ficus septica Burm. f.	Moraceae	Fig of Java	Flower
Foeniculum vulgare Mill.	Apiaceae	Fennel	Fruit, seed
Glycyrrhiza glabra L.	Fabaceae	Mulathi	Root
Graptophyllum pictum (L.) Griff.	Acanthaceae	Caricature plant	Leaf
Guazuma ulmifolia Lam.	Sterculiaceae	Bastard cedar	Leaf
Gunnera macrophylla Bl.	Melastomaceae	Sukmo	Fruit
Helicteres isora L.	Sterculiaceae	Kayu ules	Fruit
Hibiscus rosa-sinensis L.	Malvaceae	Shoe flower	Leaf
Imperata cylindrica (L.) P. Beauv.	Poaceae	Cogon grass	Rhizome
Jasminum sambac (L.) Ait.	Oleaceae	Arabian jasmine	Flower
Kaempferia galanga L.	Zingiberaceae	Galangal	Rhizome

Continued

Botanical name	Family	Common name	Part(s) used
Languas galanga (L.) Stunz.	Zingiberaceae	Greater galangal	Rhizome
Litsea cubeba (Lour.) Pers.	Lauraceae	May chang	Bark
Litsea odorifera Vahl	Lauraceae	Trawas	Leaf
Loranthus sp.	Loranthaceae	Oak mistletoe	Stem
Melaleuca leucadendra (L.) L.	Myrtaceae	Cajeput	Leaf
Melastoma malabathrichum L.	Melastomataceae	Singapore rhododendron	Leaf
Mentha arvensis L.	Lamiaceae	Mint	Whole herb
Merremia mammosa (Lour.) Hall. f.	Convolvulaceae	Bidara upas	Tuber
Mesua ferrea L.	Clusiaceae	Iron wood	Flower
Momordica charantia L.	Cucurbitaceae	Bitter gourd	Fruit
Morinda citrifolia L.	Rubiaceae	Indian mulberry noni	Leaf
Murraya paniculata (L.) Jack.	Rutaceae	Chinese murtle	Leaf
Myristica fragrans Houtt.	Myristicaceae	Nutmeg tree	Seed
Nigella damascena L.	Ranunculaceae	Jintan manis	Seed
Nyctanthes arbor-tristis L.	Verbenaceae	Srigading	Flower
Ocimum basilicum L.	Lamiaceae	Sweet basil	Leaf
Ocimum sanctum L.	Lamiaceae	Holy basil	Leaf
Orthosiphon stamineus Benth.	Lamiaceae	Java tea	Leaf
Oryza sativa L.	Poaceae	Rice	Grain
Parkia roxburghii G. Don	Fabaceae	African locust bean	Seed
Phaseolus vulgaris L.	Fabaceae	Kidney bean	Seed
Phyllanthus niruri L.	Euphorbiaceae	Stone breaker	Whole herb
Physalis minima L.	Solanaceae	Morel berry	Leaf
Piper betle L.	Piperaceae	Betel pepper	Leaf
Piper cubeba L. f.	Piperaceae	Cubeb	Fruit
Piper nigrum L.	Piperaceae	Black pepper	Fruit
Piper retrofractum Vahl	Piperaceae	Javanese long pepper	Fruit
Plantago major L.	Plantaginaceae	Ribwort	Leaf
Plectranthus scutellarioides (L.) R. Br.	Lamiaceae	Iler	Leaf
Pluchea indica Less.	Asteraceae	Beluntas	Leaf
Psidium guajava L.	Myrtaceae	Guava	Leaf
Punica granatum L.	Lythraceae	Pomegranate	Bark
Quisqualis indica L.	Combretaceae	Chinese honeysuckle	Seed
Rafflesia patma Bl.	Rafflesiaceae	-	Flower
Raphanus sativus L.	Brassicaceae	Radish	Root
Rauvolfia serpentina (L.) Benth. ex Kurz	Apocynaceae	Pule pandak	Root
Rheum officinale Baill.	Polygonaceae	-	Root
Ruta graveolens L..	Rutaceae	Rue	Leaf
Saccharum officinarum L.	Poaceae	Sugarcane	Stem
Santalum album L.	Santalaceae	Sandalwood	Wood
Sauropus androgynus (L.) Merr.	Euphorbiaceae	Sweet leaf bush	Leaf
Sesamum orientale L.	Pedaliaceae	Sesame	Leaf
Sesbania grandiflora (L.) Pers.	Fabaceae	Cook wood tree	Bark
Sonchus arvensis L.	Asteraceae	-	Leaf
Sterculia foetida L.	Sterculiaceae	Stink malve	Leaf
Strobilanthes crispus Bl.	Acanthaceae	-	Leaf
Symplocos odoratissima Choisy	Symplocaceae	-	Bark
Syzygium aromaticum (L.) Merr. & L.M. Perry	Myrtaceae	Clove	Flower
Tamarindus indica L.	Fabaceae	Tamarind tree	Fruit
Thea sinensis L.	Theaceae	Tea	Leaf
Tinospora crispa Hook. f. & Thumb.	Menispermaceae	Putrawali	Leaf

Continued

Botanical name	Family	Common name	Part(s) used
Usnea barbata (L.) Wigg.	Usneaceae	Dung of the wind	Thallus
Vetiveria zizanioides (L.) Nash	Poaceae	Vetiver grass	Leaf, root
Vitex trifolia L.	Lamiaceae	Indian wild pepper	Leaf
Woodfordia fruticosa (L.) Kurz	Lythraceae	Sidawayah	Flower
Zingiber amaricans Bl.	Zingiberaceae	-	Rhizome
Zingiber officinale Rosc.	Zingiberaceae	Ginger	Rhizome
Zingiber purpureum Rosc.	Zingiberaceae	-	Rhizome
Zingiber zerumbet (L.) Smith.	Zingiberaceae	-	Rhizome

Table 2: Some medicinal and aromatic plant species approved for development as phytopharmaca

Botanical name	Common name	Part(s) used	Indication(s) and therapeutic categories
Abrus precatorius L.	Saga telik	Leaf	Stomatatis aphtosa
Acorus calamus L.	Dringo	Rhizome	Sedative
Allium sativum L.	Bawang puith	Rhizome	Candidiasis, hypolipidemic
Anacardium occidentale L.	Jambu mede	Leaf	Analgesic
Andrographis paniculata (Burm. f.) Wall. ex Nees	Sambilata	Whole herb	Antiseptic, antidiabetic
Apium graveolens L.	Seledri	Whole herb	Hypotensive
Blumea balsamifera (L.) DC.	Sembung	Leaf	Analgesic, antipyretic
Carica papaya L.	Pepaya	Latex, leaf, seed	Antimalarial, male contraceptive
Centella asiatica (L.) Urb.	Pegagan	Leaf	Diuretic, antiseptic, hypotensive
Citrus aurantiifolia (Christm.) Swingle	Jeruk nipis	Fruit	Antitussive
Cucurbita moschata Duch.	Labu merah	Seed	Taeniasis
Curcuma domestica Vahl	Kunyit	Rhizome	Chronic hepatitis, antiarthritic, antiseptic
Curcuma xanthorrhiza Roxb.	Temulawak	Rhizome	Chronic hepatitis
Graptophyllum pictum (L.) Gritt.	Handeuleum	Leaf	Haemorrhoids
Guazuma ulmitolia Lam.	Jati blanda	Leaf	Hypolipidemic
Loranthus sp.	Benalu teh	Stem	Anticancer
Momordica charantia L.	Pare	Fruit	Antidiabetic
Myristica fragrans Houtt.	Pala	Fruit	Sedative
Orthosiphon stamineus Benth.	Kmis kucing	Leaf	Diuretic
Piper betle L.	Sirih	Leaf	Antiseptic
Psidium guajava L.	Jambu biji	Leaf	Antidiarrhoeal
Punica granatum L.	Delima putih	Fruit pericarp	Antiseptic
Quisqualis indica L.	Ceguk	Seed	Ascariasis
Ruta graveolens L.	Inggu	Leaf	Antiseptic, antipyretic
Sonchus arvensis L.	Tempuyung	Leaf	Nephrolitiasis, diuretic
Sauropus androgynus (L.) Merr.	Katuk	Leaf	Breast milk stimulator
Strobilanthes crispus Bl.	Kejibeling	Leaf	Nephrolitiasis, diuretic
Tinospora crispa Hook. f. & Thumb.	Brotowali	Stem	Antimalarial, antidiabetic
Vitex trifolia L.	Legundi	Leaf	Antiseptic
Woodfordia floribunda Salisb.	Sidowayah	Leaf	Antiseptic, diuretic
Zingiber officinale Rosc.	Jahe	Rhizome	Analgesic, antipyretic, anti-inflammatory

As per health laws, the Indonesian government follows the modern treatment system in its National Health System, but alternative treatments are not forbidden. Over the last five years, the increased acceptability of herbal medicines among medical doctors, as a result of their scientific validation for safety and efficacy, has significantly increased the use of herbal medicine in the country.

In accordance with the 1993 Guidelines of State Policy, the state efforts for health and traditional medicine have been strengthened within the framework of national health care legislation.[5] Traditional birth attendants are permitted to practise without registration or licence.[6] The Centre for Traditional Medicine Research, under the Ministry of Health and Social Welfare, is responsible for imparting training in traditional medicine.

State Efforts in Development of Traditional Systems

The achievement of health for all is the ultimate goal of Long Term Health Development Programme of the National Health System of Indonesia. The objectives and goals of the programme embedded in the National Health System have been formulated into five objectives for health (Panca Karsa Husada) including: improvement of people's ability to help themselves in the field of health; improvement of living environment, which can guarantee health; improvement of community nutritional status; reduction of morbidity and mortality rates; and development of health and family welfare by increased acceptance of the norms of the small and happy family. To attain these objectives, the following five operational policies of health have been formulated:

- Improvement and stabilization of health care;
- Development of health workers;
- Supervision, supply and control of drug, food and hazardous substances;
- Improvement of nutrition and health environment; and
- Improvement and stabilization of management and law.

In relation to the third operational policy, the National Drug Policy in the National Health System provides guidance for all activities in the field of drugs. One of the goals of the policy is to exploit the national potential to support the economic development and achievement of self-reliance in the drug sector.

During the two five-years development periods, 1988 and 1993, efforts have been made by the government of Indonesia for effective implementation of the policy for development of the traditional medicine industry by sustainable utilization of the resources. The efforts included modernization of diagnostic procedures and production processes including quality control of traditional medicines. Diagnosis through modern techniques and treatment through traditional medicines has been promoted. The introduction of GMP and development of a registration system and quality specifications for widely used herbal materials and preparations has ensured the quality standards of herbal medicines. Various guidelines and regulations have been issued for production and for quality control of traditional medicine. It also provides assistance and guidance for the development of traditional medicine.

To encourage the use of Indonesian medicinal plants in the formal health sector, the government has assigned a state enterprise, the National Agency of Drug and Food Control, to perform the duties of controlling the quality and safety of each herbal drug newly developed and marketed on the national or international market.

The standardized medicinal plant products classified as phytopharmaca will be gradually introduced in the formal medication in hospitals, public health centres and at other levels. In the late 1990s, the government had prepared phase-by-phase 12 phytopharmaca testing centres for pre-clinical and clinical trial in 12 provinces of Indonesia.

With regard to supply of raw material, the National Planning Development Agency (BAPPENAS) has carried out the coordination among technical departments to encourage the production of medicinal plants.

The domestication plan for potential medicinal and aromatic herbs is the top priority of the government in order to provide sustained supply of raw material to industry and conserve species of medicinal value.

Medicinal Plants of Indonesia

Indonesia, the second largest centre of biodiversity can be placed in first position if marine biodiversity is also taken into consideration. About 80% of the global medicinal plant resources are found in the Indonesian tropical forests spreading over 143 mn hectares.[7] More than 40 mn Indonesians depend directly on biodiversity making use of about 6,000 plant species.[8,9] Indonesia is a tropical country with abundant natural resources of medicinal and aromatic plants. According to the Indonesian Country Study on Biodiversity (ICSBD) estimate, 25,000 to 30,000 species of flowering plants exist in the country of islands.[10] Some 10% of the total Indonesian flora is thought to possess medicinal value.[11] According to the Indonesian Food and Drug Administration (Badan Pengawas Obat dan Makanan, BPOM), 283 species of medicinal value have been registered and are used by the society as traditional medicine.[7] Also, many plants that are useful for medicinal purposes have been imported together with details of their uses.

Most of the medicinal plants material are sourced from wild collections and very few come from cultivation. The medicinal plant species cultivated in the country include *Cinchona* spp., *Bupleurum falcatum* L., *Piper nigrum* L. and *Tanacetum cinerariifolium* (Trevir.) Sch. Bip. The cultivation methods are traditional except for *Cinchona* spp., which are grown in estates[12]. Pyrethrum (*Tanacetum cinerariifolium* (Trevir.) Sch. Bip.) is grown at higher altitudes such as Irian Jaya province, a promising cultivation area.

Some plants have been extensively used and over-exploited and include *Altsonia scholaris* (L.) R. Br., *Alyxia reinwardtii* Bl., *Pimpinella pruatjan* Molkenb., *Rauvolfia serpentina* (L.) Benth. ex Kurz and *Strychnos ligustrina* Bl. Unsustainable collection from the wild has endangered their existence.

Current Situation and Problems

In promoting the use of medicinal herbs as drugs, the present situation and problems should be taken into consideration.

Population and Social Health Care

In 2000, the total Indonesian population was about 210 mn, and about 80% of it was rural-based. The estimates of July 2001 put the country population at 228 mn, counting more than 336 different cultures speaking over 250 languages.[13] Each group has its traditions and knowledge of use of medicinal plants. For example, Melayu tribes have amassed knowledge on 182 medicinal plants used as remedies for 45 diseases, Talang Mamak tribe on 110 medicinal plants for 58 health problems and Aanak Dalam tribe on 101 medicinal plants for 54 types of diseases.[7]

Much effort has been made by the state to spread awareness about health care through health centres but to date the benefits of these activities have not yet reached the entire population. The poverty of the people (illustrated by low literacy rate, income and per capita consumption) is the major obstruction to improvement of people's ability to participate in health development programmes.

Medicinal herbs have been used since ancient times, and there is a tendency to increase their use. According to the Ministry of Health, the utilization of herbal medicine by the people of Indonesia is 48.98% for preventive purposes, 22.47% for promotive reasons, 21.78% for curative use and the rest for birth control, personal care and promotion of beauty or sexual purposes.

Abundance of Natural Sources

Indonesia has abundant raw material for herbal medicine. The potency of flora, fauna or minerals used for drugs can be developed for promoting people's ability to participate in health development efforts. According to the National Drug Policy, medicinal herbs with proved efficacy should be carefully developed and utilized in social health care. The supply of herbal medicines for these purposes should be realized through dissemination and development of the family medicinal garden, and regulation, development and control of the production and distribution of medicinal herbs by the herbal industry.

Quality of Raw Material

Generally, medicinal herbs efficacy has not been scientifically proven in Indonesia. The utilization is still mainly based on traditional procedures. It is therefore hard to ensure safe use of medicinal herbs by the people. In relation to effectiveness and efficiency of medicinal herbs, research efforts should be carried out on safety, efficacy and quality of products.

In order to produce quality herbal medicines, the production and distribution processes should comply with the principles of GMP. Efforts should be made to conserve natural drug resources in the wild and bringing them under cultivation. With regard to medicinal plants to be cultivated, research needs to be carried out to cultivate the medicinal plants to give best product quality.

Quality of Herbal Product

The country lacks the support of research and technology for efficient utilization of medicinal plants and their products. The government is responsible for controlling herbal medicines, which are useful and have a role in the realization of health care. Considering the situation and problems faced for achieving the drug development, the government should accomplish all efforts in the field of traditional medicines. Policies or valid regulations are yet to be compiled. Research needs to be strengthened especially to support the development of herbal drug material and to increase the utilization of herbal medicines in social health care.

Research Activities in Medicinal Plants

The research on plants used by indigenous people has a long history, ranging from Heyne's classical publication *De Nuttige Planten Van Indonesie* to the modern publications on the medicinal herbs of Indonesia by P. T. Eisai, and by the Plant Resources of South-East Asia (PROSEA) in Bogor. The commercialization of Jamu medicines is an indicator of interest in traditional herbal medicine in Indonesia.

Many universities and research institutes as well as non-governmental organizations (NGOs) are involved in handling the traditional medicine sector in Indonesia. The cooperative companies affiliated to large-scale herbal industries undertake the production of raw material. The NGOs deal with popularization of planting of medicinal plants for families in home gardens and ensure supply of herbal material to the cooperatives.

Almost all state and private universities conduct research on medicinal plants in branches like botany, phytochemistry, pharmacology, agronomy, microbiology and ecology. Statistics show that 490 species had been researched up until 1991, of which about 80% research concentrated on pharmacological and phytochemical aspects, 16% on the cultivation, and rest on post-harvest and other aspects.[3]

The Research Centre for Medicinal Plants in Bogor has conducted research on *Sauropus androgynus* (L.) Merr. as a breast milk stimulator and a medicinal product in capsule form has been produced by the production unit of the Centre. The Research and Development Centre for Biology has conducted research on cultivation of *Sonchus arvensis* L., *Curcuma zedoaria* (Christm.) Roscoe, *Plantago major* L., while the Technical Implementation Unit for Botanical Gardens of the Institute of Science and Technology (LIPI) studied the cultivation potential of *Alpinia purpurata* (Vieill.) K. Schum., *Gynura procumbens* (Lour.) Merr. and *Typhonium trilobatum* (L.) Schott. The Agency for Assess-

ment and Production of Technology has been exploring the benefits of *Morinda citrifolia* L. as a raw material for cosmetics, health drinks and pharmaceutical products. PT Indofarma in collaboration with Gadjah Mada University and PT Kalbe Farma, has discovered 10 derivatives of curcumin from *Curcuma longa* L., of which five have been patented in the USA and six in Europe.

The plants, which are proven effective, can be developed and utilized in health care. In this regard, some potential plants have been tested in pre-clinical and clinical trials. Research has shown that certain plant species can cure the disturbance of body functions in a disease state. The pre-clinical studies of extracts of *Phyllanthus niruri* L. showed immuno-stimulant activity, *Graptophyllum pictum* Griffith was anti-infective and analgesic and *Curcuma xanthorrhiza* Roxb. showed promising hepatotoxic activity.

Production and Utilization of Medicinal Plants

In Indonesia, both herbal drug industry and trade are developing significantly. They are expected to grow further as the government is interested in bringing expansion in both the sectors to earn more share of the global market. According to the data from Convention on Biological Diversity (CBD), the global market of herbal medicines has reached US$ 43 bn in the year 2000 and the Indonesian contribution to this was about US$ 100 mn.

The increasing use of traditional medicines has followed the expansion of traditional medicine industry. In 1992, there were 469 registered units (449 small and 20 large industries), which increased to 810 (723 small and 87 large industries) by 2000.[7] This increment was due to the growing consumption of herbal medicines, which increased significantly from about 6,052 (in 1995) to about 7,685 tonnes (in 2000). The annual growth rate between 25 to 30% is highly impressive. Traditional medicine industry was US$ 226.6 mn in 1994 with a sale turnover of US$ 30.3 mn.[14] The industry's revenue increased to approximately US$ 150 mn in 2000.[7] Herbal products such as Prolipid (cholesterol reducer), Prouric (uric acid reducer), Biofibra (slimming and natural fiber) produced by PT Indofarma (Persero) Tbk, Jakarta, Indonesia, have gained popularity on the domestic market.

The herbal medicine industry provides livelihood sources to about 1% of the Indonesian population. The annual demand of medicinal plant material was estimated between 9,000 to 10,000 tonnes during the 1990s.[3] The material was largely used by large, medium and small scale herbal industries. Small amounts were used by Jamu stands, small shops and walking vendors. Products for oral use as powder dominate the market, covering about 90% of the market as compared to pills, capsules and other dosage forms.

The demand for extracts has increased with public preference for more practical, modern and hygienic products. The production of extracts has been encouraged by the Indonesian government to support manufacture of products that can be used in formal medication. These phytopharmaca products are used in modern dosage forms of high

standards. In the efforts to produce modern medication products 31 plant species have been recommended by experts to be developed for various indications.

The Indonesian domestic market of Jamu raw materials and Jamu medicines is extremely competitive. The large firms dominate this sector with 70 to 75% of share while the medium and small firms, household Jamu manufacturers, and Jamu pedlars work to compete locally in the nationwide distribution. The export centres of raw materials and finished Jamu medicines operate at regional level.

Besides using medicinal and aromatic plants as raw material for manufacture of herbal medicine, some plants are also used for cosmetics and hydrotherapy, which are better known under the term sanitation per aqua (SPA). The plants containing volatile oils like cananga oil from *Cananga odorata* Hook. f. & Thoms., clove oil from *Syzygium aromaticum* (L.) Merr. & L. M. Perry and black pepper oil from *Piper nigrum* L. are used in the SPA and are becoming popular among the people of Indonesia.

Export of Medicinal and Aromatic Plants

Indonesian export figures for traditional medicines continue to rise dramatically. The volume of exported medicinal plants is relatively low. In 1993, the export value of medicinal plants from Indonesia was only US$ 24.33 mn.[14] With respect to aromatic plants, Indonesia is among the top essential oil and spice exporting countries. In 1987, the total export value of essential oils was US$ 31.03 mn with an annual growth rate of 15%.[15] Indonesia is estimated to possess 70 species of prospective aromatic plants, of which 37 have already been developed at various levels, but only 9 species were being utilized up until the late 1990s. The country mainly exports vetiver, cananga, citronella, patchouli, and clove oils. In 1995, it exported essential oils worth US$ 27 to 28 mn.[3]

Problems and Constraints

The Indonesian traditional medicine industry is facing many problems and complexities in its development. The technologies for cultivation, production and product development are lacking. R&D is inadequate. There are also inconsistencies in demand-supply and raw materials, and a lack of scientific literature to support the safety and efficacy of the traditional medicines. In addition, marketing is constrained by lack of standardization, inadequate scientific information to support the products, poor financial resources and insufficient market information. The Jamu system is closely interwoven with the traditional lifestyle that hinders its modernization.

The country faces problems of low educational levels and inadequate information reaching farmers and entrepreneurs. The production and processing of essential oils generally makes use of traditional equipment, resulting in inefficient quality control, production and packaging. Indonesia lacks the support of research for technology development and efficient utilization of resources. The research activities are fragmented and not product-oriented.

Conclusions

Indonesia is endowed with rich wealth of medicinal and aromatic plant resources. The use of traditional medicines for health care is common. The herbal drug industry is developing fast and export volumes are increasing significantly. There is a need to put more research effort into developing technologies for modernization of traditional medicine units. Medicinal plants as raw materials have a big potential for export from the country. Knowledge and experience of many Indonesian tribes should be documented and thoroughly researched, since they might introduce the world community to new drugs.

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Chapter 5
The Status of Herbal Products: the Case of East Africa

by Ermias Dagne

Introduction

The East African region covers the countries of Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Rwanda, Seychelles, Somalia, Sudan, Tanzania and Uganda. The region has a variety of vegetation ranging from dense montane tropical and rain forests to woodlands and dry savannahs. The montane forests of Kenya, Tanzania and western Uganda are abode to a large number of endemic plant species. About 40% floristic diversity in Tanzania is found in the montane forests. The world's centre of diversity of cultivated plants lies in Ethiopia, Somalia and Sudan.[1,2] Madagascar located off the southeastern coast of Africa is one of the world's most fascinating centres of plant diversity and endemism. It is home to highly threatened habitats of flora and fauna.

The plant resources of the region continue to be used in the health-care system as well as for flavour and fragrance purposes. These resources have the potential to serve as raw materials for the production of a variety of herbal products on industrial scale. A number of plants in the region possess chemical constituents with interesting biological properties. For instance, the anti-cancer maytansines from *Maytenus* and bruceantins from *Brucea* species were first discovered from East African plants. Many more unique plants are also found in the region.

It is obvious that African countries can benefit immensely if these resources are sustainably tapped through processing and value addition. There is therefore the need to intensify R&D efforts in medicinal and aromatic plants.

Traditional Systems of Medicine

Traditional medicine is both the dominant and the most popular system of health care in the region. About 80% of the population rely upon traditional medicine for their health-care needs. It is an affordable alternative health-care system for the rural population. Traditional medicine has been integrated to some extent in the national health-care systems of Uganda, Sudan and Rwanda. A legal framework for traditional medicine exists in Ethiopia, Madagascar and Eritrea. Ethiopia and Rwanda have national budget

allocations for development and popularization of traditional medicine. Associations of traditional medical practitioners exist in Ethiopia, Madagascar and Rwanda.[3]

Traditional medicine is also practised extensively in urban centres in most of the countries of the region. The local communities and traditional medical practitioners have deep knowledge of medicinal and aromatic plants which they use as remedies. The unfavourable ratio of modern medical doctors to patients is another reason why traditional medicine is preferred in all the countries of the region. Although traditional medicine plays a large role in primary health care, it is not yet effectively backed by science and technology.

Medicinal Plant Resources

The East African countries are endowed with rich resources of medicinal and aromatic plant species. About 1,200 species of medicinal and aromatic plants are used in Kenya, 600 in Ethiopia, 300 in Uganda, 151 in Somalia, 142 in Eritrea, 100 in Tanzania and 60 species in Sudan by the local communities and traditional medical practitioners.[4-8]

Most of the medicinal plant material supply comes from wild collections, while a few are cultivated. In Tanzania, *Cinchona* spp. are cultivated in commercial tea estates of southern highlands and new plantations of *Acacia nilotica* (L.) Delile, for increasing the gum Arabic production, have recently been established. Kenya and Tanzania are the world's largest suppliers of clove (*Syzygium aromaticum* (L.) Merr. & L. M. Perry) and pyrethrum (*Tanacetum cinerariifolium* (Trevir.) Sch. Bip.). Kenya is a major supplier of pyrethrum to the world market and has maintained a leading status since 1933 when it first started commercial production of pyrethrum. Pyrethrum is also a major cash crop in Rwanda. In Kenya, the lack of processing facilities coupled with adverse climatic conditions have resulted in the decline of pyrethrum production from 16,000 tonnes in 1992 to 6,000 tonnes in the year 2000, but even at this level production far exceeds any other country of the world. The production of pyrethrum in Tanzania has improved to 4,000 tonnes in 2000 from 2,220 tonnes in 1992.[9]

Over-harvesting and habitat destruction have threatened the existence of many plant species of medicinal and commercial importance. For example, 236 plant species are threatened in Tanzania, the most prominent being *Acacia farnesiana* (L.) Willd., *Xylopia aethiopica* (Dunal) A. Rich. and *Warburgia salutaris* (Bertol. f.) Chiov.

Research and Developmental Activities

Chemical studies not only contribute to advancing knowledge but also help in finding ways and means of adding value to natural products in the countries of origin so that the producing communities derive more benefits and therefore become more aware of the advantages of the sustainable utilization of these resources.

At present, many efforts are directed by the scientific community from Africa and elsewhere towards the study of the botany, chemistry and pharmacology of African plants and a considerable amount of information is now available in the literature.

Typically, most of the chemistry-oriented papers report isolation and characterization of novel compounds from the African flora. Other studies deal with the biological and pharmacological activities of crude extracts or isolated compounds. The selection of the plant for studies is based on folk medicine, commercial and chemotaxonomic significance and biological activity. In the biologically-oriented studies, workers usually attempt to establish if there is a scientific basis for the traditional medical claims regarding the plants.

Much of the chemical and other studies on African plants was conducted in the past in laboratories in distant lands. In many instances, this hindered continuous and thorough studies on many locally important plants. Although natural products research is carried out mainly at universities, some countries in East Africa have established research institutes that focus on integrating herbal remedies into health-care programmes. Prominent institutes include the Kenya Medical Research Institute (KEMRI), the National Therapeutics Institute of Uganda, the Institute of Traditional Medicine in Tanzania, the Madagascar Institute for Applied Research (IMRA) and the Ethiopian Health and Nutrition Research Institute (EHNRI).

One can follow progress of research in natural products by monitoring the literature with the aid of databases. Of the main databases that compile information on natural products and medicinal plants, the most important include Natural Product Alert (NAPRALERT), chemical abstracts, the Dictionary of Natural Products, and Beilstein abstracts. However, a large body of knowledge generated in Africa may not be cited in these or other databases.

This shortfall was considered when constructing the ALNAP (African Laboratory for Natural Products) Database. Relevant published and unpublished documents, monographs, dissertations, conference proceedings, etc., dealing with African plants are regularly entered in the ALNAP Database with title, authors, keywords, abstract, biological activity and geographic area. Information can be retrieved through a quick search, which is then transferred to a text format, saved, printed or transferred via e-mail. In 1995, there were only 1,000 entries in the database; in 2001 the records have exceeded 12,000.

As of September 2001, the ALNAP Database is on the Internet and managed by the National Information Services Corporation (NISC) of the United States of America (USA) through its branch in Grahams Town, South Africa. The ALNAP Database can be accessed along with 13 other databases such as the Commonwealth Agricultural Bureau (CAB) Health Database, and Medline at www.nisc.com. The NISC has plans to distribute the ALNAP Database on CD-ROM.

A quick search of the above databases in the assessment of the extent of research work on medicinal and aromatic plants in a given African country. A summary of one type of search is shown in Table 1. Hits from the ALNAP Database thus reflect the extent of work carried out on the biology, chemistry, pharmacology, ethnobotany, etc. of the plants of the respective African countries.

Table 1: Records in databases dealing with Eastern African countries

Country	Number of records		
	ALNAP Database (12,140 ref.) Focus: natural products	CAB Database (20,310 ref.) Focus: health	Other (14) Databases (ca. 500,000 ref.) Focus: various
Burundi	5	112	251
Comoros	2	29	39
Djibouti	1	37	45
Eritrea	4	16	37
Ethiopia	300	610	1,266
Kenya	235	1,183	2,078
Madagascar	131	340	495
Mauritius	15	64	105
Rwanda	50	139	416
Seychelles	2	26	76
Sudan	49	401	561
Tanzania	149	863	1,594
Uganda	29	525	1,116

Cultivation of Medicinal and Aromatic Plants

The enormous demand for medicinal and aromatic plants is generally met by indiscriminate harvesting of natural flora including those in forests. This is because the demand can no longer be met by traditional methods of supply. Such continued and indiscriminate use of wild plants accelerates the rate of their extinction. Furthermore, wild plants are often heterogeneous in terms of their active constituent content, thus leading to difficulties in assuring standardized quality. This problem can be alleviated if plants are cultivated and systematically processed and formulated before use.[10]

The cultivation of medicinal and aromatic plants is not yet developed in Africa, except for a few commercially exploited plants like pyrethrum and clove. On the other hand, the scarcity of drug plants is causing traditional healers and others to travel long distances to get them from the wild. Destructive harvesting practices to maximize collections for short-term commercial gains are driving several plant species to extinction. The increasing demand for medicinal plants and their requirement for high quality products clearly call for the need to cultivate and properly process these plants.

Value Addition and Processing

In most African countries, plant medicines are sold as crude drugs in medicinal plant markets with very little processing and value addition. Harvesting herbs with care, drying them under the shade, packaging and labelling them well, makes a considerable contribution to adding value to these products. Even the preliminary steps of processing and quality improvement such as sorting and cleaning are lacking in many countries of the region. It is therefore important that steps be taken to encourage establishment of enterprises that process and formulate herbal remedies. Such enterprises could play an important role in improving quality of medicinal plants.[11-13]

In Kenya, the International Centre for Insect Physiology and Ecology (ICIPE) is making notable attempts to manufacture and market herbal products. It has established a subsidiary company that produces and sells several neem-based products including neem oil, soap, powder and concentrate. Other products include natural honey, packaged attractively under the trade name "Eco-Honey". The company, in collaboration with the University of Nairobi (UOB), produces a cough remedy under the trademark "Naturub". It also undertakes studies in cooperation with other countries of Eastern Africa, including Tanzania, Uganda and Ethiopia, to produce natural insect repellants.

As a result of the simple process requirements for production of essential oils, many emerging and developing countries are engaged in this venture and derive considerable benefits from it. The area of essential oil production is an excellent entry point for the industry and is also one of the best ways of obtaining value-added products from plants. Essential oil production is carried out on a limited scale in East Africa. Enterprises and organizations in the region that are engaged in producing herbal products are shown in Tables 2 and 3.

Table 2: Some herb products and their producers in countries of Eastern Africa

Country	Manufacturer(s)	Products
Ethiopia	Essential Oils Research Centre (EORC), Addis Ababa	Essential oils of lemon grass, eucalyptus, palmarosa (each over 1 tonne per annum)
	Ariti Herbal Products, Addis Ababa	Essential oils of myrrh, frankincense, opopanax, eucalyptus (each 100 kg per annum); fennel, thyme, rosemary, ginger, clove, cinnamon (each 1 to 5 kg)
	Ethiopian Spice Factory, Addis Ababa KASSK Spices and Herb Extraction Factory PLC, Addis Ababa	Large scale production of oleoresin of ginger and red pepper
Kenya	Mount Kenya Herbs, Naromoru	Feverfew leaf (1,000 kg per annum), other medicinal plants
	International Centre for Insect Physiology and Ecology (ICIPE), Nairobi University of Nairobi (UOB), Nairobi	Naturub (relief from congestion, aches), neem powder, neem soap, neem solution, eco-honey, basil oil
	Pharmacy Department, UOB, Nairobi	Mupal (herbal medicine for stomach and duodenal ulcer)
	Kenya Industrial Research and Development Institute (KIRDI), Nairobi	Essential oils of myrrh, olibanum and opopanax (distillation capacity of 100-130 kg of raw material at a time)
	Vetochem Ltd., Nairobi	Essential oils from Kenyan resins
	Pyrethrum Board of Kenya, Nakuru	Pyrethrum products
	-	Rosin and turpentine from pine resins
Madagascar	The Madagascar Institute for Applied Research (IMRA), Antananarivo	Variety of herbal products
Sudan	Gum Arabic Co. Ltd., Khartoum	Largest supplier of unprocessed gum Arabic

Trade and Marketing

African medicinal and aromatic plants have high local, national and global importance. The annual combined value of medicines and other non-wood forest products in Uganda has been estimated at about US$ 40 mn.[14] Most of the medicinal plant material is used in traditional remedies and some exported oversees. In addition to clove and pyrethrum, the major medicinal plant species exported are pygeum (*Prunus africana*

(Hook. f.) Kalkman) and the pepperbark tree (*Warburgia salutaris* (Bertol. F.) Chiov.), mainly to European Union (EU) countries.

Table 3: Some herb products and their producers in countries of Central Africa

Country	Manufacturer(s)	Products	Annual processing capacity (kg)
Zimbabwe	Essential Oil	Tea tree oil	3,000
		Eucalyptus oil	2,000
	Four Seasons, Harare	Coriander, lavender, marjoram, basil essential oils	100
Malawi	Pirimiti Trading Services, Blantyre	Baobab, tamarind, sausage tree, and moringa seed	500
	Private producers	Lemon balm oil	1-5
Zambia	Qiensabe, Lusaka	Rosemary	500
		Lemon grass oil	500

Sudan is the world's largest supplier of gum Arabic to the international market. In 2001, Sudan exported 18,984 tonnes of gum Arabic worth US$ 19.8 mn to the international market. Sudan also exports significant quantities of medicinal plant material to the world market. The average annual export of medicinal and aromatic plants from Sudan was worth US$ 10 mn during 1995 to 1999. The export of plants for herbal teas, excluding mint leaves, to the USA, was worth US$ 0.26 mn in 1997. The export of plant and plant parts for perfumery, medicaments and insecticidal, fungicidal or similar purposes to EU countries was worth US$ 4.5 mn. Most of the crude drugs go to Germany, the UK and Italy.[15, 16]

Somalia is the world's largest exporter of myrrh, opopanax resins and beyo and maidi brands of olibanum resins. Gum Arabic and olibanum are the major items of export from Eritrea. Madagascar exports significant quantities of *Prunus africana* (Hook. f.) Kalkman, *Catharanthus roseus* (L.) G. Don, *Centella asiatica* (L.) Urb., *Voacanga africana* Stapf and *Rauvolfia vomitoria* Afzel to the world market.

Future Directions

The following measures need to be taken to develop the herbal industry in the countries of East Africa. Focus should lie on processing resources that are abundantly available and now exported in raw form. Much attention should be given to African plants that enjoy extraordinary worldwide demand but for which the resource base is being depleted. African industries should focus on such species and invest in R&D in order to find ways and means for their conservation and sustainable utilization. The introduced species that do well in Africa should also be widely cultivated and utilized. For instance, clove and pyrethrum are not indigenous to Africa, but have been introduced in the region, with Tanzania and Kenya as the world's largest suppliers of these two species. Successful attempts in product formulation and utilization of pyrethrum have been made in Kenya, where the Pyrethrum Bureau runs a Research Centre and publishes a regular scientific journal, the *Pyrethrum Post*. Likewise, *Pinus* species originally from America, are now

cultivated in some African countries and the resin is processed in Kenya for production of rosin and turpentine.

Ways and means should also be sought to use herbal remedies to ameliorate the conditions of HIV-AIDS patients. Such patients suffer from a number of HIV-associated diseases such as diarrhoea, mouth sores, and skin rashes, which can be treated effectively using herbal products.

Conclusions

There is enormous potential in East Africa for development of a profitable industry based on traditional herbal remedies and aromatic plants. For this to be successful, it is essential to take steps to cultivate medicinal and aromatic plants. It is also imperative to conserve in particular vulnerable and slow-growing species in their natural habitat. There is a need to promote R&D efforts in medicinal and aromatic plants directed at value addition.

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Chapter 6
The Status of Medicinal and Aromatic Plants in Central and Southern Africa

by Marianne J. Ngoulla

Introduction

Central Africa covers the countries of Burundi, Cameroon, Central African Republic, Democratic Republic of Congo (DR Congo), Equatorial Guinea, Gabon, Republic of Congo, Rwanda, and Sao Tome and Principe Island. Southern Africa covers Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe.[1] Both regions are endowed with diverse vegetation types constituting tropical rainforests, coastal and alpine forests, savannahs, woodlands and scrublands. The vegetation is rich in species diversity, including medicinal and aromatic plants, and endemism.

As in the rest of Africa, medicinal and aromatic plants are the major constituents of traditional medicine and fulfil the health-care needs of the majority of the population. The communities and traditional medical practitioners (TMP) have practised traditional medicine (TM) for over ten thousand years. The TM knowledge has been acquired through observation, spiritual revelation, experience and training. The information was enriched as it was passed from one generation to the next.

According to the World Health Organization (WHO), over 33% of the world population and over 50% of the population in the poorest countries of the African and Asian continents do not have regular access to the most basic essential medicines.[2] There is therefore a need for medicinal plants for the populations, through development of quality products with proven safety and efficacy at an affordable cost.

Traditional Medicine Systems

Traditional medicines fulfil the health-care needs of about 63% of the population in Central Africa and 70% in Southern Africa. They represent both a popular and dominant medical system in Malawi, Mozambique and Swaziland and their popularity is on rise in South Africa. The TMP make use of a wide range of medicinal and aromatic plants in their remedies.

A legal framework for traditional medicine exists in DR Congo, Equatorial Guinea, Lesotho, Malawi, Mozambique, Namibia, Sao Tome and Principe, Zambia and Zimbabwe. There are no official legislative or regulatory texts for traditional medicine in Burundi, Central African Republic, Equatorial Guinea, Gabon, Rwanda, and Sao Tome and Principe. Associations for TM exist in almost all the countries except DR Congo.[3]

Current Status of Phytomedicines

Legal Framework

The legal situation regarding herbal preparations is changing. Countries in Central and Southern Africa are organizing a registration procedure to confer medicine status on herbal preparations.[4] Promotion of this sector is possible if there is a political will on the part of the governments to ensure regional registration, a commitment to allow the use of proven phytomedicines, and provide loans, tax breaks and credit for the investors.

Access to Biological Resources and Intellectual Property Rights (IPRs)

The TMP have a significant role in the health care of the people and are willing to enter into partnerships with interested researchers and investors to investigate the regional biological resources for commercialization. In such cases, appropriate legal document with unambiguous provisions on the royalties, benefit-sharing formulae, responsibilities and rights of the parties, etc., will facilitate the smooth implementation of the projects. Furthermore, clauses on the perpetuity of the benefits derivable from such partnerships will enhance full cooperation of the TMP. In June 1998, a summit of heads of states of the Organization of African Unity (OAU) recommended that member governments should:

- Give due attention as a matter of priority to the need for regulating access to biological resources, community knowledge and technologies and their implications for IPRs as entrenched in the international trade regime of the trade related aspects of Intellectual Property Rights Agreement (TRIPS);
- Adopt the draft model legislation on access to biological resources and call on Member States to initiate the process at national level involving all stakeholders in accordance with national interest and enact law;
- Initiate a process of negotiation among African countries on diversity with emphasis on access to biological resources and protection of community rights; and
- Develop an African common position to safeguard the sovereign rights of the member states and the vital interests of the local communities and forge alliance with other countries on the revision of TRIPS in 1999.

Medicinal and Aromatic Plant Resources

Medicinal plants play an important socio-economic role by fulfilling health-care needs and providing employment to local people. Central and Southern Africa have rich resources of medicinal and aromatic plants. There are about 40,850 plant taxa in Cen-

tral Africa and about 24,000 species of vascular plants in Southern Africa, of which many are of medicinal value. Central Africa is home to about 6,000 endemic species, of which 175 have been reported rare.[5] An estimated 250 ethnic groups living in forests of Central Africa depend on medicinal plants for their health-care needs and livelihood.[6] More than 3,000 plants species in South Africa, 800 in Republic of Congo, 600 in Zambia, 500 in Cameroon, 500 in Zimbabwe, 93 in Sao Tome and Principe, and 59 species in Rwanda are used by the local communities and TMP for their medicinal, aromatic and health-giving properties.[1] In Gabon, among the 58 botanical families of vascular plant species 29 families contain plant species of medicinal value.[7] Some Pan African medicinal plants and their uses are given in Table 1. Out of 3,000 species of medicinal plants, 350 have common and widespread use in traditional medicines in countries of Southern Africa. The most widely used medicinal plant species in South Africa are given in Table 2.

Table 1: Some Pan African medicinal plants and their uses

Botanical name	Common name	Uses
Alchornea cordifolia (Schumach.) Muell. Arg.	Christmas Bush	Gastro-intestinal (GI), respiratory and urinary ailments
Alstonia boonei	Emien	Bark antimalarial
Anthocleista nobilis G. Don.	Cabbage Tree	Antidiabetic, antifertility, antivenereal
Bersama abyssinica Fresen.	-	Anthelminthic, aphrodisiac
Bridelia feruginea Benth.	-	Edible
Butyrospermum paradoxum (C. F. Gaertn.) Hepper	Shea Butter Tree	Shea butter (seed fat) used for boils and rheumatism; bark for labour and parturition; leaves for collyrium
Carapa procera DC.	Uganda Crab Wood	Seed fat for burns, fungi, lice
Catha edulis (Valh) Forssk. ex Endl.	Khat	Anorectic CNS stimulant
Chasmantyhera dependens	-	Antivenereal, bruise, fractures
Chlorophora excelsa (Welw.) Benth.	African Oak	Tooth extraction
Chrysophyllum albidum G. Don.	White Star Apple	Malaria, yellow fever
Cocculus pendulus (Forst.) Diels	-	Hypertension
Costus afer Ker Gawl.	Spiral-ginger	Cough, hypertension
Cryptolepis sanguinolenta	-	Fever, inflammation
Dichrostachys cinerea (L.) Wight & Arn.	Marabouthorn	Leprosy, antivenereal
Elaeis guineensis Jacq.	Oil Palm	Bronchitis, gonorrhea, metrorrhagia
Garcinia kola Heckel	Bitter Kola	Aphrodisiac, vermifuge
Khaya senegalensis (Desr.) A. Juss.	African Mahogany	Malaria
Lonchocarpus sericeus (Poir.) Kunth ex DC.	Senegal Lilac	Analgesic
Moringa oleifera Lam.	Horseradish Tree	Flavouring agent, colic pains
Nauclea latifolia Sm.	African Peach	Antipyretic in malaria, nausea
Sclerocarya birrea (A. Rich.) Hochst.	African Hog Plum	Diabetes, dysentery, malaria
Trema guineensis (Schumach.)	African Elm	Asthma, bronchitis, cough
Uvaria spp.	Finger Root	Jaundice, malaria
Vernonia amygdalina Delile	Bitter Leaf	Cardiotonic, hypotensive
Voacanga africana Stapf	-	Mental disorders, analgesic

Table 2: The most widely used medicinal plant species of South Africa

Medicinal plants	Activities
Agathosma betunina (Berg) Pill.	Urinary tract infections
Aloe ferox Mill.	Purgative (internal), sun-screen and dermatological medication (external)
Aspalathus spp.	Allergy, appetite
Harpagophytum procumbens (Burch.) DC. ex Meiss.	Anti-inflammatory agent
Hypoxis hemerocallidea Fisch. ex C. A. Mey. & Avé-Lall.	Immunomodulator
Pelargonium reniforme Curtis	Pediatric use in bronchitis
Phyllobolus spp.	Anxiolytic agent
Siphonocheilus aethiopicus (Schweinf.) BL Burt.	Fever, antimicrobial agent
Sutherlandia frutacens (L.) R. Br.	Adaptogen, wasting syndrome
Warburgia salutaris (Bertol. f.) Chiov.	Antimicrobial agent

Most of the medicinal plant material is wild-collected though a little comes from cultivation. Nearly 70% of medicinal plant material collection in DR Congo and about 30% in Sao Tome and Principe is from wild sources.

South African countries have the highest concentration of threatened plant species in the world.[8] The existence of about 13% species among a total of 17,000 endemic plants is threatened. It has further been estimated that the number will continue to grow as a result of prevailing practices of over-harvesting, deforestation, and diversion of forests for agriculture and other developmental activities. Among the threatened species, many are medicinal and aromatic plants. Over-harvesting has threatened the existence of *Harpagophytum procumbens* DC. ex Meiss. in Botswana, *Siphonocheilus aethiopicus* (Schweinf.) Bl. Birtt. in Namibia and *Warburgia salutaris* (Bertol. f.) Chiov., *Ledebouria hypoxidoides*, *Mystacidium millaria*, *Ocotea bullata* E. Mey. and *Aloe ferox* (L.) Burm. f. in South Africa. Other threatened species include *Artemisia afra* Jacq., *Harpagophytum zeyheri* Decne., *Hypoxis rooperii* Moore and *Sutherlandia frutescens* (L.) R. Br.

Among the 13 key species of high socio-economic value, *Gnetum* spp., *Baillonella toxisperma* Pierre, *Prunus africana* (Hook. f.) Kalkman, and *Pausinystalia johimbe* (Schuma.) Beille have been given special attention for their conservation.

Research and Development

The quantity and quality of data regarding the safety and efficacy of traditional medicine are far from sufficient to meet the criteria needed to support its use worldwide. The reasons for the lack of research data are not only inappropriate health-care policies, but also a lack of adequate or accepted research methodology for evaluating traditional medicine. It should be noted that published and unpublished information on research in traditional medicine in various countries exists, but further research in safety and efficacy is required and the quality of the research needs to be improved.

In 1992, the global spending on health research was US$ 56 bn - less than 4% of total global expenditure on health related matters. Of that, no more than 10% was allocated to research related to the health needs of developing countries.

The combined investment in R&D into acute respiratory infections, diarrhoeal diseases and tuberculosis, which kill over 7 mn people a year, was US$ 133 mn (about 0.2% of global spending on health research and development). These three diseases account for almost one-fifth of the global disease burden. Malaria, which accounts for 3% of global disease burden and almost 10% in sub-Saharan Africa, fared as poorly, attracting about 0.1% of research funds.[9]

R&D activities are undertaken by a number of state and privately-owned universities, research institutes, herbal companies and non-governmental organizations. The National Botanical Institute of South Africa is engaged in the ethnobotanical surveys, development of a medicinal plants database and conservation of over-harvested medicinal plants of Southern Africa. The National Medicinal Plants Database for South Africa holds the floristic, chemical and ethnopharmacological data on the 300 most important plants of South Africa. The Association of Commonwealth Traditional Medicine Practitioners for West Africa is promoting the collaboration and exchange of traditional knowledge and experience between traditional medical practitioners at national and regional levels in Cameroon.

The South Africa Council for Scientific and Industrial Research (CSIR) undertakes R&D work and is a key provider of information and technology solutions to the member nations of the Southern African Development Community. The Office of Medicinal Plant Studies of the Ministry of Health, Mozambique and Eduardo Mondlane University gather ethnomedical information on local plant species used to treat common diseases. The National Herbarium and Botanic Gardens (NHBG) of Malawi conducts research on economic botany, medicinal plants biodiversity, documentation and assessment of the efficacy of botanical pesticides, and ethnobotanical study of medicinal plants used in maternal and child health.

To promote the rational use of indigenous traditional medicine, the Department of Pharmacology, University of Cape Town, and the School of Pharmacy, University of Western Cape, South Africa are developing monographs on medicinal plants. The consortium of the Medical Research Council, University of Cape Town, University of Pretoria, University of Western Cape and Council of Scientific and Industrial Research in South Africa are undertaking research on development of antimalarial medicines from indigenous medicinal plants. South African Druggists Ltd. and BioNatural, privately-owned companies, are developing finished products from African medicinal and aromatic plants.

R&D activities in most countries of Central and Southern Africa are constrained by lack of financial assistance and skilled staff.

Trade and Marketing

Medicinal and aromatic plants are an important source of subsistence to the rural population. Equatorial Guinea, Cameroon, DR Congo, Zambia, South Africa, Mozambique, Zimbabwe and Malawi are the major countries in medicinal plants trade, which takes place in both formal and informal markets. Plant material is exchanged between neighbouring countries e.g. South Africa exports *Swartzia madagascariensis* Desv. to Lesotho; Swaziland exports *Warburgia salutaris* (Bertol. f.) Chiov. to South Africa and Mozambique; and Malawi and Mozambique export *Jateorhiza* spp. to Zambia, Zimbabwe, Mozambique and South Africa. Malawi and South Africa importation is rising as a result of depletion of their own resources. A quantity of medicinal plants material is also traded to the international market.

The key species in international trade are *Warburgia salutaris* (Bertol. f.) Chiov. from Mozambique, Swaziland, Zimbabwe and South Africa; *Harpagophytum procumbens* DC. ex Meiss. from Botswana and Namibia; and *Harpagophytum zeyheri* Decne. from Namibia. South Africa also exports *Panax ginseng* C. A. Mey., *Glycyrhiza* spp., *Origanum* spp., and *Salvia* spp. to Germany. Equatorial Guinea, Cameroon and DR Congo export *Prunus africana* (Hook. f.) Kalkman, mainly to France and Italy. Cameroon exports *Pausinystalia johimbe* (Schuma.) Beille, *Physostigma venenosum* Balfour, *Strophanthus gratus* Baill. & Franch., and *Voacanga africana* Stapf to the international market. There are many more plants that are specific to respective countries and used locally in traditional medicines. Some important African medicinal plants in international trade are given in Table 3.

Table 3: Important African medicinal plants in world trade

Botanical name	Local name	Active constituent(s)	Uses
Aloe spp.	Aloe	Barbaloin, aloe-emodin	Healing properties
Aspalathus spp.	Bush Tea		Caffeine-free beverage tea
Catharanthus roseus (L. G. Don)	Madagascar Periwinkle	Vincristine, vinblastine	Leukaemia
Centella asiatica (L.) Urb.	Gotu Kola	Asiaticoside	Cicitrizant, polutice
Dioscorea spp.	African yams	Diosgenin, sitosterol	Cortisone manufacturing
Harpagophytum procumbens (Burch.) DC. ex Meiss.	Devil's Claw	Harpagosides	GI and rheumatic ailments
Pausinystahlia johimbe (K. Schum) Pierre ex Beille	Yohimbe	Yohimbine	Aphrodisiac
Phystostigma venenosum Balf.	Ordeal Bean	Physostigmine	Antiglaucomic
Prunus africana (Hook. f.) Kalkman	Pygeum	-	OTC prostate remedy
Rauvolfia vomitoria Afzel.	African snakeroot	Reserpine, yohimbine	Hypertensive
Senna alexandrina Mill.	Senna	Sennosides	Laxative synergic
Strophanthus spp.	Kombe	Strophanthtidin	Cardiac glycosides
Strychnos icaja Balli.	Strychnine		GI problems, hernia, malaria
Tabernanthe iboga Baill.	Iboga	Ibogaline	Hallucinogen
Tamarindus indica L.	Tamarind	Hydroxycitric acid	Poultice for boils
Trigonella foenum-graecum L.	Fenugreek	Diosgenin	Contraceptive, galactagogue
Warbrugia ugandensis Sprague	Pepper bark	Polygodial	Antifeedant, antiyeast
Withania somnifera (L.) Dunal	Ashwagandha	Withaferin, withanolides	Asthma and uterine sedative

Reliable information on the market of medicinal plants is scarce in most of the countries. According to an estimate, there are more than 27 mn consumers of herbal medicine alone in South Africa. Durban, Faraday and Kwazulu-natal are important trade centres for medicinal plants material in South Africa. At national level, 20,000 tonnes of raw material of about 700 plant species, worth US$ 60 mn, are traded annually. Over 4,000 tonnes of plant material of about 400 plant species are traded annually in Kwazulu-natal Province alone.[1] Many of the traded species are threatened and should become the subject of urgent conservation and cultivation programmes.

Opportunities and Constraints

There is a large and growing local and international demand for African medicinal plants, which offers an opportunity for African countries to earn foreign revenue through sustainable harvesting and export of medicinal plant material. There also exists a great potential for cultivation of medicinal plants, which are in great demand in the international market.

A negative policy environment, the unregulated nature of trade, over-harvesting and rapid loss of biodiversity due to deforestation are the major constraints in the development of herbal industry. A wide gap exists between supply and demand of medicinal plant material. Lack of skilled personnel, processing technologies and product standardization and quality control is responsible for limiting the potential of the herbal industry in Africa. Most of the current market players have restricted business skills and lack market information.

Actions for Promoting the Quality of Plant Material Supply

The management of wild plants and their cultivation is required in order to provide a sustained supply of plant material to local communities and the phytomedicine industry. Cultivation should be promoted in order to reduce reliance on wild plant stocks and provide material of consistent quality to industry. The most popular and commercially used species need immediate attention to bring them under cultivation. Special attention should be paid to slow-growing species, to adopt them for cultivation: government and NGOs should work towards this goal. Sufficient market information should be made available and strong networks for information-sharing among industries should be established. Resource surveys should be carried out to reveal the exact number of medicinal plant species and their abundance in nature.

Conclusions

The lack of organization in the sector, particularly in Africa, highlights the need to develop an active network among all stakeholders involved in this sector. There is a great potential for exploitation of the medicinal and aromatic plant resources of Central and Southern Africa. Not only will this give economic benefit, but it can also improve the health-care status of the region.

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Chapter 7
The Status of Medicinal and Aromatic Plants in Libya

by Abdurazag Auzi

Introduction

Libya has a total area of about 1,759,540 square km of which about 90% constitute the Sahara desert plus surrounding scattered oases. The largest oasis, Alkufra, which lies beneath the desert rock, has a huge underground water supply. The rest of the landmass constitutes semi-desert region with sparse grazing land for sheep, goats, camels and cattle, and a natural farmland along the Mediterranean coast. In the northwestern plains and northeastern highlands, the farmers use mainly traditional methods to grow oranges, olives, almonds, wheat, grapes, etc.

Medicinal and Aromatic Plant Resources

In Libya there are about 1,825 vascular plant species, of which 134 are endemic. About 450 species are reported to be of medicinal value in the country.[1] Some important plant families are Apiaceae, Asteraceae, Lamiaceae, Poaceae, Fabaceae, Brassicaceae and Abiaceae. Medicinal plants are distributed throughout the country, especially in Jabel Al-akhdar, Ghadames, Gharian, Awbari and Tarhona regions. Many of these plants are associated with a long history of traditional use (Table 1).[2] More than a hundred species are massively used by Bedouins or local people in folk medicine as hot or cold drinks, or chewed fresh or dry. These are also used externally to cure dermal diseases, viral or bacterial infections, insect or animal bites or burns and sometimes for the treatment of hair problems. These medicinal plants are very well documented in different flora.[3,4] Many species of medicinal plants, such as *Asperula arvensis* L., *Cupressus sempervirens* L., *Juniperus phoenicea* L., *Pinus halepensis* Mill., *Quercus coccifera* L., *Tribulus longipetalus* Viv., *Veronica cymbalaria* Bodard and *Vahlia dichotoma* (Murray) Kuntze have become threatened by extinction[5,6] owing to over-harvesting and diversion of forest-land containing medicinal plants to agriculture. There is an urgent need for initiating programmes for collection and conservation of the endangered and rare plant species, to save them from extinction through heavy grazing, human use and drought, which are common in the country.

The best known medicinal plant of Libya is *Silphium cyrenaicum* (now extinct). It existed during Greek and Roman times (900 to 100 B.C.). The plant was used for the treatment of many illnesses and was so important to the economy of the country that at that time it used to be sold for its weight with silver or gold and its picture was depicted on currency coins.[2] It has been reported that *Silphium* used to grow abundantly in Cyrenacia (Jabel Al-akhdar region) but heavy exploitation led to its extinction hundreds of years ago. Many scientists, such as Keith (1965), Abulugma (1985), Alganay (1994) and Kamal (1999) have suggested different species for *Silphium,* but their suggestions are questionable.

Table 1: List of plants associated with long history of traditional use in Libya

Botanical name	Family	Therapeutic use(s)/indication
Achillea santolina L.	Asteraceae	Expectorant, carminative, anthelmintic
Ajuga iva Schreb.	Lamiaceae	Antiemetic, antidiarrhoeal
Alhagi maurorum Medik.	Fabaceae	Antirheumatic, laxative, diuretic
Aloe vera (L.) Burm. f.	Aloaceae	Emmenagogue, promotes hair growth
Ammi majus L.	Apiaceae	Carminative, antispasmodic
Anvillea garcinii (Burm. f.) DC.	Asteraceae	Hypoglycaemic
Artemesia herba-alba Asso	Asteraceae	Vermifuge (against worms for babies)
Artemesia judaica L.	Asteraceae	Common cold, hypoglycaemic, anthelmintic
Borago officinalis L.	Boraginaceae	Antirheumatic
Capparis spinosa L.	Capparaceae	Expectorant, diuretic, antirheumatic
Cassia obovata Collad.	Fabaceae	Purgative
Ceratonia siligua L.	Fabaceae	Tonic, demulcent
Citrullus colocynthis (L.) Schrad.	Cucurbitaceae	Purgative or hydragogue
Cynara cardunculus L.	Asteraceae	Diuretic, laxative, antianaemic
Cynara scolymus L.	Asteraceae	Hypoglycaemic, hypocholesterolemic
Cynomorium coccineum L.	Balanophoraqceae	Laxative
Datura stramonium L.	Solanaceae	Antispasmodic, mydriatic, leaves smoked for asthma
Ecballium elaterium (L.) A. Rich.	Cucurbitaceae	Jaundice
Ephedra alata Decne.	Ephedraceae	Antiasthmatic
Eruca sativa Mill.	Brassicaceae	Tonic, aphrodisiac
Globularia vulgaris L.	Scrophulariaceae	Diuretic
Helichrysum stoechas (L.) Moench	Asteraceae	To clear small calculi
Hyoscyamus albus L.	Solanaceae	Sedative, analgesic (small dose), hallucinogenic (large dose)
Juniperus communis L.	Cupressaceae	Digestive, antiseptic, renal stimulant
Lavandula multifida L.	Laminaceae	Insect repellent, perfume
Lepidium sativum L.	Brassicaceae	Expectorant
Lupinus albus L.	Fabaceae	Hypoglycaemic, hypotensive
Marrubium vulgare L.	Lamiaceae	Hypoglycaemic
Peganum harmala L.	Zygophyllaceae	Anthelmintic, antibacterial, protozoacidal
Plantago major L.	Plantaginaceae	Malaria, ear ache, dysentery
Ruta graveolens L.	Rutaceae	Expectorant, convulsion, jaundice
Salvia officinalis L.	Lamiaceae	Nervous disorders, dizziness, trembling
Teucrium polium L.	Lamiaceae	Hypoglycaemic, common cold
Thymus capitatus L.	Lamiaceae	Tonic, carminative
Trigonella foenum-graecum L.	Fabaceae	Tonic, anabolic and lactagogue
Urtica urens L.	Urticaceae	Haemostatic, antianaemic, hypoglycaemic
Viola tricolor L.	Violaceae	Urinary problems, diaphoretic
Withania somnifera (L.) Dunal	Solanaceae	Hypotonic, aphrodisiac

The most demanded herbal medicines from Libya are chamomile, thyme and rosemary. Libya exports medicinal plants to Egypt, but this activity is not controlled by the government but handled by the private sector. There is at present a lack of information on formal trade of medicinal and aromatic plants from the country. About 30% of the population relies on traditional medicine in Libya. The Ministry of Health is planning to establish herbal medicine clinics as well as Good Manufacturing Practices (GMP) in the production of herbal medicinal products, which are mostly imported from Italy and other European countries.

Research and Development in Medicinal Plants

Scientific studies of the Libyan flora began about 200 years ago when the Swedish scientist J. Rothman collected many plant samples from western Libya and stored them at the Riks Museum in Sweden. Since then, countless collectors and travellers have visited Libya, and there has been considerable interest in the plants of the region. A number of world scientists have undertaken botanical expeditions in the country. For example, P. della Cella (1817) collected plants from the Eastern part of the country (Bomba Gulf); D. Viviani (1824) wrote a book on *Flora Libycee Speciments* and included 1,200 plant samples; Barratte & Durrand (1910) wrote a book on *Flora Libycee Prodromus* with 1,156 plant samples. During the Italian occupation, R. Pampanini published *Plantae Tripolitanae* in 1914 and *Predromo Della Flora Cirenaica* in 1931. In 1942, R. Corti visited the southern parts of the country, Fezan and Ghat, and wrote a book about his visit. In 1965, H. G. Keith published two volumes of *A Preliminary Checklist of Libyan Flora* and during the period between 1976 and 1988, a group of Libyan scientist published *Flora of Libya* comprising 145 volumes, one for each family.

The Libyan Medicinal and Aromatic Plant Research Programme was initiated in January 2001 (2001-2005)[1,7] at the Faculty of Pharmacy, University of Elfateh, Tripoli. The programme focuses on chemical and biological evaluation of Libyan medicinal and aromatic plants.

In the first phase, the relevant literature on the past work has been collected from current periodicals and other resources. The collection and documentation of the information on traditional uses of medicinal plants from herbalists have been initiated and are still in progress. In the second phase, which started in 2002, the phytochemical investigation and analysis of the most important medicinal and aromatic plants in traditional and conventional medicine are being undertaken. In the third and final phase, the plant extracts or single plant constituents will be screened to discover their potential biological activities.

The isolation of active constituents will be monitored by a bioassay (a definite pharmacological effect). Evaluation of toxicity and therapeutic properties and tests for microbial activity are planned under this project. Emphasis will be made on those plants that are traditionally used for the treatment of some diseases such as diabetes, hypertension, ulcer, inflammation and hypercholesterolemia.

The agronomical studies aim to provide information about the medicinal and aromatic plant growth and the properties of their oils and active constituents.[3] These studies and investigations will include the effect of radiation on quality of medicinal plants, soil analysis, cultivation including soil preparation, irrigation, fertilizers, time of sowing and harvesting for optimum yield.

A second programme, for the establishment of a Libyan National Herbarium, has been proposed by the Ministry of Environmental General Authority (EGA), Tripoli and is financially supported by the Italian Ministry of Foreign Affairs. The objectives of the programme are to provide a better understanding and wider knowledge of the systematics, evolution, ecology and conservation biology of major groups of Libyan native plants and their relatives.

The third programme, led by the EGA, Tripoli has been in progress since January 2001 and concentrates on creation of a database on Libyan flora, giving remote access, ideally suited for disseminating and making available valuable knowledge to a wide client base.

The faculties of pharmacy at the University of Elfateh, Tripoli and the University of Garyounis, Bengazi are involved in phytochemical and biological screening of the country's medicinal and aromatic plants. The faculties of science of both universities are involved in botanical explorations and identification of plants of economic importance. The Biotechnology Research Centre and the Agricultural Research Centre, under the Ministry of Environment and the Ministry of Agriculture respectively, are engaged in the conservation of genetic resources of plant species of medicinal value.

Opportunities and Constraints

Medicinal and aromatic plants are an important source of drugs for health care in Libya. The country has a vast area of different geographic conditions suitable for cultivation of aromatic and medicinal plants. With the increase in demand for medicinal and aromatic plants in the market over the last decade, the share of aromatic plants and their essential oils has increased tremendously. There is scope in the country for establishment of small-scale phytochemical industries.

At the same time, there is a lack of R&D activities in the field of medicinal plants. As a result of over-exploitation, some plants have become rare and endangered. There is also an imminent threat of genetic erosion of medicinal and aromatic plant species through heavy grazing, human use and drought, which are common in the country. The economical constraints of the country mean that international assistance is needed for the collection and conservation of the genetic resources of endangered species of medicinal value.

Conclusions

Although the country is endowed with a number of medicinal and aromatic plants used by its ethnic societies, there is a lack of well documented ethnomedical information. There is also a lack of regulated trade of medicinal and aromatic plants to international

market. R&D programmes on medicinal and aromatic plants in the country have just begun to explore the possibility of utilizing national resources of medicinal and aromatic plants.

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Chapter 8
The Experience of the Iberoamerican Programme of Science and Technology for Development in Latin America

by Mahabir P. Gupta and Armando Cáceres

Introduction

Herbal medicinal products have become a topic of increasing global importance, with both medical and economic implications.[1-3] In the USA, the annual retail sale of herbal medicinal products rose from US$ 200 mn in 1988, to an estimated US$ 5.1 bn in 1997, and the consumer use of these products has increased by 380% in the past ten years.[4] In the emerging and developing countries of Africa, Asia (China and India) and Latin America, medicinal plants have always played a central role in the health care of their populations. According to the WHO survey, 65 to 80% of the populations in these countries depend on traditional and herbal medicines for their primary health-care needs.

Over the past decade, herbal remedies have enjoyed a revival in many western countries, including Australia, Canada, Europe, and the USA. Although data to accurately calculate the entire global market for herbal medicines is sparse, it can be conservatively estimated that worldwide sale of herbal products lies in the range US$ 25 bn per year; of this Europe accounts for US$ 7 bn.[5]

In 1999, Latin American consumption of drugs was less than 5% of world consumption (approximately US$ 343 bn) amounting to US$ 16.5 bn.[6] The consumption of drugs as a percentage of gross national product (GNP) in developed countries increased from 0.65 to 0.95% from 1975 to 1990, while it decreased from 0.79 to 0.67% in emerging and developing countries during the same period. In Latin America, the annual per capita consumption of drugs is approximately US$ 21. These figures vary among different countries of the region (Argentina US$ 65, Brazil US$ 17, Bolivia US$ 6) and among different regions of the same country, as is the case in Brazil (Northeast, less than US$ 5; South, US$ 70; Sao Paulo, US$ 90).[7]

Mostly international companies control the Latin American market for pharmaceuticals. The participation of national companies is small, accounting for 50% in Argentina, 20% in Brazil and Colombia, and 10% in Costa Rica and Ecuador. The processing

of raw material for pharmaceutical industry is scarce and pharmaceutical end products are imported to some extent, e.g. Brazil used to import less than 10% of its needs, but owing to globalization this situation is changing very fast and end-product import is strongly increasing.

The balance of payments of Latin America in drugs is significantly deficient. The larger countries of the region like Argentina, Brazil and Mexico import approximately 10% of their requirements of finished pharmaceutical products, while Central American countries import approximately 80%, and others, like Bolivia, Chile, Peru and Venezuela import around 25 to 50%. The availability of raw materials and auxiliary products in the region for the production of drugs is very scarce and it is estimated that 75% of this need has to be met by importation. With respect to the finished products, the industry with national capital supplies 50% of the need in Argentina and Chile; 30% in Mexico and Uruguay; 20% in Colombia, Brazil, Peru, Venezuela; and and only 10% in countries like Costa Rica, Ecuador and Panama. This means that companies with foreign capital supply a major part of the US$ 8.5 bn pharmaceutical market.

Market of Medicinal Plants

It appears logical to think that access of the poor to drugs, increased market control by transnational companies, and a continually decreasing participation of the public sector in the supply of drugs should stimulate the use of cultivable medicinal plants in the region with the objectives of improving health coverage of the population together with decreasing the deficit in balance of payments. Use of medicinal plants as drugs is widespread in a major part of the Latin American population; in some countries this may amount to about 70%. The world market of finished pharmaceuticals of plant origin is estimated at US$ 86 bn annually.

Based on the experience of the Latin American Programme of Science and Technology for the Development (CYTED), it can be said that the Latin American countries indeed have a clear interest in the exportation of cultivated medicinal plants as a source of income for their weak economies and to improve local supply.

The impossibility of access to modern drugs by a significant part of the Latin American population, the increasing control of the pharmaceutical industry by international companies, and the decreasing participation of the national governments in the purchase and distribution of medicaments should stimulate the use of medicinal plants in order to improve health care. Other reasons such as the green consumerism and the growing demand for natural products in developed countries; the search for new pharmaceuticals from the plant kingdom to combat chronic and life-threatening diseases; and the free market economy creating demand for the new materials and products, should stimulate national laboratories to produce plant-based medicines.

Latin America exports significant quantities of crude drugs mainly in the dried form and to some limited extend, as simple extracts and even pure drug entities. These plants

are mainly gathered from wild sources, a practice that may endanger the species. Only a few countries of the region have large cultivation programmes for a selected number of medicinal plant species. Many medicinal plants are imported from industrialized countries, and some of them can easily be cultivated in Latin American countries.

Owing to the lack of reliable information on trade statistics, it is very difficult to estimate the Latin American market of medicinal plants and their derivatives. More information is provided concerning aromatic plants, mainly from Chile, Argentina and Brazil. Brazilian statistics are available until the year 1990. Table 1 lists important export items in other countries of Southern and Central America.[8] Table 2 gives a list of medicinal and aromatic plants in Latin America that have a potential for industrialization.

Table 1: Important medicinal and aromatic plants in export from selected Latin American countries

Country	Medicinal and aromatic plants and products
Argentina	*Matricaria chamomilla* L., *Cynara cardunculus* L. extract, heterosides, *Pinus* spp. (turpentine oil), *Citrus* sp. (orange oil), and *Cymbopogon nardus* (L.) Rendle (citronella oil)
Chile	*Buddleia globosa* Hope, *Foeniculum vulgare* Mill., *Lippia citriodora* Kunth, *Matricaria chamomila* L., *Melissa officinalis* L., *Peumus boldus* Molina, *Polygonum sanguinaria* J. Remy FT, *Quillaja saponaria* Molina, *Rosa* sp., *Smilax medica,* and essential oils from *Citrus* spp. and *Mentha* spp.
Costa Rica	*Cassia reticulata* Willd., *Curcuma longa* L., *Cymbopogon* spp., *Hibiscus sabdariffa* L., *Ocimum* spp., *Petiveria alliacea* L., *Quassia amara* L., *Rosmarinus officinalis* L., *Ryania speciosa* Vahl, *Tecoma stans* (L.) Juss. ex Kunth, *Thymus* spp. and *Vetiveria* spp.
Guatemala	*Elletaria cardamomum* (L.) Maton, *Neurolaena lobata* (L.) R. Br., *Smilax* spp., *and Tagetes lucida* Cav.
Honduras	*Matricaria* spp., *Polypodium aureum* L.
Mexico	*Arctostaphylos uva-ursi* (L.) Spreng., *Mimosa tenuiflora* (Willd.) Poir., *Opuntia* spp., and *Valeriana mexicana* DC.
Panama	*Cephaelis ipecacuanha* (Brot.) Tussac, *Hibiscus sabadariffa* L., and *Morinda citrifolia* L.
Paraguay	*Bulnesia sarmientoi* Loren. ex Griseb., *Lippia citriodara* Kunth, *Mentha piperita* L., and *Stevia rebaudiana* (Bertoni) Bertoni

Chile

In Chile, a few commercial enterprises are involved in the international trade of medicinal plants, which exports over US$ 20 mn of medicinal plants, of which quillaja (*Quillaja saponaria* Molina) amounts to US$ 80,000. Other important export items are boldo (*Peumus boldus* Molina), *Origanum majorana* L., rosa mosqueta (*Rosa moschata* Herrm., *Rosa rubiginosa* L., *Rosa canina* L.) and sarsaparrila (*Smilax medica* Schltdl. & Cham). The amount exported during the years 1992 to 1994 reached 10,000 to 11,000 tonnes per year.[9]

Quillaja, rosa mosqueta and boldo are collected from the wild sources. Rosa and boldo are exported mainly to Brazil and Argentina, while origanum and quillaja are exported principally to Germany.

Table 2: Important industrializable medicinal plants of Latin America

Scientific name	Vernacular name	Part(s) used	Therapeutic use(s)/indication	Source country(ies)
Acacia tenuiflora Willd.	Tepescohuite	Bark	Wound healing, cosmetic	Mex
Acanthoxanthium spinosum (L.) Fourr.	Amor seco	Leaf	Hepathic disorders	Bol
Achillea millefolium L.	Aquilia, milenrama	Floral part	Disinfectant	Bra, Por
Achyrocline satureioides DC.	Marcela	Inflorescence	Antispasmodic	Uru
Aesculus hippocastanum L.	Castaño de la India	Seed	Varicose veins	Chi
Allium cepa L.	Cebolla	Bulb	Flu	Pan, Rdom, Ven
Allium sativum L.	Ajo	Bulb	Arteriosclerosis, hypotensive, CVS disorders	Bol, Col, Ecu, Pan, Rdom, Spn, Ven
Aloe vera (L.) Burm.	Aloe, sábila	Leaf	Cathartic, wound healing, cosmetic, anti-inflammatory	Gua, Pan, Par, Per, Por, Rdom, Ven
Aloysia citriodora Palau	Cedrón	Leaf, flower	Digestive, antimicrobial	Chi, Ecu, Gua, Por
Althaea officinalis L.	Altea	Root	Gastritis	Por
Ambrosia peruviana Willd. / *Chrysanthemum parthenium* (L.) Bernh.	Altamisa	Leaf, flower	Stomach ache	Gua, Spn
Arctostaphylos uva-ursi Spreng.	Uva ursi	Leaf	Urinary antiseptic	Chi
Aristeguietia glutinosa (Lam.) King & Robinson	Matico	Leaf	Antimicrobial	Ecu
Arnica montana L.	Arnica	Flower	Tonic	Gua, Spn
Artemisia absinthium L. / *A. ludoviciana* Nutt.	Ajenjo	Leaf	Diabetes, abortive, antitussive, digestive, dyspepsia	Bra, Ecu, Gua, Por, Spn, Ven
Artemisia vulgaris L.	Artemisa	Stem, leaf	Nervousness	Gua, Spn
Avena sativa L.	Avena	Flower, fruit	Tonic	Chi
Baccharis polyantha Kunth	Chileo	Leaf	Anti-inflammatory	Ecu
Baccharis trinervis Pers.	Carqueja, santa maría	Leaf, stem	Hepatic diseases	Bol, Pan, Uru
Bauhinia candicans Benth.	Pata de vaca	Leaf	Hypoglycemic	Chi
Bixa orellana L.	Achiote, bija, urucum	Leaf, seed	Wound healing, colourant	Bra, Ecu, Pan, Rdom, Spn
Borago officinalis L.	Borraja	Leaf, seed	Blood purifier, expectorant, lipolytic	Col, Ecu, Per, Por, Ven
Brassica nigra (L.) Koch	Mostaza	Seed	Emetic	Por
Bursera graveolens (Kunth) Triana & Planch.	Palo santo	Root, bark	Analgesic	Per

Continued

Scientific name	Vernacular name	Part(s) used	Therapeutic use(s)/indication	Source country(ies)
Byrsonima crassifolia HBK	Nance	Leaf, bark	Diarrhoea	Pan, Spn
Caesalpinia tinctoria Benth.	Tara	Fruit	Astringent, wound healing	Per
Calea urticifolia (Mill.) DC.	Juanislama	Leaf	Cancer, colitis	Spn
Calendula officinalis L.	Caléndula, china	Leaf, flower	Rheumatic pains, antiseptic, digestive	Bol, Bra, Chi, Col, Ecu, Gua, Por
Capsicum annuum L. / *C. frutescens* L.	Pimiento, ají	Fruit	Vasodilator, analgesic	Pan, Spn, Ven
Carica papaya L.	Papaya, lechosa	Leaf	Digestive	Col, Ecu, Gua, Ven
Carum carvi L.	Comino	Floral part	Spice	Por
Cassia angustifolia Vahl.	Sen	Leaf, fruit	Laxative, cathartic	Chi, Gua, Par, Per, Uru
Cassia fistula L.	Cañafístula	Leaf, fruit	Laxative	Pan, Rdom, Spn
Cassia grandis L. f.	Carao	Leaf, fruit	Anaemia, skin	Spn
Cestrum parqui L'Hér.	Andrés Waylla	Leaf	Anti-inflammatory	Bol
Chamomilla recutita (L.) Rausch.	Manzanilla, camomila	Flower	Anti-inflammatory, aromatic, digestive, disinfectant, antispasmodic	Arg, Bol, Bra, Col, Ecu, Gua, Par, Por, Rdom, Spn, Uru, Ven
Chenopodium ambrosioides L.	Apazote, paico, ipazote	Whole plant	Liver disorders, antiparasitic	Bol, Ecu, Pan, Rdom, Spn
Cinchona pubescens Valh. / *C. calisaya* Wedd.	Quina, cascarilla	Bark, leaf	Antipyretic, antiparasitic	Chi, Ecu, Gua, Per
Copaifera officinalis L.	Copaiba	Resin	Wound healing, antiseptic	Per
Crataegus oxyacantha L. var. *curvisepala*	Crataegus, espino blanco	Inflorescence	Cardiovascular, cardiac tonic	Chi, Por
Crescentia cujete L.	Tutumo	Fruit	Respiratory diseases	Pan, Per
Croton draconoides Muell. Arg. / *C. lechleri* Muell. Arg.	Sangre de drago	Latex	Wound healing	Ecu, Per
Curcuma longa L.	Cúrcuma	Rhizome	Anti-inflammatory	Gua, Spn
Cyclanthera pedata (L.) Schrad.	Chigua	Fruit	Hypocholesterolemic	Per
Cymbopogon citratus Stapf.	Té de limón, limoncillo, capim limao	Leaf	Digestive, carminative, flavouring agent	Bol, Bra, Gua, Pan, Por, Rdom
Cynara cardunculus L.	Alcachofa	Leaf	Liver disorders, cholagogue, CVS disorders	Bol, Bra, Col, Ecu, Per, Ven
Cytisus scoparius (L.) Link	Giesta	Flower	Diuretic	Por
Dalea coerulea L. f.	Iso	Flower	Antitussive	Ecu
Derris utilis (A. C. Smith) Ducke	Barbasco	Root	Insecticide	Per

Continued

Scientific name	Vernacular name	Part(s) used	Therapeutic use(s)/indication	Source country(ies)
Desmodium molliculum (HBK) DC.	Manayupa	Aerial part	Depurative	Per
Dracontium loretense Krause	Jergón sacha	Tubercule	Anti-inflammatory	Per
Elettaria cardamomum (L.) White & Maton	Cardamomo	Seed	Digestive, flavouring agent	Gua
Equisetum bogotense HBK / *Equisetum arvense* L. / *E. giganteum* L.	Cola de caballo	Stem, leaf	Vasoconstrictor, diuretic, blood purifier, antiseptic	Bol, Bra, Ecu, Pan,Per, Por, Spn, Ven
Eryngium spp.	Escorzonera	Aerial part	Respiratory disorders, antipyretic	Per
Erythroxylum coca Lam.	Coca	Leaf	Stomach ache	Bol
Espeletia spp.	Frailejón	Leaf	Bronchodilator	Ven
Eucalyptus globulus Labill.	Eucalipto	Leaf	Expectorant, antitussive, flu, diuretic, antiseptic	Chi, Ecu, Gua, Pan, Per, Por, Spn
Foeniculum vulgare Mill.	Hinojo	Seed, leaf, root	Digestive, female disorders	Bol, Col, Gua
Genipa americana L.	Huito, Jagua	Fruit	Respiratory afflictions	Pan, Per
Gentianella alborosea Fabris.	Hercampuri	Whole plant	Lipolytic	Per
Geranium robertianum L.	Geranio	Flower	Aromatic	Por
Geranium sessiliflorum Cav.	Pachuchaqui	Whole plant	Hypoglycaemic	Per
Ginkgo biloba L.	Gingo, ginkgo	Leaf	Cerebral vasodilator	Bra, Chi, Spn
Gnaphalium vira-vira Molina	Wira-wira	Flower	Expectorant	Bol
Hamelia patens Jacq.	Chichipince	Leaf	Wound healing	Pan, Spn
Hibiscus sabdariffa L.	Rosa de Jamaica, hibiscus	Calyx	Diuretic	Bra, Gua, Pan
Hypericum perforatum L.	Hipericum/Hipericao	Leaf, flower	Liver disorder	Por, Spn
Jatropha curcas L.	Tempate, coquillo	Leaf	Herpes	Gua, Mex, Pan, Spn
Jatropha macrantha Muell. Arg.	Huanarpo macho	Aerial parts	Aphrodisiac	Per
Juglans neotropica Diels	Nogal	Leaf, fruit	Blood, antiseptic, cosmetic	Per, Spn
Juniperus communis L.	Zimbro	Bark	Aromatic	Por
Krameria lappacea (Dombey) Burdet & B. B. Simpson	Ratania	Root	Astringent, haemostatic	Per
Lamium album L.	Ortiga	Leaf	Depurative, rheumatism, arthritis	Gua, Por
Laurus nobilis L.	Louro	Leaf	Aromatic	Por
Lepidium meyenii L.	Maca	Tuber	Tonic, aphrodisiac	Per

Continued

Scientific name	Vernacular name	Part(s) used	Therapeutic use(s)/indication	Source country(ies)
Lippia dulcis Trev.	Orozuz	Leaf, flower	Expectorant	Gua
Lycopus sp.	Tipo	Leaf, flower	Antitussive	Ecu
Malva sylvestri L. / *M. parviflora* L.	Malva	Leaf, flower	Expectorant, digestive, emollient, respiratory disorders	Col, Ecu, Gua, Por
Marrubium vulgare L.	Marrubio	Leaf	Digestive, febrifuge, diuretic	Gua, Por, Ven
Marsdenia condurango Reichb. f.	Condurango	Bark	Digestive	Ecu
Maytenus ilicifolia C. Mart.	Congorosa	Leaf	Diuretic, wound healing	Bra, Uru
Maytenus macrocarpa (Ruiz & Pav.) Briq.	Chuchuhuasca	Bark	Antirreumatic, aphrodisiac	Per
Medicago sativa L.	Alfalfa, medicago	Leaf, flower	Mineral replenisher, reconstituent	Bra, Chi, Ecu, Ven
Melia azedarach L.	Paraiso	Leaf	Anti-inflammatory	Ven, Pan
Melissa officinalis L.	Toronjil, Melissa	Leaf	Tranquillizer, sedative, digestive	Bol, Bra, Chi, Por,Ven
Mentha citrata Ehrh.	Hierbabuena, menta verde	Leaf	Nervous disorders, cough, stomachache, colic	Bol, Col, Gua, Pan, Spn
Mentha piperita L. / *M. viridis* L.	Menta	Leaf	Digestive, eupeptic	Chi, Ecu, Gua, Por, Ven
Mentha pulegium H. & B.	Poleo, menta, poejo	Leaf	Digestive, aromatic, urinary system	Bra, Chi, Col, Per, Por
Mikania guaco Humb. & Bonpl.	Guaco morado	Leaf	Antiallergic	Ven
Minthostachys mollis Griseb.	Muña	Aerial part	Antiseptic	Per
Momordica charantia L.	Cundeamor, Balsamino	Whole plant	Hypoglycaemic	Pan, Ven
Moringa oleifera Lam.	Ben	Apex	Anti-inflammatory	Ven
Morus alba L.	Morera	Leaf	Hypoglycaemic	Chi
Myrciaria dubia (Kunth) McVaugh	Camu camu	Fruit	Vitamin supplement	Per
Myroxylon peruiferum L. f.	Bálsamo del Perú	Resin	Antiseptic, wound healing	Per
Nasturtium officinale R. Br.	Berro	Whole plant	Bronchitis	Rdom, Ven
Ocimum basilicum L. / *O. sanctum* L.	Albahaca, toronjil	Leaf	Digestive, flavouring agent, antispasmodic	Bra, Gua, Pan, Rdom, Ven
Ocotea caparrapi Nates	Comino	Leaf	Colitis pains	Spn
Olea europaea L.	Olivo	Leaf	Hypotensive	Chi, Por
Origanum vulgare L. / *O. virens* Hoffmanns. & Link / *Lippia graveolens* HBK / *L. micromera* Schauer	Orégano	Leaf	Antispasmodic, aromatic, diabetes	Chi, Col, Por, Rdom, Spn
Panax ginseng C. A. Mey.	Ginseng	Root	Nervous system	Bra, Gua, Pa, Spn

Continued

Scientific name	Vernacular name	Part(s) used	Therapeutic use(s)/indication	Source country(ies)
Papaver rhoeas L.	Papoila	Flower	Sedative	Por
Passiflora incarnata L. / *P. caerulea* L. / *P. edulis* Sims. / *P. ligularis* Juss. / *P. quadrangularis* L.	Pasionaria, pasiflora, granadilla	Aerial parts, leaf	Sedative	Chi, Gua, Pan, Spn, Ven
Persea americana Mill.	Aguacate	Leaf, fruit, seed	Abortive, CVS disorders	Col, Pan, Spn
Petiveria alliacea L.	Apacin, anamú, mapurite, guine	Leaf, root	Febrifuge, abortive, anti-inflammatory	Bra, Rdom, Pan, Spn, Ven
Peumus boldus Molina	Boldo	Leaf, bark	Digestive, hepatic ailments, cholagogue	Bra, Chi, Gua, Par, Spn, Uru
Phyllanthus amarus Schum.	Chancapiedra	Aerial parts	Diuretic, antiviral, hepatoprotector	Ecu, Per
Pimpinella anisum L.	Anís	Seed, fruit	Carminative, digestive, aromatic	Bol, Gua, Par, Por
Piper angustifolium R. & P.	Matico	Leaf	Antiseptic, wound healing	Per
Plantago major L.	Llantén, tanchagem	Leaf	Disinfectant, colds, cancer, wound healing	Bol, Bra, Ecu, Rdom, Spn, Ven
Polypodium aureum L.	Calahuala	Rhizome	Anti-inflammatory, immunomodulator	Ecu, Gua
Prunus vulgaris Schur	Carejeira	Peduncle	Diuretic	Por
Psidium guajava L.	Guayaba	Leaf, fruit	Diarrhoea	Es, Gua, Mex, Pan
Psychotria ipecacuanha (Brot.) Stokes	Ipecacuana, raicilla	Root	Expectorant	Gua, Pan
Quassia amara L.	Hombre grande	Bark	Antiparasitic, tonic	Gua, Pan
Rhamnus frangula L.	Frángula	Bark	Laxative	Chi
Rheum palmatum L.	Ruibarbo	Rhizome	Laxative, appetite stimulant	Chi, Col, Gua, Par
Rosa rubiginosa L. / *R. moschata* Herrm.	Rosa mosqueta, mosqueta	Fruit, seed	Cosmetics	Arg, Bra, Chi
Rosmarinus officinalis L.	Romero	Leaf, flower	Antirheumatic, digestive, flavouring, aromatic, eupeptic, respiratory diseases	Bol, Bra, Col, Esp, Gua, Por, Ven
Ruta graveolens L. / *R. chalepensis* L.	Ruda	Leaf	Pain, nervousness, female disorders	Bra, Col, Por, Rdom, Spn
Salvia spp. / *S. officinalis* L.	Matico, salvia	Leaf	Hepatic disorders	Bol, Bra, Ecu, Por
Sambucus nigra L. / *S. canadensis* L.	Sauco, sabugueiro	Leaf	Laxative, diuretic, flu, respiratory diseases	Bra, Col, Ecu, Gua, Por
Schinus molle L.	Molle, pirú, falso pimiento	Leaf	Diuretic	Bol, Ecu, Per
Silybum marianum (L.) Gaertn.	Cardo mariano, cardo	Seed, flower	Cholagogue, hepatoprotective	Arg, Por, Spn
Smilax utilis Hems. / *S. aspera* L. / *S. lanceolata* L.	Zarzaparrilla, salsaparrilha	Rhizome	Diuretic, antioxidant	Bra, Ecu, Gua, Spn, Ven

Continued

Scientific name	Vernacular name	Part(s) used	Therapeutic use(s)/indication	Source country(ies)
Solanum melongena L.	Berenjena	Fruit	Diuretic, obesity	Col, Ven
Solanum radicans Hill.	Puchun qóra	Leaf	Laxative	Bol
Tabebuia spp.	Palo de arco	Stem	Antiarthritic	Ven
Tagetes lucida Cav.	Pericón	Leaf, flower	Dysentery, flatulence, antimicrobial	Gua, Spn
Taraxacum officinale Wigg.	Diente de león, amargón	Leaf, flower, root	Depurative, hepatoprotective, diuretic	Bol, Bra, Ecu, Per, Por, Ven
Taraxacum officinale F. H. Wigg. group	Diente de león, amargón	Leaf, flower, root	Depurative, hepatoprotective, diuretic	Bol, Bra, Ecu, Per, Por, Ven
Tessaria integrifolia R. & P.	Pájaro bobo	Leaf	Respiratory disorders	Per
Thymus vulgaris L.	Tomillo	Flower	Aromatic, respiratory antiseptic	Bra, Por
Tilia europaea L. / *T. platyphyllos* Scop. / *T. tomentosa* Moench / *Justicia pectoralis* Jacq.	Tilo	Flower, leaf	Sedative, tranquillizer, emollient	Chi, Ecu, Gua, Pan, Por, Rdom, Spn, Uru
Trigonella foenum-graecum L.	Fenogreco	Seed	Emollient, gastritis, ulcers	Gua, Por
Turnera diffusa Willd. / *T. ulmifolia* L.	Damiana	Leaf, flower	Tonic, nervousness	Spn
Tynanthus panurensis (Bureau) Sandwith.	Clavo huasca	Stem	Antirheumatic, aphrodisiac	Per
Uncaria tomentosa (Willd. ex Schult.) DC.	Uña de gato	Bark	Revitalizer, anti-inflammatory	Ecu, Gua, Pan, Par, Per
Urtica dioica / U. urens	Ortiga	Leaf, stem	Antirheumatic, antiallergic	Bol, Col, Ecu, Gua, Ven
Valeriana officinalis L. / *V. jatamansi* Jones / *V. prionophylla* Standl.	Valeriana	Root, rhizome	Sedative, tranquillizer, anxiolytic	Bol, Bra, Chi, Col, Ecu, Gua, Per, Spn
Verbascum thapsus L.	Verbascum	Flower, leaf	Depurative	Por
Verbena littoralis HBK	Verbena	Leaf, flower	Colds, digestive, febrifuge	Col, Gua, Pan
Zea mays L.	Maíz	Stigma	Digestive, diuretic	Ecu, Pan,Por
Zingiber officinale Roscoe	Jengibre	Rhizome	Carminative, antiemetic	Ecu, Pan, Rdom

Ar=Argentina; Bol=Bolivia; Bra=Brazil; Chi=Chile; Col=Colombia; Ecu=Ecuador; Gua=Guatemala; Mex=Mexico; Pan=Panama ; Par=Paraguay; Per=Peru; Por=Portugal; Rdom=Dominican Republic; Spn=Spain; Uru=Uruguay; Ven=Venezuela.

During the period 1992 to 1994, Chile imported about 118 tonnes of medicinal and aromatic plants, corresponding to about US$ 0.32 mn. The main plants imported were ginseng roots (from South Korea and the People's Republic of China), oregano (from Peru), and small quantities of belladonna, cascara, Alexandrian senna, chamomile, valerian, hamamelis, ipecac and salvia. The commercial balance corresponding to medicinal plants was positive during 1992 to 1994.

The essential oils exported from Chile are mainly lemon oil and peppermint oil. In 1994, the Chilean export of essential oils reached 517 tonnes, which corresponded to US$ 0.51 mn. The import of essential oils during the same period reached a volume of 100 tonnes, corresponding to US$ 1.32 mn. The main products imported were citrus oils, although lavender oil was also imported during this same period in small amounts. Cultivation trials for substituting imported products have recently been started.

Argentina

The pharmaceutical industry in Argentina imports approximately 500 tonnes of vegetable extracts and approximately 20 tonnes of heterosides annually worth US$ 8.0 and 1.5 mn, respectively. Argentinean export is approximately 2 tonnes of artichoke extract (US$ 24,000), about 460 tonnes of other vegetable extracts (US$ 3.0 mn) and 11 tonnes of several heterosides (US$ 1.5 mn). Chamomile (*Matricaria recutita* L.) is cultivated and exported on a large scale, primarily to Germany and Italy as a medicinal plant.[10]

In 1996, Argentina exported 1,680 tonnes of lemon oil, valuing US$ 28.7 mn, mainly to the USA and the UK. Argentina also imports essential oils, mainly orange peel oil. The commercial balance on essential oils is very favorable to Argentina, representing an annual income of approximately US$ 35 mn.[11] Table 3 shows the contribution of Latin America, compared to estimated world production, of some essential oils.[12]

Brazil

Brazilian annual import of medicinal plants, plant extracts, glycosides, alkaloids, essential oils (Table 4) and semi-synthetic steroid hormones had a vlue of US$ 40 to 45 mn in the early 1990s.[13]

Imported medicinal plants are liquorice *(Glycyrrhiza glabra* L.*)*, cascara sagrada *(Rhamnus purshiana* DC.*)*, oregano *(Origanum majorana* L.*)* and chamomile *(Matricaria recutita* L.*)*. Exported plants are guarana *(Paullinia cupana* Kunth*)*, tonka beans *(Coumarouna odorata* Aubl.*)* and *Pilocarpus* spp., exported under the name of Aarruda liquorice. Brazil imports heterosides mainly digoxin, diosmin and glycyrrhizin. The balance of heterosides trade is very favorable to Brazil owing to export of rutin, manufactured from native plant *Dimorphandra gardneriana* Tul. Caffeine is the main alkaloid imported, whether natural or synthetic. The balance of alkaloid trade is also favourable to Brazil owing to the export of pilocarpine salts (from *Pilocarpus microphyllus* Stapf. ex Wardleworth): 10 to 12 tonnes per year are produced.

Table 3: Contribution of Latin America compared to estimated world production of some essential oils

Essential oil	Latin American contribution		World production (tonnes)
	Country	Volume (tonnes)	
Turpentine	Brazil	8,000	250,000
	Argentina	4,000	
Cornmint oil	Brazil	100	145,000
	Paraguay	100	
Orange oil	Brazil	18,000	30,000
	Argentina	200	
Lemon	Argentina	2,000	5,400
Eucalyptus (cineole type)	Brazil	70	3,000
	Paraguay	30	
	Bolivia	10	
	Uruguay	10	
Citronella	Argentina	200	2,800
	Brazil	150	
Lavander	Spain	130	1,300
Lime	Mexico and Peru	-	1,200
Lemongrass	Brazil	300	1,000
	Guatemala	200	
Petitgrain	Paraguay	250	300
Vetiver	Brazil	8	200
Palo rosa	Brazil	100	100
Palmarosa	Paraguay	8	55
Cardamom	Guatemala	30	50
Boldo	Chile	-	20
Brazilian pepper tree	Chile and Mexico	-	0.1

Table 4: Brazilian trade on medicinal plants and related products

Products	Import		Export	
	Volume (tonnes)	Value (mn US$)	Volume (tonnes)	Value (mn US$)
Alkaloids	25	15.0	20	30.0
Essential oils	12,500	15.0	-	2.5
Heterosides	20	1.3	300	6.0
Medicinal plants	1,500	1.6	800	3.5
Plant extracts	600	2.5	200	3.5
Steroid hormones	20	12.0	-	7.0

There are six medicinal plants that have been validated scientifically and can be recommended for use: *Ageratum conyzoides* L. (anti-inflamatory), *Cecropia glaziovii* Snethl. (hypotensive), *Maytenus ilicifolia* Mart. ex Reissek. (antiulcer), *Mikania glomerata* Spreng. (bronchodilator), *Passiflora edulis* Sims (sedative), and *Phyllanthus niruri* L. (kidney stones). These plants are being studied from the agronomic point of view with the goal of large-scale cultivation. The Medicinal Plants Germplasm Centre in Brazil maintains many accessions of medicinal plants. Furthermore, Brazil is developing the cultivation of introduced plants such as *Digitalis lanata* Ehrh., *Duboisia myoporoides* R. Br.,

Duboisia leichhardtii (F. Muell.) F. Muell., *Artemisia annua* L., and *Papaver bracteatum* Lindl.

The increasing demand for herbal medicines in both industrial and developing countries is creating a new pattern of medicinal plant harvesting exceeding sustainable capacity. In 1996 and 1997, the World Bank issued reports on medicinal plants, in which it argued that medicinal plants are a possible bridge between sustainable economic development, affordable health care and conservation of vital biodiversity.[14,15]

The demand of the majority of the people in emerging and developing countries for medicinal plants has been met by indiscriminate harvesting of spontaneous flora including that in the forest. The tropical rain forest in South America is suffering loss from deforestation, desertification and diversion of forest lands to agriculture, endangering species of medicinal and economic value. The rational commercial exploitation of natural products from the forest is the only way to avoid destruction by local population and external economic interest in search of short-term gain. Rational exploitation can be achieved with no permanent damage to the ecosystem. Scientific management of already damaged areas can accelerate recovery.

Present Status of Plant-based Pharmaceutical Industry in Latin America

Under the auspices of the Iberoamerican Network on Phytotherapeutic Products (RIPROFITO), a survey has been carried out into the status of plant-based pharmaceutical industry in 21 countries of Iberoamerica. Sixteen countries completed the questionnaire. The following conclusions have been drawn:

- The plant-based pharmaceutical industry in this region is marginal or only just beginning, and its participation in the total pharmaceutical market is very low;
- The manufacturing firms, in general, are small-scale industries that pack dried and pulverized medicinal plants as either individual plants or mixtures, or else formulate them as extracts;
- The industrial infrastructure is generally very poor, with noticeable lack of qualified personnel, and frequently the quality of the final products is questionable;
- Some companies produce pharmacopoeial grade natural products, such as pilocarpine, rutin and hesperidin, while others produce essential oils and vegetable dyes such as bixin, norbixin, and cochineal;
- The isolated natural products are usually directed for export; and
- Few laboratories produce modern dosage forms based on vegetable extracts.

According to this survey, obstacles to the development of a plant-based pharmaceutical industry in Latin America include: lack of awareness of socio-economic and medical benefits of this industry; lack of manufacturing technical know-how; resistance in prescription of phytomedicines by doctors; lack of national and sectorial policy; unawareness or lack of quality control procedures and methods of standardization; difficulty in the availability of large quantities of medicinal plants of high quality; lack of R&D in agrotechnology, pharmaceutical technology, therapeutic validation, etc.; problems in regis-

tration of phytomedicines and other legal issues; lack of awareness of market trends; and lack of government incentives to the phyto-industry in financing, tax exemption, etc.

The national pharmaceutical industry is not encouraged to undertake the manufacture of phytopharmaceutical products, since they do not appear economically feasible, technology is lacking and there is also a lack of confidence in the acceptability of these products. In general, governments and health authorities do not believe that industrialization of medicinal plants will have a significant impact on health care. Reference to plants is made in the context of recovering cultural values of local traditions or as a cheaper alternative because of the limited resources avilable for medical assistance to a population without access to modern drugs.

Only a few countries of the region have serious interest in the utilization of plants. Some countries have national commissions on the utilization of medicinal plants or national research programmes for their study. However, most of the countries do not have a well-defined national policy to stimulate industrialization of medicinal plants and their use in primary health care.

The problem of quality control and standardization of medicinal plants and phytomedicines represents a serious constraint. Only Argentina, Brazil and Mexico have national pharmacopoeias that are currently being updated. The fourth edition of the Brazilian Pharmacopoeia (200 monographs, first and second fascicles, up to Feb. 2001) lists 20 monographs on medicinal plants, of which six cover native plants. The lack of specifications to determine the authenticity, purity and quality of vegetable material is one of the limiting factors for phytopharmaceutical production.

RIPROFITO is engaged in preparing monographs on seven South American plants: *Achyrocline satureioides* (Lam.) DC., *Baccharis crispa* Spreng., *Croton lechleri* Muell. Arg., *Lippia graveolens* Kunth, *Mimosa tenuiflora* (Willd.) Poir., *Petiveria alliacea* L. and *Uncaria tomentosa* (Willd. ex Schult) DC.

A general lack of acceptance of phytomedicines by doctors is another major obstacle. At present, it is difficult to assure a continuous supply of medicinal plants of high quality and in the quantities required in Latin America. This is due to the fact that the majority of the plants are collected from wild sources. With a few notable exceptions, medicinal plants are not cultivated scientifically in the region. Brazil, Cuba and Guatemala, among others, are some of the countries with a few organized programmes for cultivation of medicinal plants.

In the region, there are only a few countries that have experience in handling multifunctional pilot plants, one of which is financed by the United Nations Industrial Development Organization (UNIDO). There is an urgent need for the development of process technologies, protocols of unit processes, quality control and the adaptation of introduced technologies. A lack of awareness in this region of the world market potential of medicinal plants and their products is another major hurdle.

In Latin America, one of the serious problems that has hindered the development of plant-based pharmaceutical industry is the lack of appropriate regulations for registration and quality control of phytomedicines. In practice, all the countries of the region use the regulations of the Food and Drug Administration of the USA (USFDA) as reference for registration and quality control of pharmaceutical products. As a consequence of the dependence of the Latin American Drug Control Organizations on USFDA regulations, registration of phytomedicines has not been possible. Laboratories that work on industrialization of medicinal plants face a difficult problem, since their products are not accepted as drugs and are frequently classified as dietary supplements. The usual approach taken by the regulatory responsible agencies has been to give information regarding the existence of a committee or working group to prepare special regulations for the registration of phytomedicines. In reality, this is an excuse for not facing and solving the problem. While recognizing the problem, these agencies do not provide a solution and as a result there is a lack of quality control of the manufactured phytomedicines, and at the same time the industry feels unprotected because of disloyal competition, and thus does not invest. In addition, there is a difficulty in patenting phytomedicines. There is some initiative for resolving this situation, mainly in Europe, and this can be adopted by Latin America.

Recently, the CYTED programme has published a comparative analysis of existing legislation on registration of herbal products in Iberoamerica.[16]

Contribution of CYTED

CYTED, through its Fine Pharmaceutical Subprogramme initiated in 1990, has made significant contributions to collaborative research and training programmes in the area of medicinal plants. Subprogramme IV has been active in the area of aromatic plants. Currently, Subprogramme X has five thematic networks and four pre-competitive research projects. Over 1,500 scientists are involved on this endeavour.

RIPROFITO is active in organizing training courses on agro-technology, pharmaceutical technology of phyto-therapeutic products, industrialization and quality control of medicinal and aromatic plants. It has organized two workshops in Panama in cooperation with the International Centre for Science and High Technology (ICS-UNIDO), and two courses in Brazil in cooperation with UNIDO. Some of the more significant documents relevant to these workshops have been published.[17-20]

Conclusions

Latin American countries that are producing plant-based products have to overcome several problems to be competitive in the world market. Some of the problems associated with these industries are lack of knowledge in agro-technology, pharmaceutical technology, extraction processes and quality control, high-yielding varieties of medicinal plants, domestication of native species, difficulties of marketing, lack of R&D on product and process development, and lack of qualified manpower. In order to overcome these constraints, developing countries need to develop the technological and scientific capacity for production of plant-derived products of international standards.

Latin American countries have very rich biodiversity and tradition of medicinal plants. However, the phyto-pharmaceutical industry is still in its infancy. Development is found only in bigger countries like Argentina,Brazil, Chile, and Mexico. Furthermore, training workshops and involvement of local governments and private sectors is therefore needed to generate awareness in the other countries of the region.

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Part 2
Quality Control and Standardization

Chapter 9
Quality Assurance of Medicinal and Aromatic Plants

by Sukhdev Swami Handa and Karan Vasisht

Introduction

The World Health Organization (WHO) encourages, recommends and promotes traditional/herbal remedies in national health-care programmes because these drugs are easily available at low cost, comparatively safe, and people have faith in them. Herbal drugs (herbal medicinal products) represent a substantial proportion of the global drug market and in this respect internationally recognized guidelines for their quality assessment are necessary. The WHO Assembly in a number of resolutions, has emphasized the need to ensure quality control of medicinal plant products by using modern techniques and applying suitable standards, and has published quality control methods for medicinal plant material.[1-3]

The single and most important factor standing in the way of wider acceptance of herbal drugs is the non-availability or inadequate standards of checking quality by modern methods. This also hinders modernization or modification of production methods, as there is no way to establish the equivalence of the product made by the modified method with the original. The main reason advanced for the difficulty in developing quality control standards is that most of these products use whole herbs, or parts of plants or their total extracts, and in many cases a mixture of a number of plants. These drugs thus quite often contain a varied number and quantity of chemical constituents. It is challenging to develop suitable standards because a vegetable drug or a preparation thereof is regarded as one active entity in its entirety, whether or not the constituents with therapeutic activity are known. Standardization of a herbal drug is not just an analytical operation ending with identification and assay of an active principle. Rather, it embodies total information and controls necessary to guarantee composition consistency.

Standardization of the presumed active compounds of a plant drug in general does not reflect the reality since only in a few cases drug activity does depend upon a single component. Generally, it is the result of concerted activity of several compounds, some in isolation and inert but contributing to the activity of the plant. Although these inert

components do not directly affect pathological mechanism, it is reasonable to use the complex mixture of components provided by a medicinal plant because the inert components might add to the stability of active components and influence their bioavailability and excretion. If different active compounds are present in a plant drug, they might have additive or potentiating effect.

Directives on the analytical control of a plant drug must take into an account the fact that the plant material has a complex composition. Therefore, the analytical limits cannot be set as precisely as for the pure chemical compound. Plant drugs are inevitably inconsistent and their composition is influenced by several factors such as age of the plant, geographical source and climate, harvesting period, method of drying, storage period and conditions. To eliminate some of the causes of inconsistency, use should be made of cultivated rather than wild plants which are often heterogeneous with respect to above factors and consequently in their content of active principles. All these factors make standardization of herbal medicinal products a difficult task, requiring innovation while applying modern techniques to develop standards for medicinal plants and their products.[4]

Quality Control of Raw (Plant) Material

Consistent quality of herbal medicinal products can only be assured if the starting materials are defined in an explicit and rigorous manner. Each plant used for processing should be botanically identified and checked using its pharmacognostic and chemotaxonomic characteristics. Comparison of a sample from raw material with herbarium specimens maintained in a manufacturing house repository can prove useful. The geographical source, season of collection, method of drying, parts of the plant used, whether fresh or dried, should be recorded. A general protocol followed for quality control of raw plant material is shown in Figure 1.

Authentication

The plant material is collected from an appropriate geographical source at an appropriate stage of its growth and under conditions to ensure consistency of material and hence quality. It is authenticated by detailed taxonomical study and the correct botanical identity is established so that chances of deliberate or unintentional adulteration or substitution are avoided.

Foreign Matter

Plant parts other than those constituting the drug are considered as foreign matter. This also includes any other matter of plant or mineral origin present in the drug sample. The medicinal plant material should be entirely free from soil, stones, dust, insects and other animal contamination including animal excreta.

Organoleptic Evaluation

Organoleptic examination refers to evaluation of the material by means of organs of sense and includes the macroscopic appearance of the drug including its form, surface and size; odour; taste; occasionally the sound or snap of its fracture; and the feel to the touch. It is advisable to compare the drug sample with reference drug to check variability due to individual human perception. The form is in general observed without pre-treatment. However, drugs like herbs, leaves and flowers can be softened by moistening them in water and then spreading on filter paper to examine the true shape of the drug. The colour of the drug is inspected in diffuse daylight or similar light and should match, or be close to the reference sample. When colour is described in a combination of two colours, the latter is the main colour. The odour and the taste should only be determined if the drug is known to be non-toxic. Aromatic drugs should be gently crushed to observe the odour.

Visual inspection is a quick and simple means for establishing identity, purity and to some degree quality of a herbal drug. Carefully dried leafy drugs retain their colour and freshness and over-drying makes them brittle: this can easily be detected by visual examination.

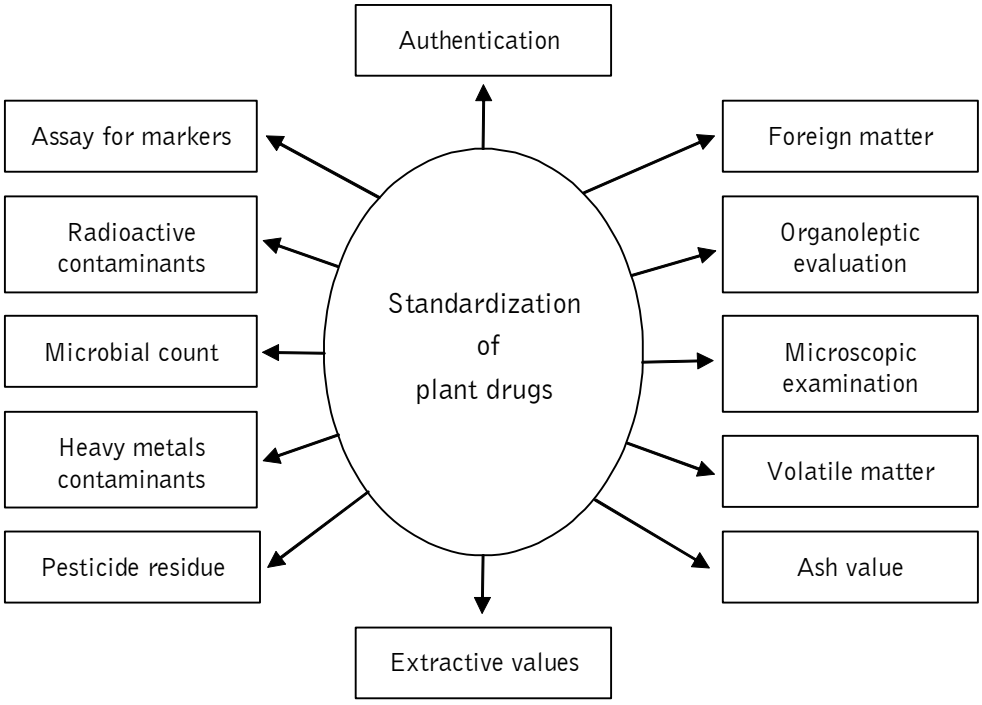

Figure 1: Authentication and standardization of herbal raw material

Microscopic Examination

Microscopic examination of the plant drug is not only essential for the study of adulterants but also in correct identification. The technique is used to determine characters of tissues, cells and cell content in sections, powders or surfaces of herbal drugs.

Diagnostic microscopic features like type of stomata, trichomes, fibres, vessel thickenings and ergastic cell content are of immense value in plant drug standardization. Quantitative microscopy of drugs, which contain a constant number of some parameters like stomatal number, stomatal index and palisade ratio, is of help in differentiating closely allied species.

Volatile Matter

For volatile-oil-containing drugs such as mint, oregano and basil, the volatile-oil content is determined by water distillation using standardized apparatus designed for this purpose. This constitutes an important quality control parameter and the per cent range content of volatile oil is specified for such aromatic drugs in their official monographs.

Ash Value

On incineration, plant drugs leave an inorganic ash. The percentage of ash produced is an indicator of care taken during the processing of plant material, especially for underground parts. The total ash, acid-insoluble ash, water-soluble ash and sulphated ash are determined using standard procedure described in official documents. A high acid-insoluble ash (consisting of silica) in many drugs such as senna, clove, liquorice, valerian and tragacanth indicates contamination with earthy material.

Extractive Values

The determination of extractable matter refers to the percentage of matter extracted from the drug using specified quantity of solvent. Such extractive values provide an indication of the extent of polar, non-polar and medium polarity components present in the plant material. The determination of extractive values is today less relevant since more sophisticated methods of assaying active constituents are available. However, the extractive values in some instances are a quick indicator of gross quality of the plant material.

Pesticide Residues

The use of biocidal agricultural chemicals, collectively known as pesticides, has greatly helped to reduce the presence of insects, fungi and moulds in food. However, their excessive and irrational use has resulted in contamination of soil and water lines. The toxic residues in medicinal plants can result from soil or water line pollution in an area, agricultural practices of using pesticides in cultivation of medicinal plants, or fumigation during storage. Soil or water line pollution in an area can also result in pesticide residues in wild-collected plants, which otherwise are free from them. Since many herbal preparations are taken over long periods of time, limits for pesticide residues should be established following the recommendations of the Food and Agriculture Organization of the United Nations (FAO) and the WHO. These recommended guidelines also give the analytical methodology of determining pesticide residues. Special emphasis is paid to checking the presence of Persistent Organic Pollutants (POPs) like DDT, aldrin, dieldrin and toxaphene congeners, which are not allowed in medicinal plants.[3,5]

Heavy Metal Contamination

Contamination of medicinal plant materials with metals like arsenic, cadmium, lead, mercury and nickel can be attributed to many causes especially to environment pollution from industrial activity. The limits in parts per million of such heavy metals in medicinal plants should remain within specifications.

Microbial Contamination

Medicinal plant materials normally carry a high number of bacteria and moulds, often of soil origin. While a large range of bacteria and fungi forms the naturally occurring microflora of herbs, there may be a need to specify the total count of aerobic microorganisms, yeast, moulds and the absence of specifically objectionable microorganisms. Current practice of harvesting, handling and production often causes additional contamination and microbial growth. The determination of *Escherichia coli* and mould may reflect care taken in production and harvesting. In addition, mycotoxin contamination should be fully considered. The presence of aflatoxins in plant material can cause health hazards if absorbed even in very small amounts. Their presence should be therefore ruled out after using a suitable clean-up procedure. Microbial count should be determined using pharmacopoeial or other validated procedure.

Radioactive Contamination

Radioactive contamination should be tested for if there are reasons for concern. Irradiation may have been used as procedure for microbial decontamination and sterilization of plant materials after harvest. Effluent from adjoining industrial area can contain radioactive contaminants and flow into an area where the plant material is collected. Dangerous contamination may equally result from a nuclear accident. Under all such circumstances strict WHO guidelines should be followed.

Assay for Active Constituents or Marker

The quality of a drug depends on the content of active constituents, the amount of which depends upon a number of factors that affect the quality of crude drugs. In drugs where the active constituents are known with certainty, the amount should be analyzed to assure the quality of the plant material. However, in a number of cases, either the information on active constituents is incomplete or they are not known. Under these circumstances, any one of the chemically characterized components of the plant (called marker) is used as a reference for evaluating the quality of the plant material. Thus, the marker is a constituent of a medicinal plant material that is chemically defined and of interest for quality control purposes. Under most appropriate conditions, the marker should be one responsible for the biological activity of the drug or one of the constituents responsible for the activity. However, when an inactive or inert chemical constituent is used for quality assessment, its choice should be justified. When only inert chemical components are known from the plant, a judicious selection of one of them for marker purposes should be

made giving priority to a component specific to the plant under consideration and its stability. The correlation of inactive marker to quality is indirect on the assumption that since the marker content is appropriate, the unknown active components will also be present in the desired amount. With advancement in isolation and identification techniques, this difficulty will be overcome in the future with the isolation of active constituents of drugs.

At present, a wide variety of analytical tools are available for determining the content of crude drugs. The choice varies from country to country, depending on the existing regulations and facilities available. Chromatographic methods with wide range of sophistication are more important for evaluating the crude drugs. Of the many available chromatographic methods, thin layer chromatography (TLC) has become widely accepted for rapid and positive analysis of plant drugs. It can be used for both qualitative and quantitative determination of components of crude drugs. Qualitative determination of components through TLC requires simple apparatus (affordable in all laboratories of the world). The method is rapid and can be easily mastered. TLC can be used for quantitative purpose using a densitometer. The method has been ultra-modernized, where all steps in the procedure are carried out automatically in a complete automation unit.[6] Quantitative TLC carries advantage over high performance liquid chromatography (HPLC) as it accepts comparatively unpurified samples without much compromise on the efficiency. HPLC and gas chromatography (GC) are used routinely for estimation of components of crude drugs.

The International Conference on Harmonization (ICH) guidelines on validation of analytical procedures and methodology provide internationally acceptable methods of assaying and validation of assay procedures for determining active constituents in plant drugs.[7,8]

Spectroscopic methods including ultraviolet, infrared, fluoremetry, nuclear magnetic resonance (NMR), tandem mass spectroscopy (MS-MS), are now used routinely for analysis of crude drugs. More recently, a combination of chromatographic and spectroscopic method has become more popular for drug analysis. Radioimmunoassay (RIA) is of limited value but is highly sensitive and usually very specific. The plant molecules are generally non-immunogenic, but they are rendered immunogenic by linking to carrier proteins, such as haptens (molecules which combine with antibodies but do not stimulate their production). RIA has been used in the selection of high-yield strains of *Digitalis* and *Solanum*.

Quality Control of Processed Herbal Drugs

General Protocols

The quality control of a herbal preparation is determined by the quality of the starting plant material, development, in-process quality controls, GMP controls, and specifications applied to them throughout development and manufacture. Consistent quality will result from exercising strict control during all stages of manufacturing practices with adequate provisions for batch analysis and using standardized method of preparation. Various processes used in the manufacture of herbal products lack standardized procedures. Thus, the same herbal product prepared by two different manufacturers may vary in its potency and even in the physical appearance. Large-scale commercialization

of herbal drugs necessitates scientifically evolved standardized methods of herbal drugs production. In-process testing may be adopted to ensure consistent quality of finished products rather than relying solely on the testing of finished product prior to market release. It is important to validate manufacturing processes to identify critical steps, selecting appropriate monitoring procedures and periodic review of processes for improvement proposals. The advancement and improvement in technology is taking place continuously and such technologies should be used whenever and wherever feasible.[4]

A universal protocol should be followed to provide information on general characters, identification tests and other applicable tests discussed under quality of raw material, such as inorganic and toxic metal impurities, microbial limits, absence of mycotoxins and pesticide residues besides safety, assay and stability.

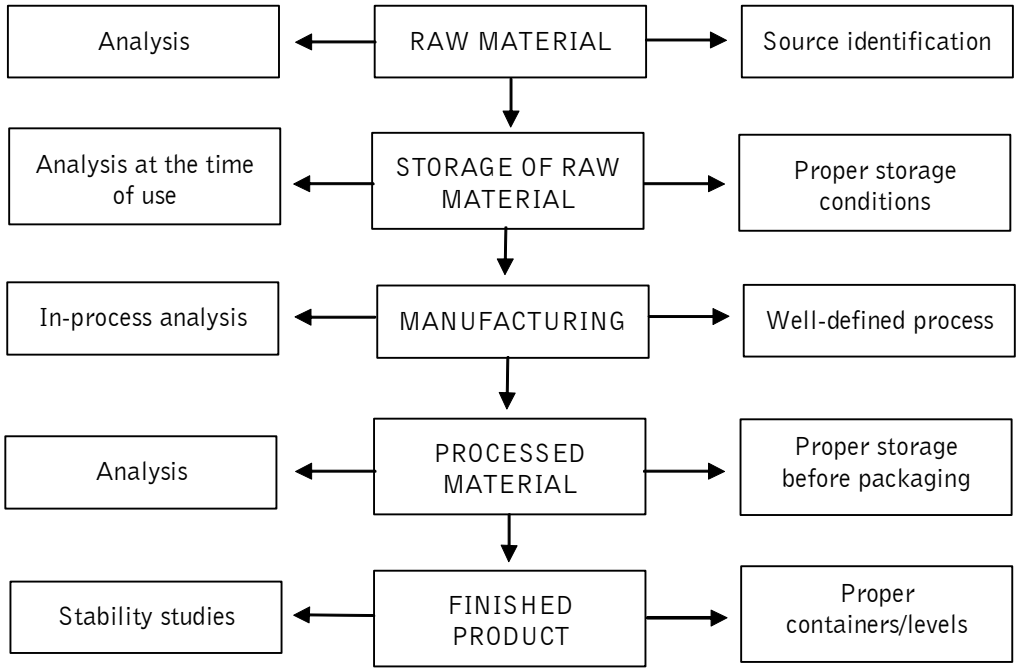

Figure 2: General protocol for standardized production of herbal drugs

Chemical Assay

Qualitative and quantitative characterization of the active ingredients, if known should be made. If the active ingredient(s) are not known with certainty, the preparation should be assayed using marker substance(s). Additionally, the mixture should be analyzed to develop finger-print profile using IR, UV, HPLC, TLC or GC to ensure consistent quality of the preparation.

Bioassay

A bioassay method should be used whenever required. Useful bioassays have been developed for testing a number of biological activities: these are fast and can be used as routine.

Stability

A herbal medicine is a composite mixture of active components with numerous constituents; some of them may be complementary for optimization of the activity. A herbal preparation in its entirety is thus regarded as the active substance. Owing to this inherent complexity of herbal medicines, there may be no single stability indicating assay or parameter to ensure that the other substances present are stable and that their content as a proportion of the whole remains constant. Consequently, in addition to ensuring stability of therapeutically active constituents, the stability of whole preparation should be ensured using some suitable procedure, e.g. finger-print chromatogram on TLC, HPLC or GC; appropriate overall methods of assay; physical and sensory tests or other appropriate tests. If a herbal medicinal product contains several plant materials or preparations of several plant materials, and it is not feasible to determine the stability of each active ingredient, the product stability should be determined by methods such as chromatography, widely used assay methods, and physical and sensory or other appropriate tests. The determination of variation in active constituents and overall profile of the preparation during the proposed shelf-life should be determined and should conform to specifications.

Safety Assessment

In general, documented clinical experience of long-term use without any evidence of toxicity problems should be adequate for risk assessment. However, documented evidence of long use without associated toxicity should be available. If long-term traditional use cannot be documented, toxicity data should be generated. Moreover, in cases of medicines (a) for chronic diseases; (b) for which some adverse drug reactions have been reported; or (c) which are made from plants known to be toxic, it is advisable to carry out some minimal animal toxicity testing to ensure safety. A close watch should be kept on possible adverse reactions since it is not safe to rely only on evidence of prolonged use. It is advisable to undertake toxicity studies in experimental animals of the more widely used traditional medicines, to ensure their safety.[3]

Pharmacopoeial Status of Herbal Drugs

Internationally, several pharmacopoeias including the British Pharmacopoeia, the European Pharmacopoeia, the Indian Pharmacopoeia, the Japanese Pharmacopoeia, the Pharmacopoeia of Republic of China, and the United States Pharmacopoeia have provided monographs stating quality parameters and standards of many herbs and some products made out of these herbs used in these countries. However, basically these pharmacopoeias are designed to cater to chemical based medicines and pharmaceutical necessities by giving their standards and test methods. The International Pharmacopoeia provides tests, methods and general requirements of quality specifications for pharmaceutical substances, excipients and dosage forms. The selection of monographs for the International Pharmacopoeia is determined by the substances included in the current WHO model list of essential drugs. A brief review of few of the important pharmacopoeias concerning quality control of herbal materials and herbal remedies is given below. It

should be noted that a number of them are not official documents in their countries, and are intended only for information.[9]

European Pharmacopoeia (EP)

The European Pharmacopoeia is a common pharmacopoeia for Member States of the European Union. Up until 2002, it had 106 published monographs on herbal drugs, 39 on plant raw material obtained after treatment, 20 on oils and waxes, and 19 on extracts and tinctures. As such, the EP is an outstanding example in furthering the safe use of herbal medicinal products and the continent has most stringent regulations for marketing of herbal medicinal products.[10]

Complete German Commission E Monographs - Therapeutic Guide to Herbal Medicines

This 1998 publication is an English translation of the Commission E evaluation of herbal drugs in Germany. It contains information for 299 herbs (191 approved and 108 unapproved), 8 component characteristics (2 approved and 6 unapproved), 73 fixed combinations (67 approved and 6 unapproved), as well as information on therapeutic indexes, chemical and taxonomic indexes, and European regulatory literature. As such, this is considered the most accurate information in the entire world on the safety and efficacy of herbs and phytomedicines. The new Expanded Commission E Monographs contain an in-depth overview on 107 monographs with clinical research data.[11]

European Scientific Cooperative on Phytotherapy (ESCOP)

The European Scientific Cooperative on Phytotherapy was founded in 1989 by six founder member associations from different countries of Europe, to advance the scientific status of phytomedicines. It has published 60 monographs in 6 collections of 10 each on the most important herbs of Europe. Each monograph represents an overview of current scientific data on a medicinal plant. The ESCOP monographs are recommended for use to support demonstration of the safety and efficacy of a medicinal product.[12]

British Herbal Pharmacopoeia (BHP)

The first British Herbal Pharmacopoeia was published by the British Herbal Medical Association (BHMA) in 1971, giving monographs and quality control tests for some of the common herbs and herbal products in the UK. The new expanded edition of the BHP 1996 contains monographs on 169 medicinal herbs and herbal materials. Each monograph carries detailed macroscopic and microscopic description and simple thin layer chromatographic identification test.[13]

The BHMA is now cooperating with ESCOP to advance the status of phytomedicines and promote the harmonization of regulatory status of herbal medicinal products in Europe.

Ayurvedic Formulary of India and Pharmacopoeial Standards for Ayurvedic Formulations

At present, about 1,000 single drugs and 8,000 compound formulations of recognized merit are used in India. The Ayurvedic Pharmacopoeial Committee (APC) first chose 444 preparations of Ayurveda and listed 458 single drugs used in them. The Ayurvedic Formulary of India, Volumes I and II, containing 444 and 192 formulations respectively, has been published by the government of India.[14]

Ayurvedic Pharmacopoeia of India (API)

The Ayurvedic Pharmacopoeia Committee of India has targeted a pharmacopoeial study on 600 single drugs. The three volumes of part I of the Ayurvedic Pharmacopoeia of India have been published and contain 80, 78 and 100 monographs respectively. The API has become an official document for the standards of plant drugs.[15-17]

Indian Herbal Pharmacopoeia

The Indian Drug Manufacturer's Association in collaboration with the Regional Research Laboratory of Council of Scientific and Industrial Research published two volumes, in 1998 and 1999, of Indian Herbal Pharmacopoeia. The two volumes, each on 20 single plant drugs, give macroscopic and microscopic details, analytical methods based on TLC, HPLC and GLC and simple parameters like ash values and extractive values.[18, 19]

Japanese Standards for Herbal Medicines (JSHM)

The Japanese Standards for Herbal Medicines was published in October 1993. It contains standards for 248 herbal medicines in Japan that are obtained from natural sources such as plants, animals and minerals; these consist of 165 from the Pharmacopoeia of Japan and 83 from the Japanese Herbal Medicine Codex (JHMC). The content of crude drugs given under descriptions are for information and not official standards for conformity.[20]

Pharmacopoeia of the People's Republic of China

The Chinese Pharmacopoeia 2000 is published in two volumes. Volume I contains 992 monographs of Chinese materia medica and traditional Chinese patent medicines. It has 76 new admissions and 248 revisions. The pharmacopoeia describes the botanical origin, the part used for pharmaceutical purposes and the guidelines for collection and post-harvest treatment, the macroscopic and microscopic description, the action, the indications and the contraindications.[21]

The United States Pharmacopoeia and the National Formulary (USP-NF)

The United States Pharmacopoeia and the National Formulary, national pharmacopoeia of the USA, has very recently adopted to include the standards of botanical drugs

(common term on the continent for herbal drugs) and has 28 official monographs on the most commonly used plants in the country. The development and addition of these monographs in the USP-NF is a result of public pressure from the soaring popularity of herbal drugs on the continent.[22]

WHO Monographs on Selected Medicinal Plants

The WHO monographs on selected medicinal plants aim to provide scientific information on the safety, efficacy and quality control of widely used medicinal plants. These monographs are not pharmacopoeial monographs but are intended to allow exchange of information and provide a model to Member States in developing their own monographs. Two volumes of monographs have been published: Volume I (1999) contains 31 monographs on 28 plants. There are two monographs each on aloe, echinacea and senna. Volumes II and III will contain 30 and 31 plants respectively.[23, 24]

WHO Quality Control Methods for Medicinal Plant Materials

This publication of 1998 contains a collection of test procedures for assessing the identity, purity and content of medicinal plant materials. A general protocol for conducting evaluation of plant material is described in the publication.[3]

WHO Guidelines for the Assessment of Herbal Medicines

In 1991, WHO published Guidelines for the assessment of herbal medicines.[25] The objective was to define the basic criteria for the evaluation of quality, safety and efficacy of herbal medicines and thereby help national regulatory authorities, scientific organizations, and manufacturers undertake assessment of the documentation/submission/dossiers of such products. The Guidelines also provide details on the preparations of the documentation and data for the assessment of herbal medicines, and address the following points:

- Assessment of quality including pharmaceutical assessment, crude plant material, plant preparations, finished products and stability;
- Assessment of safety including toxicological studies and documentation of safety based on experience;
- Assessment of the efficacy including activity, evidence required to support indications and combination products;
- Intended use including product information for the consumer and promotion.

The Guidelines suggest classification of herbal remedies into two groups: those with well-established traditional use and newly developed products. It was recommended that the requirements for assessment of these two groups should be different. As a general rule, traditional experience means long-term use, as well as medical, historical and ethnobiological background of the product. Depending on the history of the country, the long-term use may vary but would be of at least several decades.

The Guidelines suggest that all the necessary approaches should be taken to ensure

correct identification of plants. It is noted that when identification of an active principle of herbal medicine is not possible, it should be sufficient to identify a characteristic substance or mixture of substances to ensure consistent quality of herbal medicines. All herbal procedures should be carried out in accordance with Good Manufacturing Practices (GMP).

On safety assessment, these Guidelines suggested:

- All relevant aspects of the safety assessment of a medicinal product should be covered;
- No specific restrictive regulatory action should be undertaken for a traditionally used product without demonstrated harm unless new evidence demands a revised risk-benefit assessment. Documents submitted should provide evidence on long-term use;
- For drugs used over a long period, chronic toxicological risks may have occurred but may not have been recognized;
- If long-term traditional use cannot be documented, or there are doubts on safety, toxicity data should be submitted;
- If any toxicological studies are available, they should form part of the assessment. A review of relevant literature should be provided with original articles or references to the original articles.

As regards to efficacy, the Guidelines suggest that for treatment of minor disorders and for non-specific indications, some relaxation is justified in requirements of proof of efficacy. However, where traditional use has not been established, appropriate clinical evidence should be required.

For combination products, the assessment should differentiate between old and new products. An explanation of a new combination of well-known substances, including effective dose, ranges and compatibility, should be requested in addition to traditional knowledge on each single ingredient. Each active ingredient must contribute to the efficacy of the medicine.

The physical and chemical stability of the product in the final marketing container should be tested under defined storage conditions, and the shelf-life should be established.

The Guidelines suggest that the name of the product, a quantitative list of active ingredients(s), dosage form, indications, expiry date and lot number be included on the label, and package inserts should provide detailed information on the pattern for modern drugs.

The Sixth International Conference of Drug Regulatory Authorities which was held in Ottawa, Canada in October 1991, recommended that the WHO Guidelines for the Assessment of Herbal Medicines be adopted by all Member States and adapted to their local needs as a means of ensuring adequate standards of quality, efficacy, safety and information.

These Guidelines are reported in WHO Technical Report Series, No. 863 and are also included in Chapter 2 of Quality Assurance of Pharmaceuticals: A compendium of guidelines and related materials, Volume I, published in 1997.

During the last decade, scores of publications have been produced by WHO covering practically all aspects of herbal medicinal products to encourage the Member States to integrate the use of alternative or traditional systems of medicine into national health-care programmes and assure their safe use.

Good Manufacturing Practices (GMP)

GMP is that part of quality assurance that ensures that products are consistently produced and controlled to the quality standards appropriate to their intended use and as required by the marketing authorization or product specification.

In most countries, the manufacturing premises of the pharmaceutical industry are inspected and approved by the Drug Controller during the course of operations. This ensures observance of GMP. Wherever production of traditional medicines is undertaken on a large-scale, such units should also be subjected to the system of inspection and registration. Similarly, publication of product information and promotion should be controlled by drug regulatory authorities. The quality and safety of pharmaceutical products is ensured by following proper procedures for inspection and checks before, during and after manufacture; and these cannot be ensured by mere one-time inspection at the end of processing. This facet is becoming increasingly emphasized and thus some voluntary and statutory codes have been developed to ensure observance of GMP. Some points of relevance to good manufacturing practices are listed below for general guidance.[7,8,25,26]

Premises

Building should be located in clean, healthy surroundings, and designed, constructed, adapted, located and maintained to suit the operations carried out therein. Herbal drug manufacturing establishment, pharmacy or factory as far as possible shall not be situated adjacent to an open sewage, drain, public lavatory or any factory which produces an obnoxious odour or large quantities of soot, dust or smoke. The walls of the room(s) in which manufacturing operations are carried out shall be impervious to water and capable of being kept clean. The flooring shall be smooth and even, and shall be such as not to permit retention or accumulation of dust or waste products.

Working Space and Storage Area

The manufacturer shall provide adequate working space (for manufacture and quality control) and adequate rooms for the orderly placement of equipment and materials used in any of the operations for which it is employed so as to minimize or eliminate any risk of mix-ups between different drugs, raw materials of one drug by another drug that is manufactured, stored or handled in the same premises. There shall be adequate space in

storage areas for materials under test, approved and rejected with arrangements and equipment to allow dry, clean and orderly placement of stored materials, and suitable facilities for products wherever necessary under controlled temperature and humidity.

Good House-keeping and Loss Prevention

Facilities, systems and procedures should meet a high standard of safety, orderliness, hygiene and comply with loss prevention policy of the organization.

Equipment

Equipment including services and containers should be designed, constructed, adapted, located and maintained to suit the processes and products for which they are used. Cleaning of equipment may involve use of water and detergent solutions. Wherever necessary, cleaning may involve the use of suitable scrubbers and air pressures for herbal or mineral materials that may have stuck to equipment parts. A brief and stage-wise cleaning procedure for different equipments should be available, and records of all cleaning operations done periodically maintained.

Raw Material

All raw materials including crude herbs, herbal extracts, in process material and recipients shall be properly stored in the separate raw material store, maintained at desired temperature and humidity based on the raw material characteristics. Each bag, drum or any other type of container used for raw material storage shall be properly identified with a label indicating name of material, quantity, source of supply and also clearly stating the status of raw material such as under test, approved and rejected. The labels shall further indicate the identity of the particular supply in the form of batch or lot number, in absence of which the date of receipt of the consignment shall form the distinctive identity number. All raw materials shall be sampled and tested by the quality control chemists and shall be used only on approval after testing. If the technical person rejects raw material, these should be separated from the other raw material in the storage area. Procedure of first in first out should be adopted for raw materials. Records of the receipt, testing and approval or rejection and usage of the raw material shall be adequately maintained.

Production Procedures and Documentation

The batch manufacturing record of each batch of herbal drug irrespective of the type of product (classical preparation or patent and proprietary medicine) must be maintained. Manufacturing records are required to provide an account of the manufacturing history of each batch of the medicine, including method showing how it has been manufactured, what raw materials have been used, whether each of the raw material was tested and approved, tests conducted during the various stages of manufacture (if any) like taste, colour, physical characteristics and chemical tests as may be necessary or indicated in the approved text. Records of finished product produced, and yields obtained,

test report of the finished product packaging records and labelling records shall be maintained. The equipment used shall also be properly labelled, indicating the name of the product and batch number for which it is being used and also indicating the status of machine such as cleaned, ready for use, or under cleaning or under repair, etc.

Packaging Material

All packaging materials like bottles, caps, vials, boxes, cartons and others intended for packaging shall be procured and stored properly. Controls on issue and use of these packaging materials shall be adequately exercised so as to avoid issue of wrong labels, cartons, etc. All containers and closures shall be adequately cleaned and dried before packing the product. Records of such cleaning shall be maintained.

Quality Control

A defined quality control system should exist comprising checking of all incoming materials and finished products. There should be independent overseeing of processes and examining of samples of finished products. The personnel of quality control units should have particular expertise to deal with medicinal plant materials, and should be able to carry out identification tests, check adulteration and confirm uniformity in a consignment of plant materials. Reference samples of plant materials must be available for comparison in visual and microscopic examination and chromatography. The person in charge of quality control should be directly responsible.

Personnel

Staff employed must have the requisite qualifications and training, and must be available in adequate numbers to suit the production processes and products.

Waste Disposal

Suitable arrangements shall be made for the disposal of waste water and other residues from the manufacturing premises in a manner as may not affect the health of the people in the area.

In summary, the following are the basic requirements of GMP:

- All manufacturing processes are clearly defined, systematically reviewed in the light of experience and shown to be capable of consistently manufacturing medicinal product of the required quality and complying with their specifications;
- Critical steps of manufacturing processes and significant changes to the process are validated;
- All necessary facilities for GMP are provided, including appropriately qualified and trained personnel, adequate premises and space, suitable equipment and services, correct materials, containers and labels, approved procedures and instructions and suitable storage and transport;

- Instructions and procedures are written in an instructive form in clear and unambiguous language, specifically applicable to the facilities provided;
- Operators are trained to carry out procedures correctly;
- Records are made, manually and/or by recording instruments, during manufacture to demonstrate that all the steps required by the defined procedures and instructions were in fact taken and that the quantity and quality of the product was as expected. Any significant deviations are fully recorded and investigated;
- Records of manufacture including distribution which enable the complete history of a batch to be traced, are retained in a comprehensible and accessible form;
- The distribution of the products minimizes any risk to their quality;
- A system is available to recall any batch of product from sale or supply;
- Complaints about marketed products are examined, the causes of quality defects investigated and appropriate measures taken in respect of the defective products and to prevent reoccurrence.

Good Agricultural and Good Collection Practices

To ensure high and reproducible quality of medicinal plant raw material free from adulterants, toxic contaminants and undesirable micro-organisms, and to respect the provisions of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), there is a need to establish cultivation of plant material using good agricultural practices. Under good agricultural practices, the crop of medicinal plants should receive the bare necessary amount of fertilizers and pesticides, the cultivable area should be free of industrial pollutants, and all important aspects should be clearly documented. The collecting personnel should have sufficient knowledge of the plant and adequate botanical training, and should be in good hygiene and health. The equipment and method used during collection should be such as to check cross-contamination and the material should be harvested at the stage best to yield highest quality.[28]

Collection from wild habitat often presents special problems with regard to confusion with similar plants, environment damage and lack of control. The collecting personnel are poorly qualified. They should be trained to correctly identify the plants and to follow sustainable harvesting of wild plants. The collections must comply with regional and national conservation legislation. Collection methods should ensure optimum conditions for regeneration of the harvested plants and under no circumstances should they lead to biodiversity degradation. The species that are listed as endangered in CITES must not be collected unless there is a legitimate reason to do so and the necessary authorization of competent authority has been obtained.

The collected material should be free of toxic weeds and delivered as quickly as possible to the processing location. Proper drying and packaging should be carried out to check deterioration of quality and risk of pest attack. The material should be stored in a well ventilated place that restricts the entry of rodents and insects. The control of temperature and humidity should be adequate to the place of storage.

Regulatory Bottlenecks with Herbal Drugs

Since in many countries herbal medicines are not clearly regulated by law and products are therefore unregistered and not controlled by regulatory bodies, a special licensing system is needed. This should offer opportunities to screen the constituents to demand proof of quality before marketing and to ensure a correct and safe use, and also to oblige licence holders to report suspected adverse reactions with a post-marketing surveillance system.

In 1994, the WHO Office for the Eastern Mediterranean published the Guidelines for Formulation of National Policy of Herbal Medicines, and in November 1995 WHO prepared a draft on worldwide review on the regulatory status of traditional herbal medicines.

Major Constraints in Herbal Drug Standardization and Guidelines for Strengthening Quality Control

Main Dependence on Wild Sources

Raw material is primarily collected from wild sources: this results in variable quality owing to a number of factors such as ecotypic, chemotypic, genotypic and ontogenetic variations. This can be avoided by resorting to cultivation of medicinal plants used in herbal drug production. Certification of genuine raw material by an appropriate authority may ensure quality of raw material.

Adulteration and Substitution

Trade in medicinal plants is extremely disorganized and there are deliberate or undeliberate attempts to adulterate or substitute a genuine drug. Certification of authenticity of the plant material by a recognized agency in a state or district may assist in making available the genuine plant material for human consumption.

Multilingual Nomenclature

In Southeast Asian countries, a plant is popularly known by its local name: these vary widely with the different languages practised in various parts of a country. For this reason, the medicinal plants wherever used as herbal drugs must be referred to by their botanical names and authorities.

Public Test Houses for Herbal Drugs

A number of countries at present have complete absence of testing facilities of herbal drugs. Every state and district needs to encourage establishment of test houses for the analysis of herbs and herbal drugs. WHO could take the initiative to set up these test houses initially in some selected national and regional research laboratories which offer facilities for analysis. Uniform protocols based on herbal pharmacopoeias and WHO

Guidelines may be adopted and these centres may be authorized to issue certificates of authentication. An initial investment in this direction could provide a permanent solution for the establishment of plant drug testing houses in the long run.

Preparation of Herbal Drug Manual or Herbal Pharmacopoeia

There is an urgent need to make available monographs on quality control of each plant used for herbal drug production. Southeast Asian countries must encourage the production of their respective herbal pharmacopoeias. WHO has published monographs on important plants of the world, which can be used as a model for preparing such monographs in each country. The use of herbal products is very well regulated in the Europe, and the European Pharmacopoeia contains over 180 monographs on medicinal plants and their products.

Poor Investment in R&D for Establishing Standards of Herbal Drugs

Very few attempts have been made to evolve standards for herbal drugs. R&D institutions engaged in herbal drug development must give priority to setting internationally acceptable standards for plant drugs.

Lack of Safety Evaluation Facilities

Quite a number of herbal drugs are introduced without confirmation or establishment of safety aspects. Facilities for establishing safety of herbal drugs need to be made available.

Absence of Herbal Drug Regulations

Many countries of Africa, Latin America and Southeast Asia have not yet framed regulations for production, quality control, distribution and sale of herbal medicines. There are sometimes unsupported claims of use of herbal drugs or exaggerated therapeutic claims. In the absence of herbal drug regulations in the country, such exploitation cannot be checked.

Lack of Trained Manpower

In most countries, the state drug testing laboratories do not have the appropriate trained manpower for undertaking quality control of herbal drugs. The absence of standards for herbal drugs and lack of trained staff hampers implementation of any regulation on quality control of herbal drugs.

Conclusions

WHO and the Southeast Asian region have long realized the potential value of traditional remedies including medicinal plants (herbal drugs) which constitute the greater part of traditional medicines.

In dealing with traditional/herbal medicine, it is the aim of WHO to provide safe and effective remedies for use in primary health care. Consequently, countries supported by WHO should place special emphasis on the utilization of herbal medicines by establishing a fixed-term plan for activity on Standardization and Quality Control of Herbal Medicines. The objective of this activity should be to assure the quality of herbal medicines, particularly those widely and commonly used by local populations, and to promote their utilization in primary health-care programmes by:

- Initiation of steps towards the establishment of national policies and planning strategies for overall domestic development of herbal drugs on aspects such as promotion of the use of herbal medicines in national health-care delivery systems, establishment of regulatory authorities and steps towards improvement of agricultural and industrial production;
- Development of methodologies for assessing efficacy of medicinal plants;
- Development of regulatory mechanisms for introducing plant-derived drugs and herbal preparations from traditional pharmacopoeias into health-care delivery systems;
- Developing programmes and strategies for the improvement of traditional medicines by setting standards and quality-control procedures for the production of herbal drugs on industrial scale to meet primary health-care needs;
- Development of agro- and process-technologies and sharing the innovations among countries of the region, as well as development of quality control, safety standards, standardization of bioassay procedures and implementation of regulatory requirements;
- Promoting cultivation using good agricultural practices and employing appropriate post-harvest technology to maintain quality of raw material for production of herbal medicines and preparing manuals on cultivation, production and quality of herbal medicines for common use;
- Human resource development by imparting training and initiatives leading to the development of indigenous skills and capabilities to adopt and innovate methods for establishing quality control of herbal drugs;
- Conducting systematic surveys and exploration of natural resources to have assured supply of quality raw materials for herbal drug production to stimulate investment in this sector;
- Establishment of mechanisms for regional cooperation for preservation, propagation, crop improvement of medicinal plants in cooperation with international organizations;
- Collation of exchange of information, establishment of regional databases on plants, exchanging herbal material used for reference purposes and establishment at sub-regional and international levels of information networks covering technical and other aspects.

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Chapter 10
European Harmonization Efforts for the Quality of Medicinal and Aromatic Plants

by Arnold Vlietinck

Introduction

The legal situation regarding herbal medicinal products varies from country to country. In some, they are well-established, whereas in others they are regarded as food and therapeutic claims are not allowed.[1] For classification of herbal medicinal products, factors such as product description in a pharmacopoeia monograph, its prescription status, claim of a therapeutic effect or period of use are considered by the regulatory authorities. Some countries draw a distinction between officially approved and officially recognized products, under which the latter can be marketed without further scientific assessment by the authorities.

In countries where herbal medicinal products are neither registered nor controlled by regulatory bodies, a special licensing system is needed. Its goals would be to enable health authorities to screen constituents, demand proof of quality before allowing marketing, ensure correct and safe use, and also oblige licence-holders to report suspected adverse reactions within a post-marketing surveillance system.[2, 3]

The situations in Europe and in the USA are diametrically opposed, and a brief assessment of the situation in the USA can allow appreciation of European Union (EU) effort to ensure quality of herbal medicinal products marketed within its Member States.

Legislative Framework in the USA

In the past, most herbal medicinal products were regulated as food, and only a few were listed by the Food and Drug Administration (FDA) in Over-the-Counter (OTC) monographs.

The Nutrition Labelling and Education Act (NLEA) of 1990 required all food manufacturers to include nutritional labelling, and the FDA to establish criteria for approving health benefit labelling for foods. The intention of the NLEA was to increase the amount

of information available to the consumers. However, the FDA took an aggressive stance and planned to regulate food supplements as drugs. As a result, an exemption to the NLEA was introduced noting that vitamins, minerals, herbs and similar nutritional substances are consumed differently from conventional food, and thus should be subject to more lenient standards of evidence for their health benefits.

In 1994, the Dietary Supplement Health and Education Act (DSHEA) came into force. This established that dietary supplements may be useful in preventing chronic diseases and therefore help to limit long-term health-care costs. Herbs and other botanicals, vitamins and minerals now fall under the definition of dietary supplements and include all such products presented in dosage forms such as capsule, tablet, liquid, etc., and those not presented as a conventional food, but labelled as dietary supplement.

The law provides that a dietary supplement is considered to be a food that does not need pre-market approval by the FDA unlike a food additive that does need this approval. A statement on the label of a dietary supplement is permitted if a benefit is claimed related to a classical nutrient deficiency, if the role of the nutrient or the dietary ingredient is established, or if the mechanism of action to maintain a biological function is characterized. In addition, however, it needs to be clearly stated that this statement has not been evaluated by the FDA, and that this product is not intended to diagnose, treat, cure or prevent any disease. Furthermore, the ingredients, e.g. the plants or parts of plants and their quantity, must be clearly stated. If the dietary supplement claims to conform to standards laid down in an official compendium (United States Pharmacopoeia) but fails to meet them, then the product is regarded as misbranded. This also applies to a product that is not covered by an official compendium and fails to match the identity, strength, quality and purity as stated on its label.

The new law provides for the establishment of an Office of Dietary Supplements within the National Institutes of Health which should explore the role of dietary supplements to improve health, and should promote scientific studies of the benefits of dietary supplements.

At present, the possibilities for marketing a herbal medicinal product as a drug and claiming its medicinal value are low, because the FDA does not accept bibliographic evidence of effectiveness, but prefers randomized controlled trials as evidence of efficacy.

Legislative Framework in Europe

The EU has developed a comprehensive legislative network to facilitate the free movement of persons, services, food and capital within its Member States. According to Council Directives 65/65/EEC and 75/318/EEC, pharmaceutical products require premarketing approval before gaining access to the market. Requirements for the documentation of quality, safety, and efficacy, the dossier and expert reports are laid down in Council Directive 91/507/EEC. Council Directive 75/319/EEC obliged the Member States to check all products on the market at that time, with a deadline of 12 years, to determine

whether they meet the requirements of these directives. Different countries have taken different approaches in reviewing herbal medicinal products.[4]

Harmonization Efforts

In the European Community, two new registration procedures for human and veterinary medicinal products to achieve free movement of medicines within the EU common market have been established.

In the centralized procedure, which is compulsory for medicinal products derived from biotechnology and available at the request of companies for other innovative products (not for well-established products), applications are submitted directly to the European Agency for the Evaluation of Medicinal Products (EMEA) in London. Their assessment is conveyed to the Commission for transformation into a market authorization applicable to the whole EU. This procedure does not apply to well-established products.

The decentralized procedure, applicable to conventional medicinal products, is based on the principle of mutual recognition of national authorization. This procedure provides, as a general rule, that an assessment by one national authority should be sufficient for subsequent registration in other Member States. Under this procedure, the Summary of Product Characteristics (SPC), approved by the first authority, must be taken into account. If difference in evaluation occurs between national authorities, a decision will be reached through a European Community procedure. For herbal medicinal products, uniform criteria regarding assessment of safety and efficacy do not exist at present at European level, and therefore there is only a guideline for the quality of herbal medicinal products.

European Scientific Cooperative on Phytotherapy (ESCOP)

The European Scientific Cooperative on Phytotherapy was founded in 1989, with main objectives to establish harmonized criteria for the assessment of herbal medicinal products, to support scientific research and to contribute to the acceptance of phytotherapy at European level.

The ESCOP Scientific Committee, comprised of delegates from each Member State, was first given the task of compiling proposals for monographs summarizing the medicinal uses and safety of plant drugs. The first fifteen monographs were published during 1990-92 and submitted for assessment to the Committee for Proprietary Medicinal Products (CPMP) of the EMEA.

On the advice of the CPMP, the format of the SPC was adopted for subsequent documentation. Since November 1992, the ESCOP Scientific Committee has been working on proposals for SPC on individual plant drugs, primarily those for which European or National Pharmacopoeial Monographs exist.

In preparing drafts, the ESCOP Scientific Committee has the advantage that it can incorporate the views, knowledge and experience, not only of different nationalities, but

also of individuals from a variety of scientific and professional background. The Committee has two sub-committees and assesses information from published scientific literature on each plant drug with the assistance of leading researchers on specific plants, who are invited to the meetings of the Committee for discussion and critical evaluation of the literature. Drafts prepared by the sub-committees are then circulated to an independent Board of Supervising Editors for appraisal. Where appropriate, comments are incorporated into the final version. By the end of 1999, no fewer than six fascicules comprising ten SPC each had been published.

Although after thorough assessment the CPMP published only four ESCOP monographs on anthraquinone laxatives in May 1994, many other ESCOP monographs have been or are being assessed by the EMEA Working Group on Herbal Medicinal Products (HMPWG). These are then drafted as core SPC and distributed as working documents. In this way, no fewer than 16 ESCOP monographs have been assessed and distributed by the HMPWG.

EMEA Working Group on Herbal Medicinal Products (HMPWG)

In 1997, the European Parliament and the European Commission requested the creation of a working group on herbal medicinal products at the EMEA. On the proposal of the EMEA Executive Director, the Management Board established an *ad hoc* working group on herbal medicinal products at the EMEA in June 1997 to address the issue of quality, safety and efficacy of herbal products.

Consequent to the 1997-98 report on the activities of the *ad hoc* working group on herbal medicinal products, the Management Board in February 1999 endorsed the proposal to make the group to become a permanent working party of the EMEA.

A new mandate of the EMEA HMPWP has been drawn up, bearing in mind the intention of the European Commission to improve the existing regulatory framework for mutual recognition as a part of the review of the European Marketing Authorization System, and to introduce a new directive on traditional herbal medicinal products.

Mandate for the EMEA Working Party on Herbal Medicinal Products (HMPWP):

The revised mandate for the HMPWP has been adopted by the EMEA Management Board in December 2001 (EMEA/HMPWP/76/01). The main thrusts of the mandate are to facilitate mutual recognition of marketing authorizations in the field of herbal medicinal products and minimize CPMP arbitrations, and to give technical advice in the preparation of a future EU directive on traditional herbal medicinal products and support its implementation:

- By creating a forum for exchange of experience in the field of herbal medicinal products among Member States;
- By providing guidance to competent authorities for the assessment of herbal medicinal products; and
- By providing guidance to applicants on marketing authorizations for herbal medicinal products.

To serve these purposes, the following tasks will be continued:

- Development of new guidance and common criteria for interpretation on how to adequately prove quality, safety and efficacy of herbal medicinal products, with particular reference to:
  - new scientific data;
  - well-established use of herbal medicinal products as referred to in bibliographic applications for marketing authorizations making use of scientific literature, WHO, ESCOP and European Pharmacopoeial monographs wherever they exist.
- Establishment and regular update of a common understanding of existing legislation and guidelines with relevance to herbal medicinal products. In particular, the HMPWP will discuss:
  - the suitability of relevant parts of the Notice to Applicants;
  - the application of Community legislation on well-established medicinal products to herbal medicinal products;
  - the existing provisions in the Good Manufacturing Practices of herbal medicinal products and starting materials;
  - theexisting quality, safety and efficacy guidelines for herbal medicinal products; and
  - the need to further develop European Pharmacopoeial monographs in collaboration with the European Pharmacopoeia.
- Advice given upon request to the Mutual Recognition Facilitation Group (MRFG) and upon request to the CPMP in case of arbitration on herbal medicinal products.
- Advice given upon request to the European Commission on relevant proposals for legislative amendments.

Herbal Medicinal Products in the European Union 2000-2001

A compilation of documents prepared from 1997 to 1999 by the HMPWG were presented in a report available from EMEA, while the results obtained in 2000-2001 are given below:[6]

Regulatory Aspects

Final Comments for the Revision of Notice to Applicants (NTA):

The *ad hoc* HMPWG suggested the inclusion of tabular formats specific to herbal medicinal products in the Notice to Applicants Vol. 2B Part I C1 (EMEA/HMPWP/16/99).

Integration into the Common Technical Document (CTD), July 2001:

The CTD is an internationally agreed format for applications to be submitted to regulatory authorities in Europe, the USA and Japan - the three International Conferences on Harmonization (ICH) regions. From 1 July 2003, all new applications should be made in accordance with the EU-CTD presentation outlined in the 2001 edition of NTA, Vol. 2B or its updates. In the meantime, companies are encouraged to use and switch to the CTD format as soon as possible.

Legislative Initiatives

Directive on traditional herbal medicinal products, draft No. 3, May 2001 marks significant changes in the policy of the European Commission. The highlights of the draft are:

- The title of the Directive has been changed from traditional medicinal products to traditional herbal medicinal products. This change restricts the accommodation of the traditional medicines derived from animal and mineral sources;
- A new clause in Article 3 of the Directive strictly limits the sale of OTC products directly to the public without the intervention of trained herbalists;
- Clause 3 in Article 5 of the Directive has been deleted to simplify the registration of herbal medicinal products; and
- The important role of the centralized committee has been emphasized by the inclusion of the sentence, "It shall fulfil further responsibilities conferred upon it by this Directive and other Community law, in particular with regard to the implementation of Commission Directive 1999/83/EC as far as herbal medicinal products are concerned" in Article 14 of the Directive.

Quality Issues

The following quality issues have been addressed during the period:

- The document on Good Agricultural Practices (GAP), issued by the European Herb Growers Association (Europam) of 5 August 1998, formed the basis for Good Agricultural and Collection Practices for the starting material of herbal origin (EMEA/HMPWG/31/99);
- Previous comments released by the Working Party including comments on the draft directive on the GMP guide for starting materials of medicinal products and inspection manufacturers (EMEA/HMPWG/17/99) and comments on the GAP document from Europam, 5 August 1998 (EMEA/HMPWG/18/99);
- The GMP inspectors services agreed at their meeting on 10 May 2001 that the Annex 7 "GMP Provisions on Herbal Medicinal Products" (EMEA/HMPWG/7/99) could be revised. A general statement that pharmaceutical producers should follow GAP should be included, rather than a binding text which would be impossible to implement. This modification was proposed at the meeting of HMPWG in July 2001; and
- The note for guidance on quality of herbal medicinal products (CPMP 28/19/00 and CVMP/814/00) and the note for guidance on specifications (CPMP/QWP/2820/00 and CVMP/815/00) were finalized. These documents were prepared by the HMPWG, reviewed by the Quality Working Party (QWP) and endorsed by the CPMP and the CVMP.

The HMPWG also exchanged information and promoted a common understanding of existing guidance and legislation (EMEA/181123/00/Rev.3) on the use of excipients in herbal teas; large variation in specifications of markers; quality of water (potable water versus purified water) to be used in preparation of extracts and finished products; and acceptability of reference to organic farming in either labelling or package leaflet of a herbal medicinal product.

The revision includes references to Note for guidance on quality of water for pharmaceutical use (CPMP/QWP/158/01 and CVMP/115/01) and the minutes of the 49th Pharmaceutical Committee Meeting with regards to mention of organic farming and accreditation logos. Communication with external partners such as the annual hearing with interested European associations from industry, scientific societies, health professionals and consumer organizations is much welcomed.

European Pharmacopoeia

At the Nice Conference in November 2000 on the Quality Evaluation of Herbal Medicinal Products, a number of issues were raised for consideration by the European Directorate for the Quality of Medicines (EDQM). These include microbial purity, water quality for the production of extracts, mycotoxins, pesticides and heavy metals. The microbial quality of pharmaceutical preparations is included in the topics for harmonization with Japan and the USA under ICH, and the European Pharmacopoeia is the coordinating pharmacopoeia. A harmonization proposal for the test methods has been presented in Pharmeuropa 13-1.

A proposal for acceptance criteria for the various categories of preparation (including herbal drug preparations) is being developed and will be published for comments.

The draft on extracts and tinctures was published in the October 2000 issue of Pharmeuropa for comments. The comments were discussed at a special session of the European Pharmacopoeia in June 2001, with the aim of presenting a revised text for adoption to the Commission of the European Pharmacopoeia.

The fourth edition of the European Pharmacopoeia has been published in both book and CD-ROM form. It came into force on 1 January 2002. Four supplements to the edition have been published to date. The online version is also available on internet.

Conclusion

At levels of both the EMEA and the European Pharmacopoeial Commission, much effort has been made to improve the European legislation and address the specific requirements of herbal medicinal products. The mutual recognition and bibliographic application for herbal medicinal products has been adopted in the light of experience gathered by competent authorities and applicants.

New legislation on traditional medicinal products at European level has been started and will be implemented soon.

The distinction between traditional medicinal products and food supplements containing herbal medicinal products without nutritional value but having physiological activity remains vague and controversial, and regulation at Member State national level remains appropriate for the time being.

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Part 3
Bio-pesticides

Chapter 11
Scope and Potential of Bio-pesticides in the Emerging Environmental Concern

by Chika Ukwe

Introduction

In the last decade, one of the essential goals set by most governments of emerging and developing countries to gauge their success in governance has remained the ability to satisfy the food needs and infrastructure facility requirement of their citizens.

Owing to a combination of factors including natural disasters (drought and desertification, famine, pest infestation, global climatic changes and its associated impact on global warming, etc.) and man-made disasters (wars, resource conflicts, irrational resource exploitation and unsustainable government policies), emerging and developing countries have found it increasingly difficult to meet their food and basic service needs.

Most emerging and developing countries are largely dependent on agriculture as a mean for generating foreign exchange and income to meet the needs of governance. Agriculture accounts for a significant portion of the total gross domestic products (GDP) of most developing countries, reaching about 40% GDP of Nigeria. Thus, it could be rightly said that agriculture has continued to remain a significant sector in the economy of emerging and developing countries. For instance, agriculture has remained the driving force of the Ethiopian economy with 90% of the population dependent on farming for their livelihood. Resource and environmental constraints have raised concerns regarding the capacity of the agricultural sector to respond to the demands placed on it and on its sustainability. Part of the concern is with the feedback of the environmental impact of agricultural intensification on agricultural production itself. These include degradation and loss of soil resources due to erosion, water logging and salinity associated with irrigation, co-evolution of pests and pathogens associated with the use of chemical controls, impact of global climate change and loss of biological diversity.[1]

Recently, the amount of food produced by these countries has not been sufficient to satisfy their needs: this has resulted in widespread food shortages as in sub-Saharan

Africa. The ever-increasing population in these countries has worsened the situation. This has necessitated the urgency on governments to increase food production within the limits of available resources, funds and arable lands. The response of the international community to reported cases of food shortages as a result of famine, drought and desertification, internecine wars, and huge pest infestations has been in the massive "donation" of agricultural produce and synthetic chemical pesticides, and to curb hunger and control the incidence of pest infestation. In Ethiopia, most development agencies have provided pesticides as part of their food security programmes because losses to pests are often high in cereal crops, particularly during outbreaks of migratory pests such as locusts, armyworms and grain-eating quelea birds.[2]

While this strategy adopted by developed countries in solving the food shortages faced by emerging and developing countries may have paid off in the short run, it has left huge environmental problems for these countries to deal with in the long run. The majority of these "donated" pesticides have been found to be toxic to humans and persist for a long time in the environment (air, land and water). Despite a ten-fold increase in the use of chemical insecticides since World War II, the loss of food and fibre crops to insects has risen from 7 to 13%.[2] Due to their ability to persist, bio-accumulate and disperse over long distances, these chemical pesticides and their by-products have been termed persistent organic pollutants (POPs).

Demand and Distribution of Synthetic Chemical Pesticides

The increasing use of a wide range of toxic chemicals deliberately released into the environment is causing widespread concern about their impact on human health and the damage caused to the environment, particularly in emerging and developing countries, which lack appropriate resources to minimize the risks and rectify problems.[3] The pesticides in emerging and developing countries are sprayed on a variety of foods (e.g. maize, rice, soybean) and non-food crops (e.g. cotton and tobacco) of which large amounts are exported to developed countries. Although pesticides can be beneficial to society, they can be dangerous if used carelessly or not stored properly.[4]

There has been a substantial increase since the 1940's in chemical pesticide sales and use in both developed and developing countries; predictions are that pesticide use will continue to grow over the next five years. Large quantities of pesticides are exported from developed countries to emerging and developing countries and these exports are increasing each year.[3] Sadly, many of these exported pesticides have been banned, restricted or not registered for use in the country of manufacture. Exports include significant amount of chemicals classified as "hazardous" or "extremely hazardous" to human health by the World Health Organization (WHO). In 1996, ten companies controlled over 80% of the global agrochemical market valued at US$ 30 bn in 1995. About 25% of agrochemical sales are in emerging and developing countries and this figure is increasing.[2] Some countries, such as India, have the ability to manufacture their own pesticides and use or export these pesticides, many of which have long been banned in developed countries.[3]

In Nigeria, there is the difficulty of accurately quantifying the demand for pesticides due to the reluctance of agrochemical sellers and companies to release data on pesticides sales and use in the country.[5] Almost all the pesticides used in Nigeria are still imported while the indigenous agrochemical companies are engaged in blending or mixing of imported materials. Only five companies in Nigeria are primarily involved in the blending and distribution of agrochemicals. These companies are affiliates of international chemical companies (Table 1).[5]

Table 1: Chemical companies involved in blending and distributing pesticides

Company	Chemicals
Chemical & Allied Products (CAPL)	Garmalin 20, pyrethroids, actellic, gramaxone, grammon
National Oil and Chemical Marketing Company	Aldrex 40, kokotine, sandox, vetox 35WP, arkotine D25, phostoxin
Ciba Geigy (Swiss Nigeria Chemical Company)	Nuvacron, elocron, dimecron 50 SCW, primextra, gesaprim galex 500EC
Co-operative Supply Association (CSA)	Copper sulphate
Basidhem Limited/Procida	Capsitex, BBS procida

The storage and handling of pesticides, even when products are in good condition, present significant hazards to those working with the pesticides, the public at large and the environment.[6] The adherence to good practices and guidelines such as those produced by the Food and Agriculture Organization of the United Nations (FAO) and the Global Crop Protection Federation, an umbrella body representing major pesticides manufacturers based in Europe, the USA and Japan, can minimize risks by eliminating exposure, or reducing it to a minimum.[6]

Public Health Risks Associated with Pesticides

The effects of POPs on health and the environment range from acute toxicity to intergenerational endocrine disrupting effects.[6] The poor storage and leakage of obsolete pesticides result in greater human exposure and environmental contamination than would normally be the case. The former FAO Director General, Dr. Jacques Diouf, captures succinctly the health risks associated with chemical pesticides saying, "*Many pesticides that have been banned or whose use has been severely restricted in industrialized countries are still marketed and used in developing countries. These chemicals pose serious risks to the health of millions of farmers and the environment".* It appears that a significant proportion of the pesticides used in emerging and developing countries on food and non-food crops are WHO class 1a (extremely hazardous) or class 1b (highly hazardous), and individuals apply many of these with little or no training in safe application or storage. Although FAO recommends that WHO 1a and 1b pesticides should not be used in developing countries, they are cheaper than less hazardous alternatives and therefore used most oftenly.[3] The consumption of food with high levels of chemical pesticide residues can cause acute poisoning while the chronic effects of consuming lower levels of pesticides over a long period of time are still not fully known.[3] The effects of pesticide residues on foods are a concern for both developed and developing countries.

It has also been reported that synthetic chemical pesticides have continued to pose major human and environmental risks particularly in the developing world despite progress made in producing more efficacious and safe pesticides.[7] A survey by the United States Environmental Protection Agency (EPA) regarding pesticides used in and around the home revealed some significant findings:

- Almost half, 47%, of all households with children under the age of five had at least one pesticide stored in an unlocked cabinet, less than 4 feet off the ground (i.e. within the reach of children); and
- Approximately 75% of households without children under the age of five also stored pesticides in an unlocked cabinet, less than 4 feet off the ground (i.e. within the reach of children). This number is especially significant because 13% of all pesticide-poisoning incidents occur in homes other than the child's home.

Studies of farmers and their families repeatedly show that there is a high risk of exposure to toxic pesticides through lack of protective clothing, leaking spray equipment, mixing and application of pesticides with bare hands, and storage of pesticides with food.[3] Recent estimates suggest that pesticides account for more than 20,000 fatalities yearly, most of which occur in emerging and developing countries, making agriculture one of the world's most hazardous industries.[8] In 1985, WHO estimated that there were 3 mn acute, severe pesticide poisonings and 20,000 accidental deaths each year. In 1990, the estimated cases of acute occupational pesticide poisoning in emerging and developing countries reached 25 mn each year.[9] With the continued increase in the use of pesticides, it is to be expected that this figure will also increase.

The International Labour Organization (ILO) report of 1996 draws attention to dangers in the agricultural sector, where pesticides cause 14% of all known occupational injuries and 10% of all fatal injuries.[2] About 50% of all pesticides related illness and 72.5% of recorded fatal pesticide poisoning occurs in emerging and developing countries, although these countries account for only 25% of the pesticides used worldwide.[10] The recognized authorities have classified 60 pesticide active ingredients as carcinogenic to some degree, and 118 as disrupting hormonal balance.[2]

A study carried out in Ethiopia for instance revealed that there were significantly lower levels of cholinesterase activity (low levels interfere with the function of the nervous system and are indications of exposure to POPs) among workers on state farms confirming absorption of POPs formulation.[11] Awareness of pesticide hazards was extremely low, with only 12% of workers knowing the danger of poisoning and attempting some precautionary measures. In India, hundreds of people die from pesticide poisoning each year. A survey of pesticides residues in food samples collected in 12 states found residues in 85% of samples with 43% above the recommended doses.[12] A seven-year study by the Indian Council of Medical Research released in 1993 analyzed 2,205 cow and buffalo milk samples from 12 states. Hexachlorocyclohexane (HCH/lindane) was detected in about 85% of the samples, with up to 41% of the samples exceeding tolerance limits. DDT residues were detected in 82% of the samples and 37% contained residues above the limit of 0.05 mg/kg, in some cases 44 times higher at 2.2 mg/kg.[13]

Environmental Risks and Pest Management

The environmental issues associated with the use of chemical pesticides against locust and similar pests are reviewed by Ritchie and Dobson and Berger and Associates.[14,15] Considering questions of environmental risks when actions are taken against pests has become increasingly important. Environmental risk involves technical understanding of risks, public perceptions, and public influence, as well as fundamental questions regarding the principles and goals for pest management.[16] A study by Scott *et al.*[17] has indicated that the integration of laboratory and field toxicity testing and biomonitoring methodologies are needed to provide holistic environmental risk assessment for pesticides. Application of this method in the environmental risk assessment for three classes of pesticides: organochlorines-endosulfan, pyrethroids; fenvalerate; and organophosphates-azinphosmethyl have been demonstrated in assessing the effects of non-point source agricultural run-off on sensitive estuarine tidal creek fauna in South Carolina.[17] According to Scott *et al.*,[17] the study reported that over a three-year period, the integration of the approach provided significant data to assist environmental regulators trying to control recurrent problems of agricultural run-off effects in the Leadenwah creek and other areas of South Carolina, the USA.

As pointed out by Perkins in his book *Insects, Experts, and the Insecticide Crisis*, the goal of many workers in pest management is to address the needs of farmers.[18] An estimated one-third of global agricultural production valued at several billion dollars is destroyed annually by over 20,000 species of field and storage pests.[19,20] The post-harvest losses are much higher in the tropics because of the more favourable climates, which offer storage insects optimum temperature and humidity conditions for their development and reproduction.[21]

The synthetic chemical pesticides have been used to eradicate pest infestation of agricultural produce and in disease control due to their effectiveness, relatively long shelf-life, and the ease with which they can be transported, stored and applied.[22] These have at the same time contributed to reduction of incidence of pest infestation of crops, but have also resulted in serious problems such as toxicity to humans, pollution of soils, water and air,[22-24] and the development of pesticide resistance necessitating the use of larger and larger doses at increasing cost to the farmer and to society as a whole.[22,25,26]

The pesticide residues may also contaminate surface water bodies as well as aquifers in areas with high water tables.[27-29] Methyl bromide for instance has been reported to reduce soil biodiversity and cause air pollution in neighbouring areas, and is classified as an ozone-depleting substance.[27] The environmental contamination is prohibitively expensive to remedy. A major goal of pest management should be to minimize environmental impacts of the use of pesticides through development of national pesticide policies, pesticide risk awareness-raising, and risk reduction through integrated pest management.[16]

International Concern and Convention on Persistent Organic Pollutants (POPs)

The growth in world trade of chemicals during the 1960's and 1970's has led to increasing concerns about the risks of using hazardous chemicals, one example being pesticides in emerging and developing countries which did not have the necessary expertise or infrastructures to ensure their safe use.[30]

Numerous hazardous synthetic pesticides are classified as persistent organic pollutants. POPs are a class of chemicals that persist in the environment, are capable of long-range transport, bio-accumulate in human and animal tissue and have significant impacts on the human health and environment, even at low concentrations.

Over the years, increasing evidence of the damage caused by these classes of pesticides to human health and environment has been reported and has received the attention of the international community.[29] These pesticides are highly mobile, and do not respect arbitrary geopolitical boundaries. An approach of joint management within a transboundary will be of benefit on local/regional and global scales and is being demanded urgently. Recognizing the inherent dangers in the continued use of synthetic chemical pesticides, the international community under guidance of the United Nations (UN) initiated action in the early 1990s on a much wider geographical scale to achieve a reduction in the levels of POPs and indeed pesticides. These concerns led to the development of the International Code of Conduct on the Distribution and Use of Pesticides by FAO, and the London Guidelines for the Exchange of Information on Chemicals on International Trade by the United Nations Environment Programme (UNEP). The concerted international actions have also resulted in the adoption of several conventions and protocols related to pesticides management. Some of these include the POPs protocol to the Convention on Long-range Transboundary Air Pollution in 1998, the Global Programme of Action for the protection of the marine environment from land-based activities in 1995, the Convention on the Prior Informed Consent Procedure (PIC), and more recently the Stockholm Convention on Persistent Organic Pollutants in May 2001.[17]

The objective of the Stockholm Convention on POPs is to protect human health and the environment from these pollutants. The Convention is global in scope and multimedia in coverage, which means that it promotes reduction and elimination of "total releases" to all media: air, land and water. It initially focuses on twelve chemicals (nine of which are pesticides), which can be grouped into the following three categories:[7]

- Pesticides: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene (also an industrial chemical and unintentional by-product), mirex and toxaphene;
- Industrial chemicals: polychlorinated biphenyls (PCBs) - also unintended by-products; and
- Unintended by-products: dioxins and furans.

The United Nations Industrial Development Organization (UNIDO) participated actively in all the interagency cooperative events, international meetings and intergovernmental negotiating committees that led to the intergovernmental negotiations for the

preparation of the Stockholm Convention and has been recognized by the Global Environment Facility (GEP) as a POPs implementing agency owing to its comparative advantage in this field.[7]

Obsolete Pesticide Stocks and Disposal Efforts

The obsolete pesticides are defined as stocked pesticides that can no longer be used for their original purpose or any other purpose and therefore require disposal.[31] FAO has warned that huge amounts of obsolete and unused pesticides continue to threaten human health and the environment in many emerging and developing countries. FAO has urged the international community to increase its efforts to solve "this environmental tragedy". The stocks of obsolete pesticides are present in the majority of emerging and developing countries and the quantities in individual countries range from a few tonnes to several thousands.[31] In 1994, FAO conducted an inventory of obsolete pesticide stocks in Africa and the Near East. The recent estimates from FAO suggest that there are more than 100,000 tonnes of obsolete pesticides in emerging and developing countries, with 20,000 tonnes in Africa. The amount of stocks in the Near East countries is estimated at 5,000 tonnes.[6] The enormous stocks of pesticide waste also exist in Eastern Europe and parts of the former Soviet Union; several countries in Asia and Eastern Europe have stocks in excess of 5,000 tonnes each. Owing to environmentally sound disposal facilities, stocks are constantly increasing, some over 30 years old. In Africa particularly, large proportions of obsolete pesticides are leftover from earlier foreign assistance programmes. They can no longer be used because they are now banned or have deteriorated as a result of prolonged storage.

The storage conditions in emerging and developing countries rarely meet international standards. In many countries, pesticide containers are kept in the open; containers deteriorate and leak their content into the soil, contaminating soil, water and groun dwater.[31] Most stocks are located in urban areas or near water bodies putting groundwater, irrigation and drinking water at risk.[6] Many of these chemicals are so toxic that a few grams could poison thousands of people or contaminate a large area. Among the highly toxic and persistent pesticides in obsolete stocks identified by FAO were aldrin, DDT, dieldrin, endrin, HCH, lindane, malathion, parathion and others.[6]

According to FAO, in Africa and the Near East only 1,511 tonnes have been disposed of in 10 countries (Niger, Uganda, Madagascar, Mozambique, Zanzibar, Yemen, Tanzania, Zambia, Seychelles, Mauritania). In Nigeria, a collaborative effort between UNIDO, FAO and the Federal Ministry of Environment led to the organization in early 2001 of an awareness-building workshop on hazardous waste and obsolete pesticide stocks. This is being followed by an inventory-training workshop on obsolete pesticides and hazardous wastes, which will lead to a full inventory of obsolete pesticide stocks in Nigeria before disposal.

The total costs to remove obsolete pesticides in Africa alone are estimated at more than US$ 100 mn. The preferred way to dispose of obsolete pesticides is high tempera-

ture incineration. None of the emerging and developing countries, except for a few recently industrialized, have facilities for the safe and environmentally sound disposal of pesticides. Instead, these are repacked and shipped to a country with a hazardous waste destruction facility. Unless prevention occurs, FAO has warned, it is likely that accumulation of hazardous pesticides in the environment will continue unabated since the worldwide sales of pesticides increased substantially in the mid-1990s.

The main causes for the accumulation of pesticides according to FAO are:

- Pesticides banned while in storage;
- Inability to forecast pest outbreaks and excessive donations;
- Unsuitable products or packaging;
- Poor assessment of pesticides requirements (donations made out of season);
- Inadequate coordination among and within aid agencies;
- Inadequate storage facilities and poor stock management;
- Ineffective or wrong pesticide formulations; and
- Aggressive sales practices and commercial interests of the pesticide industry.[31]

The long-term solution to disposal problems lies in preventing accumulation of obsolete pesticides, according to FAO. The stocks should be kept as small as possible and pesticide use should be drastically reduced. FAO has called upon its members to apply integrated pest management and to reduce the use of pesticides wherever possible.

Integrated Pest Management (IPM): A Paradigm Shift in Pest Control

Integrated pest management is an approach to pest control that utilizes regular monitoring to determine if and when treatments are needed. The approach employs physical, mechanical, cultural, biological, chemical, and educational tactics while minimizing economic, environmental, and human health risks, to keep pest numbers low enough to prevent unacceptable damage or annoyance.[32-35]

Control programmes for eradicating pests have failed, especially in emerging and developing countries largely for economic and other reasons. Prior to the latter decades of the 19th century, farmers relied almost exclusively on cultural methods such as crop rotation in their efforts to control pests. Chemical controls began in the 1870s with the development of arsenical and copper-based insecticides. The use of biological control dates from the late 1880s when the Vedelia beetle (from Australia) was introduced to control the California citrus pest, the cottony cushion scale.[1] Efforts were also made to identify, develop and introduce pest-resistant crop varieties and animal breeds.

During the 1950s, increasing evidence suggested that the benefits of the pesticides introduced in earlier years had been obtained at a substantial cost. These included not only the increase in resistance to pest control chemicals in target populations and the destruction of beneficial insects, but also direct and indirect effects on wildlife populations and human health.[1]

IPM has emerged as the solution to the pesticide crisis, and requires skill in pest monitoring and understanding of insect ecology. In IPM programmes, treatments are not made according to a predetermined schedule but only when and where monitoring has indicated that the pest will cause unacceptable economic, medical, or aesthetic damage. The treatments are chosen and timed to be most effective and least hazardous to non-target organisms and the general environment. However, expectations regarding possible dramatic reductions in pesticide use, achieved without significant decline in crop yields as a result of adoption of IPM, have not been realized.[36-38]

It is becoming apparent, however, that the principles of IPM are useful in virtually any situation where a species has been ascribed pest status.[35] For example, in nursery and greenhouse ornamental production, reliance solely on chemical pesticides to limit insect and disease problems is yielding to IPM. In storage, processing, and distribution systems for cereal grains, unilateral reliance on chemicals for management of a variety of pests (insects, rodents, and microorganisms) is evolving towards integrated approaches with greater emphasis on sanitation, aeration of stored grains, even stocking plans for reducing infestations once packaged products have reached grocery store shelves.[39, 40]

Emergence of IPM Programmes: Reversal to Environment-friendly Methods

The use of plants and species of organisms antagonistic to plant pathogens to reduce pest impacts has a long history.[41] The toolbox of IPM approaches includes a wide range of effective, safe and economical alternatives to the use of POPs pesticides. These include biological pest control techniques such as pheromone traps and pest-mating disruptors, augmentation of native beneficial insects and microbial formulations. There are three general approaches to biological control, importation, augmentation and conservation of natural enemies. Each of these techniques can be used either alone or in combination in a biological control programme.[41] The biological control agents are generally highly specific, but some control a wide range of pathogens. *Trichoderma* spp., for example, control species of *Plasmopara, Pseudoperonospora, Rhizopus, Verticullium*, wood rot fungi, etc.[42]

Increasingly, governments, bilateral donor organizations, and other institutions are promoting IPM solutions and alternatives to POPs to reduce reliance on toxic pesticides. Organizations active in this field include UNIDO, FAO, World Bank, UNDP, and UNEP. In early 1995, these organizations with the exception of UNIDO established the Global IPM Facility to support research and implementation of IPM systems. The initiative has assisted the development of farmer-centred IPM programmes in West, East, and Southern Africa. It is now expanding to include the Near East, Central Asia and Latin America.

The Lutte Biologique Contre les Locustes et Sauteriaux (LUBILOSA) programme has developed a biological control method against locust and grasshoppers, consisting of a fungus, *Metarhizium anisoplia* var. *acridum* (flavoviride), a specific and highly virulent ocust and grasshopper disease.[43] The spores of the fungus are produced at the International Institute of Tropical Agriculture (IITA) research station, Cotonou, Benin Republic and can easily be stored. They are used as a pesticide by mixing them with an oil formu-

lation and applying them with a standard spinning disc sprayer. Field tests on different locust and grasshopper species in several countries have revealed the efficacy of the product: a consistent high mortality is reached, although achieved speed of kill is less than with chemical pesticides. In Mali, tests have been conducted in Moudiahand in the Dogon plateau.[44,45] The farmers generally displayed a positive attitude towards the biological control of locusts and grasshoppers. Most villagers who attended the demonstrations easily recognized its comparatively slower action, but acknowledged its longer persistence.[43]

Biological control is most effective when combined with other methods such as solarization and alternative fumigation techniques, the use of certain grafting methods or resistant varieties. It plays an important role in IPM approaches but, used alone, it does not meet the requirement of intensive production systems.

IPM strategies incorporating the use of biological control methods and the following elements have been shown to be most effective in pest reduction:[46]

- Tissue culture and strict sanitary conditions together with appropriate greenhouse design;
- Use of insect traps and pheromones;
- Monitoring of soil nutrients, oxygen content and moisture;
- Continuous checking of weather variables;
- Use of disease- and insect-resistant varieties;
- Use of organic soil amendments, natural pesticides, *Tagetes* spp. and other trap crops, cover crops and controlled traffic to growing areas.

Combining an environmentally sound method of soil disinfections such as solarization, with soil enrichment using beneficial micro-organisms, appears to be particularly promising.[46]

The integrated crop production systems have been developed in many parts of the world and have considerably improved the sustainability of agriculture.[27] Over the past two decades, the Asian and Pacific regions in particular have received assistance through UNDP/UNIDO and FAO for strengthening the national capabilities in pesticide development and safer and effective formulations by replacing toxic, persistent carriers/ingredients with water-based user and eco-friendly formulations.[7] Crop rotation, planting time, deep ploughing, flooding and water management, fallowing, use of cover crops, fertilization and plant-growth substrates are important elements of IPM approaches and can help in the management of a wide range of pests and diseases, especially as environmental and health considerations may limit the use of most pesticides.[46]

Experience with IPM implementation by the Global IPM Facility and others has shown that participatory approaches that work closely with farmers are the most effective means of achieving the twin goal of food security and environmentally sustainable agriculture. Training farmers to understand the ecology of their fields and become IPM experts enables them to significantly reduce or eliminate the use of highly toxic pesticides while maintaining yields. The reduction of expenditure on pesticides improves farm income and contributes to household and national food security.[47]

Bio-pesticides as Alternatives to Synthetic Chemical Pesticides

The widespread use of chemical pesticides has left (especially in emerging and developing countries) a painful series of consequences which has made necessary a conscious search for bio-alternatives today.[48] These consequences range from stockpiling and accumulation of stock to field application of pesticides. They also touch on issues of legislation and non-enforcement as well as ignorance and illiteracy.[49]

Scope and Potentials

Bio-pesticides are pest-management tools based on beneficial micro-organisms (bacteria, viruses, fungi and protozoa), nematodes or other safe biological active ingredients (Table 2).[3] The benefits of bio-pesticides include effective control of insects, plant diseases and weeds, as well as human and environmental safety. These also play an important role in providing pest management tools in areas where pesticide resistance, niche markets and environmental concerns limit the use of chemical pesticide products.

Table2: Some examples of biological control

Type of control	Examples
Insect control by:	
Bacteria	*Bacillus thuringiensis, B. sphaericus, B. popilliae, Serratia entomophila*
Viruses	Nuclear polyhedrosis viruses, granulosis viruses, non-occluded baculoviruses
Fungi	*Beauveria, Metarhizium, Entomophaga, Zoopthora, Paecilomyces, Normuraea*
Entomopathogenic nematodes	*Steinernema, Heterohabditis, Romanomermis*
Others	Pheromones, parasitoids, predators, microbial by-products
Weed control by:	
Fungi	*Alternaria, Colletotrichum*
Bacteria	*Xanthomonas*
Plant disease control by:	
Nematode trapping fungi	*Arthrobotrys*
Competitive inoculants	-
Composts, soil inoculants	-

Plant pathologists have been highly successful in using antagonists against some harmful plant pathogens. At least 30 different biological control organisms are currently available as commercial formulations for suppressing plant diseases.[50]

Pesticides of Plant Origin

Plants are known to produce contact poisons for rodents and insects, which penetrate the proboscis of the pest especially those with sucking mouths. Natural plant products and their analogues are an important source of new agricultural chemicals [51-55] used

in the control of insect pests [56] and diseases [55,57-59] with a view to countering the obvious pollution problems and hazards associated with the use of synthetic pesticides and to avoid the toxic effects of these chemicals on non-target organisms. Plants with insecticidal and repellent properties such as neem (*Azadirachta indica* A. Juss.) also offer a cheap and therefore cost-effective alternative to the large-scale pest control programmes using organophosphates and other chemicals.[60] Nigeria, for instance, is well endowed with abundant natural plant products that are still to be explored for possible exploitation against major pests that incite diseases and destroy food crops.[49]

In Ghana for example, Cobbinah recorded a total of 88 plant species used for pest control in the various farming communities of the Ashanti region.[61] The most commonly mentioned species are *Chromolaena odorata* (L.) R. M. King & H. Rob., *Azadirachta indica* A. Juss., *Capscium annuum* L., *Nicotiana tabacum* L., *Piper umbellatum* L., *Griffonia simplicifolia* (Vahl ex DC.) Baill. and *Vernonia amygdalina* Delile. Plant parts such as the leaves of *Nicotiana tabacum* L. with insect repellent activities have been used to preserve food crops. Some plants with pest control properties are given in Table 3.

Table 3: Plants with pesticidal properties

Botanical name	Family	Property
Azadirachta indica A. Juss.	Meliaceae	Systemic poison, insect repellent
Carica papaya L.	Caricaceae	Larvicidal
Cassia nodosa Buch.-Ham. ex Roxb.	Fabaceae	Larvicidal
Crotalaria retusa L.	Fabaceae	Insecticidal
Hyptis spicigera Lam.	Lamiaceae	Insect repellent
Nicotiana tabacum L.	Solanaceae	Contact poison, insect repellent
Terminalia catappa L.	Combretaceae	Insecticidal

Bio-pesticide R&D in Emerging and Developing Countries

Biological pesticides based on pathogenic micro-organisms specific to their target pest offer an ecological and effective solution to pest problems. Such bio-pesticides are an alternative to chemical pesticides, which continue to be used inappropriately, particularly in emerging and developing countries, threatening the environment and human health.[62]

The past 20 years have produced an impressive literature on bio-herbicides (almost all involving fungi). However, use of these materials has been largely disappointing.[63] The USA has registered only three bio-herbicides for commercial use, and these were all withdrawn subsequently by the manufacturers.[63,64] In a recent review on biological control of weeds, it was concluded that bio-herbicides are still unproven as practical, economically viable alternatives to chemical or mechanical weed control.[65] Some weed scientists remain optimistic that deployment of indigenous pathogens has considerable potential in weed IPM programmes of emerging and developing countries.[66]

If produced, formulated and applied in appropriate ways, bio-pesticides can provide ecological and effective solutions to pest problems. They have been shown to be effective in controlling pests that have developed resistance to chemical pesticides, leave little or no toxic residues, and are generally harmless to beneficial insects and other non-target organisms. A major benefit is that they are safe for use by humans, and represent a very much reduced hazard in terms of disposal and reuse. Chemical extracts from the neem tree (*Azadirachta indica* A. Juss.) have also been patented as natural insecticides.[67]

Bio-pesticides have not been adequately evaluated in terms of their costs relative to their benefits to farmers and others using them.[68] Dale (1999) is of the view that mere use of bio-pesticides in pest control programmes is not proof that they (or other control methods) are actually necessary. Examples to support this view from both developed [69] and developing countries [70] show that farmers commonly reduce insecticide use by 50 to 100% without any loss in crop yield after switching to IPM. In most cases, the IPM farmers do not deliberately replace the withdrawn insecticides with other control methods. This is worth nothing when predicting future trade-offs to pesticides in IPM schemes.[68]

There is thus the need and further reason for studying plants with pest control properties: such knowledge, including gene characteristics, will also pave the way for possible utilization with ensuring environmental advantages and human development, as well as providing ample evidence of its effectiveness in pest control programmes.

Selected Case Studies of Success in Bio-pesticides Development and Use

By the 1970s, research institutions around the world had started major programmes to develop new or improved alternatives to conventional pesticides.[68] Optimism was high that future pest control schemes would increasingly incorporate novel methods including bio-pesticides. More than 90% of total sales of bio-pesticides are Bt (*Bacillus thuringiensis)* products.[71] Bt is commonly used to control insect pest resistant to conventional insecticides, in glasshouse and urban environments where human exposure is a special concern and on food crops grown for organic markets.[72] Especially attractive markets are the minor (and often high value) food crops in developed countries. Bt is, nevertheless, a highly important pest control tool for many farmers, orchardists, foresters, and house owners. About 0.81 mn hectare of USA crops received Bt treatments in 1992.[73]

Emerging and developing countries have produced some of the best examples of use of bio-pesticides. Natural plant products have been used to control insect pests[56,74] and plant diseases in Nigeria and some other West African countries. Cold and hot water leaf extracts of *Carica papaya* L. were effective in reducing the growth of powdery mildew fungi *in vitro* and in reducing the spread of powdery mildew disease on pepper (*Capsicum annuum* L.).[58] Anthracnose disease of cowpea caused by *Colletotrichum lindemuthianum* was controlled using extracts of *Cymbopogon citratus* (DC.) Stapf and *Ocimum gratissimum* L. in Nigeria.[23, 24] The anti-fungal potentials of *Azadirachta indica* A. Juss. against some pathogenic organisms have been investigated. Amadioha and Obi[23] reported that hot water infusion of the leaf and oil extracts from the seeds of *Azadirachta indica* A. Juss.

significantly reduced spore germination and radial growth of *Colletotrichum lindemuthianum* in culture and checked the spread of anthranose disease in cowpea.

Extracts of *Azadirachta indica* A. Juss. and *Cymbopogon citratus* (DC.) Stapf were found to possess considerable disease controlling potential, and were recommended for exploitation as pesticide of plant origin to control soft rot of potato tuber caused by *Rhizophus oryzae* in storage.[59]

Brazilian farmers have obtained exceptional control of the velvet bean caterpillar *Anticarsia gemmatalis*, by spraying suspensions of nuclear polyhedrosis virus (NPV) to soybean *Glycine max* L. Merr.[75] Soybean farmers in some areas of Asia have also been successful with bio-pesticides, deploying *Beauveria bassiana* to control the soybean pod borer *Leguminivora glycinivorella*. Chinese farmers apply *B. bassiana* to the soil surface to infect larvae dropping from the plants over winter.[76] However, soybean farmers in neither Brazil nor China rely entirely on bio-pesticides to control target pests: these substances are just one component of the IPM programme.[68]

Policies, Regulatory Frameworks and Registration of Bio-pesticides

A range of recent international conventions are having an impact on policies relating to biological control.[77] Pro-pesticides policies, including subsidies and donations, have been very common in West Africa.[78] Many countries have now adopted IPM as part of their national crop protection strategy to diversify away from unilateral dependence on chemical products, promoting alternatives such as microbial insecticides.[79]

There has been a considerable change in most donor priorities, with more attention focusing on environmental conservation and protection of biodiversity since the United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro in June 1992.[80] The Convention on Biological Diversity has the potential of substantial impact on the use of biological control agents.[81] Some agencies are no longer supporting pesticides purchase at all because of strong environmentalist lobbies in their countries of origin.[80] The origin of Green Muscle TM, a bio-pesticide, is an example of donor positive response to public concern over excessive use of synthetic chemical insecticides during the desert locust plague in the late 1980s.[82] According to Langewald and Cherry,[80] a further motive for introduction of microbials to West Africa, as in developed countries, is development of resistance to chemical insecticides.

In most countries, before a pesticide product can be marketed and used to manage a pest problem, the product must be registered with a government agency responsible for regulating the sale, distribution and use of pesticide products.[83] For instance, in Nigeria, four government agencies - the Federal Ministries of Environment and Health, the National Agency for Food and Drug Administration and Control (NAFDAC) and the Factory Inspectorate Division of the Federal Ministry of Labour and Productivity - regulate and manage the import, export, use, registration and disposal of chemicals including pesticides in the country. The Pesticide Registration Regulation of 1996 provides the legal

framework for the registration and use of pesticides in Nigeria. As awareness of the potential impact of pesticides on user, consumer and environment developed, the registration of pesticide products became the predominant method for regulating the use of a pesticide product.[83]

The regulations and guidelines for the registration of microbial pesticides have been in place in most developed countries for less than 15 years.[84] A survey by the Organization for Economic Cooperation and Development (OECD)[85] on data requirements for bio-pesticide registration found that this was well underway for various types of bio-pesticides in OECD member countries, and that many countries had adopted similar requirements in structuring their data. The FAO guidelines on the registration of biological pest control agents[86] provided an essential basic framework. They were followed by the FAO Code of Conduct for the Import and Release of Exotic Biological Control Agents.[87] The regulating applicators of pesticide products include two steps: first, pesticide products designated for restricted use must be labelled accordingly during registration process; and secondly, a system of pesticide applicator training and certification must be implemented to ensure that only trained applicators are granted a licence to purchase and use pesticide products labelled for restricted use.[83] Since pesticide regulations differ from one country to another, guidelines on pesticide regulations are provided by an International Code of Conduct on the Distribution and Use of Pesticides adopted by delegates of the FAO conference in 1985.[88] But while registration of pesticides has become more predictable in many major markets,[89] available information suggests that in Africa, the pesticide regulatory framework is still poorly developed. Although many countries in West Africa do have their own framework, few have the resources to adequately implement or polish the system.[80]

In the USA, the EPA published in 1974 the standards for certification of applicators of restricted use pesticides in the Federal Register. The general standards prescribed for all categories of certified commercial applicators required demonstration of competence on label and labelling pesticide safety, environmental effects, knowledge about pests, knowledge about pesticides, equipment use, application techniques and State and Federal laws and regulations.[83,90]

Constraints to Bio-pesticides Commercialization

However, despite the enormous potential of bio-pesticides as substitutes for chemical pesticides and for use in IPM programmes, their development, commercialization and use has not yet lived up to expectations.[62] The enthusiasm for biological pesticides as environmentally benign alternatives to chemicals resulted in a flush of start-up bio-pesticide companies in the 1980s. The expected surge in demand for biological agents arising from increasing environmental awareness failed to materialize, and many companies have downsized, disappeared, or refocused their efforts. While plants have been used for pest control for many years in Ghana, the slow pace of scientific verification and development, the ready availability of the synthetic pesticides, the stigma of backwardness associated with their usage and the absence of marketable formulations have precluded their development and large-scale production.[61]

The market for bio-pesticides is growing but still represents less than 1% of the total crop protection market and most of this is accounted for by-products based on Bt *(Bacillus thuringiensis)*.[71,89] Currently, bio-pesticides capture a mere 1.4% (US$ 380 mn) of the US$ 28 bn global market for pesticides; and natural enemies and antagonists (including microbials, predators, parasitoids) comprise only US$ 164 mn of the US$ 8 bn insecticide market. At present, it is estimated that 185 bio-pesticide products (72 bacteria, 47 fungi, 40 nematodes, 24 viruses and 2 protozoa) are used worldwide.[91] Various reasons explain the lack of product development and market penetration of bio-pesticides including:

- Expectations that the multinational agrochemical companies would take a lead in product development;
- Over-investment from "venture capital" initiatives;
- Pursuance of an inappropriate model for bio-pesticide development based on small research teams lacking the multidisciplinary expertise required;[92,93]
- Lack of incentives, regulations and political support from government in order to tilt the competition in favour of bio-pesticides as against the less expensive conventional pesticides.

The continued development of bio-pesticides in the future will be largely dependent on the public sector as the multinational private sector seeks better investment prospects from biotechnology.[92] The synthetic chemical pesticide subsidies are wide-scale in the developing world and as long as they continue, bio-pesticides and other alternatives will lag.[68]

The expertise required to develop a bio-pesticide includes: exploration, identification and screening of pathogen isolates, mass production, storage, formulation, application, ecology, toxicology and eco-toxicology, registration and commercialization.

Prospects for Commercialization of Bio-pesticides

Many emerging and developing countries have research expertise in bio-pesticides and an adequate level of technology. However, just as in many developed countries, there is a gulf between good research ideas and implementation and adoption of a new technology. Bio-pesticide research is usually funded piecemeal, largely by the public sector, and rarely involves multidisciplinary teams that develop a microbial insecticide from start to finish.[93] The general knowledge base in bio-pesticides is built up in a haphazard way, through the uncoordinated efforts of scientists pursuing their individual research interests. This is the case for instance in Nigeria, where research into bio-pesticide formulation from plants, in particular the neem tree (*Azadiracta indica* A. Juss.), has been dispersed and non-focused with several scientists and institutions conducting research independently without collaboration. This contrasts markedly with the more focused factory-like screening and development process, which characterizes agrochemical research, and development that produces new chemical pesticides.[93]

Successfully identifying and removing the constraints to the commercialization of bio-pesticides has been one of the features of recent work by the LUBILOSA (the

biological control of locusts and grasshoppers programme) and has resulted in the transfer of a product for the control of locusts to the private sector. The successes of the LUBILOSA programme in developing and commercializing a bio-pesticide are attributable to the multinational, multi-institute, multi-disciplinary approach which brought together the whole range of necessary expertise from a number of institutes in collaborative R&D programmes.[94]

The lessons learnt from this experience suggest that significant enhancements to future bio-pesticide R&D in emerging and developing countries can be made through the adoption of this alternative model. The targeted assistance in the form of specialized support, facilities and access to expertise on a multinational, multi-institute, multi-disciplinary basis is required in emerging and developing countries in order that the constraints to the future successful development of bio-pesticides could be lifted.[62]

As summarized by the report of the workshop on Alternative Paradigms for Commercializing Biological Control, co-organized by the Experiment Station Committee on Policy and the Rutgers University, 31 May to 2 June 1998, held in New Brunswick, New Jersey, future commercialization of bio-pesticides will rely mostly on the development of a new paradigm whose components will include:

- *Exploit the advantage of living products:* the biologicals have advantage over chemicals in that they are capable of reproducing, spreading and having a lasting impact on agro-ecosystems. The inoculation of biological agents and the encouragement of their reproduction and spread should be the new focus;
- *Develop imaginative product concepts:* the introduction of commercially produced natural enemies that enhance the action of local natural enemies, for example bio-pesticide spray in a field crop, gives a new meaning to the concept of what constitutes the product;
- *Be knowledge-intensive and farmer-engaged:* farmers are a key element of a successful IPM programme and engage in regular observation, decision-making and the conservation of natural enemies. Consequently, biological products in a new paradigm are knowledge-intensive and require that farmers understand their crop systems and the dynamics of their arthropod inhabitants, both good and bad;
- *Make bio-control businesses local or regional and of medium scale:* the lessons from the multinational agrochemical industry and venture capital businesses have revealed that successful biological agents will not be developed in businesses which force them to be more successful than market allow in order to meet high overhead costs or return on investment. The concept of local production and distribution of biologicals within the farming sector, backed by centralized support for research and development, regulation and promotion, perhaps through a franchising system, emerged strongly at the workshop discussions.

Conclusions

Increasing awareness of the benefits of IPM and biological control, as well as of the economic and environmental costs of chemical pesticides, are the driving forces behind

changes in plant protection policies in Africa.[79] There are many factors that determine farmers or others accept the adoption of bio-pesticides. First, there must be a potentially effective bio-pesticide and a reliable structure for ensuring its availability. Its successful deployment will then depend on the ecological characteristics of the pests, their economic importance, value of the crop or other resources and intended market (local market, export), and, most important, how a farmer or other user perceives the bio-pesticide.[68]

It is important that bio-pesticides become more cost-effective than conventional pesticides to make them attractive to farmers. If a bio-pesticide costs more but provides no better results than a conventional pesticide, then farmers and other potential users are not likely to adopt it except in special circumstances (e.g. when organic markets are sought, if the government eliminates pesticide subsidies). The bio-pesticides will always lag if we continue to push them as pesticide mimics without properly integrating them into targeted farms or other operations. The best prospect for bio-pesticides is to use them in organized IPM programmes that combine other pest control tactics in a manner consistent with local needs and constraints.[68] Ultimately, successful adoption of microbial control in West Africa depends crucially on a collaborative approach in which all stakeholders take a participatory role.[80] In Nigeria, the International Institute for Tropical Agriculture has conducted successful trials using bio-pesticides. The farmers interviewed in the north of Nigeria confirmed that positive results were obtained in pest control using bio-pesticides. There is, in essence, a growing acceptance by farmers of the efficacy of bio-pesticides in pest control programmes. A little encouragement from governments in emerging and developing countries will certainly lead to the commercialization of bio-pesticides production and its adoption by farmers as a cost-effective alternative to the hazardous synthetic chemical pesticides in IPM programmes.

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Part 4
Biotechnological Applications to Medicinal and Aromatic Plants

Chapter 12
The Role of Biotechnology in Improvement of Medicinal and Aromatic Plants

by Maria Luisa Villarreal and Rodolfo Quintero

Introduction

Higher plants are major factories for the synthesis of many valuable chemicals of economic importance used as drugs, insecticides, fragrances, etc. (Table 1). These compounds are secondary metabolites and play a role in plant survival by allowing their proper interaction with the environment, acting against fungal, microbial or herbivore attack, as flower colours or insect attractants for pollination. There are various kinds of complex secondary metabolites, which are produced in very small amounts in plants whenever needed, and their biosynthesis is restricted to individual taxonomic groups.

The increasing use of plant secondary metabolites for human welfare has encouraged the consideration of the design of novel procedures to adequately exploit the flora producing these metabolites. Among the alternative technologies, one that could contribute to increased production levels of desirable plant chemicals is the use of biotechnological procedures that include *in vitro* culture systems of plant cells, tissues and organs, as well as gene technologies for transformation of plants and plant cells.

At present, very few procedures using plant cell cultures have been established on commercial scale. These include the production of dyes, shikonin and purpurin,[1,2] as well as the medicinal compounds berberine, sanguinarine, ginsenosides and taxol.[3-6] Although there is a number of problems associated with rational exploitation of cell/tissue/organ cultures, the major barrier being a very limited understanding of the biochemistry and physiology of the cultivated cells, there are still many benefits of this production strategy.

In vitro culture techniques could offer many advantages for the production of secondary metabolites. The main advantages include: a systematic supply of compounds under controlled optimized conditions; independence of weather, soil, disease and socio-political problems; cultivation of species of very slow growth or at risk of extinction; source of new compounds, enzymes and bio-transformation systems; cultures that sustain a genetic improvement programme faster than the traditional system and better adapta-

tion to market changes.[7] In a wider context, *in vitro* culture systems will give better understanding of plant secondary metabolite biochemistry and physiology, as well as some basic aspects of plant differentiation.

Table 1: Examples of plant secondary metabolites and their uses

Major chemical constitutent	Plant genus	Use
Pharmaceutical:		
Digitoxin	*Digitalis*	Cardiac arrhytmia
Solasodine, diosgenin	*Solanum, Costus, Dioscorea*	Steroid drug
Quinine, artemisinin	*Cinchona, Artemisia*	Antimalarial
Taxol	*Taxus*	Antitumour
Shikonin, lignans	*Lithospermum, Piper, Ginkgo*	Anti-inflammatory
Ajmalicine/serpentine	*Catharanthus*	Circulatory disorders
Morphine, codeine	*Papaver*	Analgesic, local anesthetic
Agro-chemicals:		
Thiophenes	*Tagetes*	Biocides, antinematicidal
Pyrethrins	*Tanacetum*	Insecticide
Foods and fragrances:		
Betacyanin	*Beta*	Food colourant
Essential oils (mint, lavander, rose)	*Mentha, Lavendula, Rosa*	Perfumes and food flavouring agents
Caffeine, nicotine, teophylline	*Coffea, Nicotiana, Thea*	Stimulant
Cocaine, cannabinol	*Erythroxylum, Cannabis*	Hallucinogen

Plant Cell and Organ Culture Technology

Callus and Suspension Cultures

Callus cultures are large aggregates of undifferentiated cells growing on a semi-solid media containing carbohydrates, mineral salts, vitamins and amino acids, and supplemented with plant hormones (auxins and cytokinins) responsible for keeping the growth undifferentiated. Calluses are grown under sterile conditions and are usually derived from young tissues (seedlings or meristems) of the plant. In theory, it is possible to obtain calluses from every plant species, but optimal conditions for growth depend on individual species and need to be determined. The calluses can vary in texture from hard compact to friable tissues. Callus tissue itself is not generally used to produce chemicals or conduct basic investigations on secondary metabolism, but rather as a source material to establish cell suspension cultures.

In the establishment of suspension cultures, finely fragmented calluses are transferred into liquid nutrient medium containing phyto-hormones, and grown under controlled conditions of illumination (continuous dark or light, or photoperiod) and temperature (25 to 28°C). The cell suspensions are grown in continuous agitation using a rotary shaker to supply oxygen and nutrients to the cells.

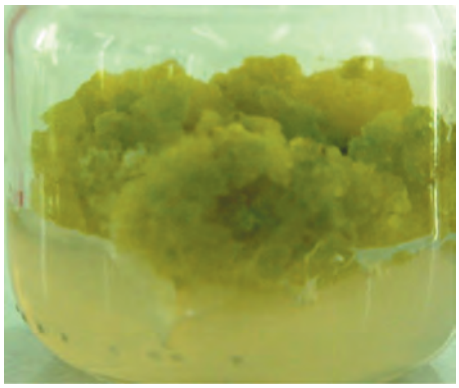

Figure 1: Callus culture of the Solanum chrysotrichum Schltdl.

The suspensions can vary from very fine dispersed cells to large aggregates; the aggregate size depends mainly on plant species, the time in culture, and phyto-hormone regimen used.

In the course of sub-culturing, suspensions can experience changes in chromosome number and stability on secondary metabolites production. Several nutritional (concentration of phosphate, nitrate/ammonium ions etc.), physico-chemical (inoculum size, illumination etc.) as well as hormonal factors (type and concentration of growth regulators) would play a crucial role in the optimized production of secondary compounds in culture. The plant cells, like several micro-organisms, are commonly grown in batch suspension cultures and exhibit important differences when compared with these micro-organisms (Table 2).

Table 2: Comparison of typical features among plant cells and fungal batch suspension cultures

Characteristics	Plant cells	Fungal cells
Size (μm^3)	$>10^5$	20-50
Doubling time (h)	>12	1-6
Time of culture (batch)	2-3 weeks	2-10 days
Type of division	Mitosis	Mitosis
Morphology	Cell aggregates	Individual cells, pellets
Oxygen requirement (vvm)	<0.5	1-2
Water content (%)	>90	80
Product accumulation	Intracellular	Frequently extracellular

Even though a number of major problems still have to be overcome in the use of plant cell cultures to produce commercial amounts of secondary metabolites, R&D studies had been extensively conducted, and the few existing industrial processes are performed using cell suspensions.

Current Problems with Cell Cultures

Plant cell cultures face both biological and technological problems that need to be solved before large-scale production of valuable metabolites from a number of plant species becomes a reality.

Biological Problems

Common biological problems that hinder adequate development of cell suspensions are slow growth, low yields and productivities, stability and storage.

In comparison to other biological systems, plant suspensions multiply at much slower rates than micro-organisms (100 times slower than bacteria), with doubling time ranging from two to six days. The low metabolic rates of plant cells result in low volumetric productivities, and in consequence such systems must be operated over extended time periods, which increases the probability of contamination.[8] During sub-culturing and because a big number of cell divisions occur, some problems in strain genetic stability may arise and could induce somaclonal variations in the cultures. Even though some of these variations could benefit in production of new valuable variants, it can also cause instability in the selected cell line.[9] Appropriate procedures for storage of selected cell lines will make a major contribution to overcoming these variations, but unfortunately storage of plant cell lines by cryo-preservation in liquid nitrogen still has low success.[10]

Technological Problems

Various technological problems are associated with cell cultures. A sufficient mixing to guarantee oxygen and nutrients transfer is necessary, but could be complicated by the shear sensitivity of the plant cells (mainly attributed to presence of cell wall as well as large cell size). The contamination probability will increase since long operational periods are needed owing to low metabolic rates. The low concentration of desirable products could considerably affect the downstream processing and the economics of the whole production process.[11]

Potential Solutions

As mentioned above, one of the main obstacles in the success of plant cell cultures is that some secondary metabolites are either not synthesized or synthesized in very low amounts by the cell cultures. Nevertheless, some new secondary products not found in the parent plant have been described in the cell cultures (Table 3).[12] Since plant cells have been regarded as totipotent and possess the genetic information of the biosynthetic pathways normally expressed in the original plant, it is important to establish the conditions in the artificial culture systems to give proper physiological state to the cell in order to produce the secondary metabolites. In the next sections, some current approaches to achieve high metabolite accumulation are described.

Table 3: Examples of novel substances found in plant cell cultures

Compound	Plant species	Biological activity
ß-peltatin	*Linum flavum* L.	Cytotoxic lignans
Rutacultin	*Ruta graveolens* L.	Active phenylpropanoid
Lucidin	*Morinda citrifolia* L.	Active anthraquinones
Epchrosin	*Ochrosia elliptica* Labill.	Alkaloid
Dihomovalerate	*Valeriana wallichii* DC.	Terpenoid

Selection of High-Yield Cell Lines

Selection and cloning of high-yield cell lines represent a classical approach, even though the low stability of cell lines demands repeated screenings to ensure that the desirable product accumulation is present.[13] Depending on the case, selection of high-yield cell lines could be done by eye (colored products), or other methods such as micro-spectrometry, use of cell sorter, Enzyme Linked Immuno-Sorbent Assay (ELISA) or Radio Immunological Assay (RIA), or some more sophisticated analytical procedure.[14-16] Criteria that could be taken into account for selecting high-yield cell lines include: level of secondary metabolite, growth rate, culture characteristics, release of secondary metabolite into the medium, and time maintenance of secondary metabolite content.

Optimization of Growth and Production Media

Some ingredients of nutrient media of plant cell cultures have shown a marked influence on cell growth: carbon source (glucose or sucrose), some macronutrients (usually nitrate/ammonium, potassium, and phosphate), as well as a balanced combination of phyto-hormones with one auxin (e.g. 2,4-dichlorophenoxyacetic acid (2,4-D), indoleacetic acid (IAA) and naphthaleneacetic acid (NAA)) and one cytokinin (kinetin or benzylaminopurine). On the other hand, depletion of some nutrients as well as addition of a balanced regimen of phyto-hormones could be crucial for enhancing secondary metabolite production. Very often, the best medium for cell growth is not the same as that needed to reach the highest production of secondary metabolites. Therefore, in such cases it is desirable to establish a two-stage process in which media for growth and production are optimized independently.[17]

Product Secretion

With a few exceptions as the case of capsaicin from *Capsicum frutescens* L., secondary metabolites from plants are stored intra-cellularly. In order to lower recovery costs, various attempts have been made to release the products from cell to medium by permeabilization of cell membranes without decreasing their viability. Addition of dimethylsulphoxide to make more permeable membranes has been successful in a few cases, such as *Coleus blumei* Benth.[18] The composition of the medium, for example low phosphate, sometimes affects the secretion of some compounds as well as elicitation that at times produces secretion of the respective phytoalexins.[19] The physical methods that have been used for this purpose are: higher temperatures, electrical permeabilization and ultrasonication.[20]

Stress: Elicitor Treatment

The 16th International Congress for Plant Tissue and Organ Culture in 1986 in the USA defined elicitors as signal molecules of biological origin that induce the synthesis of biocides called phytoalexins. Phytoalexins are regarded as defence compounds directed against an invading pathogen. In a strict sense, a natural or denatured preparation of a fungus or micro-organism, or sometimes a polysaccharide preparation of the pathogen, could act as elicitor to induce the synthesis of phytoalexins. In some cases, the synthesis of phytoalexins can also be induced by abiotic factors (e.g. UV light, pH, temperature, heavy metal ions, etc.). Plant cells usually respond very fast (hours to few days) to the application of such agents and many of the secondary products formed after elicitation are released into the culture medium, a situation that facilitates the recovery of metabolites. For these above reasons, elicitation has been used over the recent years to give a successful increase in secondary metabolite production in cell cultures.[21,22] Some examples on the effect of elicitation are presented in Table 4.

Table 4: Effect of elicitation on production of some secondary metabolites

Plant species	Elicitor	Product	Product increase related to the control
Papaver somniferum L.	*Botrytis* sp.	Sanguinarine	26
Datura stramonium L.	Cu/Cd	Lubimin/hydroxylubimin	260/600
Ruta graveolens L.	*Rhodotula rubra*	Acridons	100
Solanum elaeagnifolium Cav.	*Alternaria* spp.	Solasodine	1.7
Catharanthus roseus (L.) G. Don	*Aspergillus niger*/ osmotic stress	Ajmalicine/vindoline	5
Catharanthus roseus (L.) G. Don	*Vanadium*	Catarantine/ajmalicine	2-5
Talictrum rugosum	Yeast extract	Berberine	4-5

Immobilization of Plant Cells

The entrapment of cells in alginate beads constitutes one of the commonest methods described for plant cell immobilization.

Other methods of immobilization use polyurethane foams or gelling agents such as agar, agarose, chitosan-carrageenan or polyacrilamide.

Important advantages of the use of immobilization for biotechnological processes include: the re-use of cells, the protection of cells against shear forces and the forced contact between plant cells that leads to morphological changes and some sort of organization. There are many examples where immobilization has positive effects provoking more synthesis of secondary metabolites, and in some cases release of products into the medium, in which case the cells can be re-used. Immobilization has also been used for biotransformation reactions as well as in processes carried out in bioreactors.[23,24] Table 5 shows some examples of cell suspensions that have been immobilized.

Table 5: Examples of immobilized plant cell systems

Starting material	Plant source	Product
Biotransformation:		
Digitoxin	*Digitalis lanata* Ehrh. in alginate	Digoxin
Codeinone	*Papaver somniferum* L. in polyurethane foam	Codeine
Triptamine	*Catharanthus roseus* (L.) G. Don in agarose	Ajmalicine
De novo synthesis:		
Ajmalicine	*Catharanthus roseus* (L.) G. Don	Hollow fibre
Solasodine	*Solanum aviculare* G. Forst.	Cell aggregates
Protoberberine	*Thalictrum rugosum* Ait.	Fibreglass mats

Precursor Feeding and Biotransformation

Biotransformation can be defined as the conversion of a substance (natural or synthetic compound) by living cultures, permeabilized cells or entrapped enzymes or cells, into a different product. Plant cell in culture sometimes retains the ability to perform special reactions on compounds fed to them (Table 6). This situation can be exploited to transform cheap substances into valuable products. The type of reactions that are normally catalyzed by plant cell cultures include oxidation, hydroxylation, reduction, glucosidation, hydrolysis, isomerization and epoxidation.[25]

Table 6: Some examples of biotransformation with plant cell cultures

Substrate	Cell culture	Product
Geraniol	*Cannabis sativa* L.	Citral
Digitoxin	*Digitalis lanata* Ehrh.	Purpurea glycoside B (glucosylation), digoxin (hydroxylation)
Pregnenolone	*Nicotiana tabacum* L.	Pregnenolone palmitate
Hydroquinone	*Datura inoxia* Mill.	Arbutina
Tyrosine	*Mucuna pruriens* (L.) DC.	L-dopa

Sometimes, biotransformation can be coupled with immobilization with results that make the process more economic. Some of the requirements for successful biotransformation are the following: the required enzymes must be present in the culture, the product must be formed faster than it is metabolized, the precursor and product formed must be non-toxic to the culture, the substrate must be able to enter the cell, and the product preferably be released into the medium. Hydroxylation of ß-methyldigitoxin to ß-methyldigoxin by cultures of *Digitalis lanata* Ehrh. is one of the best known examples of biotransformaton.[26]

Also, feeding of limiting precursors either primary or intermediary metabolites of the biosynthetic pathways could result in an increase of product formation, as in the case of tryptophan that was fed as a precursor for indole alkaloids in cultures of *Catharanthus roseus* (L.) G. Don.[16]

Hairy Root Cultures

It is generally accepted that undifferentiated *in vitro* cultures produce lower levels of secondary compounds than differentiated cultures. A correlation between developmental stage of the culture and secondary metabolite production has been well established. Hairy roots represent a well developed differentiated culture that are hormone-independent and generally obtained by transformation with genes contained in plasmids of *Agrobacterium rhizogenes*.

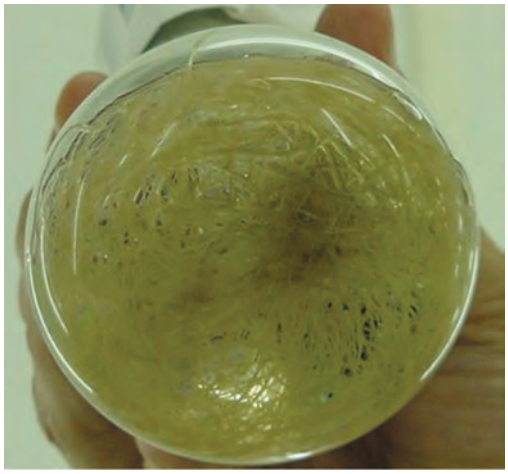

Figure 2: Hairy root culture of Solanum chrysotrichum Schltdl.

As a result of transformation, bacterial genes coding for enzymes for hormone biosynthesis are stably integrated into the plant genome. Other benefits that hairy root cultures exhibit include: stable and fast growth of culture, genetic and biochemical stability and ease of regeneration into plants. Hairy roots have been the subject of intense investigation. A massive increase of biomass over relatively short periods of culture and the complete differentiation of the root tissue warrant the production of phytochemicals at substantial levels.[27] Hairy root cultures may equal the productivity of native roots and exceed other *in vitro* systems in the production of special chemicals. Many successful processes using hairy root cultures have already been established (Table 7). The products recovered from hairy roots comprise phytochemicals such as alkaloids, terpenoids, flavonoids, phenolic compounds, anthraquinones, quinones, glucosinolates, lignans, proteins, etc.

Growth, development, and production of secondary metabolites in hairy root cultures are influenced by a number of factors such as medium composition, liquid or solid, pH, growth regulators, light cycle, temperature, oxygen supply, etc.[28] Mass cultivation of hairy roots still exhibits some problems; special type of reactors have been designed for large-scale cultures, and new designs are emerging. Because hairy roots exhibit a high growth rate and a stable production of secondary metabolites, they represent a promising system that can be used for commercial purposes in the future.

Table 7: Examples of secondary metabolites produced by hairy root cultures

Metabolite	Plant species	Reference
Solasodine	*Solanum aviculare* G. Forst.	Yu *et al.*, 1996[29]
Shikonin	*Lithospermum erythrorhizon* Siebold & Zucc.	Sim. and Chang, 1993[30]
Nicotin	*Nicotiana tabacum* L.	Flores and Filner, 1985[31]
Quinine, quinidine	*Cinchona ledgeriana* (Howard) Bern. Moens ex Trimen	Hamill *et al.*, 1989[32]
Hyoscyamine, scopolamine	*Datura stramonium* L.	Ford *et al.*, 1986[33]
Sanguinarine	*Papaver somniferum* L.	Williams and Ellis, 1993[34]
Ajmalicine	*Catharanthus roseus* (L.) G. Don	Ciau Uitz, 1994[35]
Artemisinin	*Artemisia annua* L.	Jaziri, 1995[36]
Betalains	*Beta vulgaris* L.	Hamill, 1986[37]

Shoot Cultures

Shoot cultures constitute a differentiated system that can be propagated and maintained in liquid culture by the phytohormone regimen. Shoot cultures can be transformed with *Agrobacterium tumefaciens*, and the resulting tissue exhibits different advantages of stable and fast growth, and independence of growth regulators. Scale-up of shoot cultures is still being investigated owing to their unique morphological characteristics, susceptibility to mechanical damage and possible vitrification under submerged condition as well as light requirements. It will be useful in cases where hairy roots do not form the secondary metabolite found in the aerial parts of the plants. Even though there are still many problems to be solved for mass propagation of shoots in culture, there are some cases where increased production of secondary metabolites has been attained, as in the case of alkaloid production from *Duboisia* hybrid.[38] Novel designs of bioreactors as aerosol systems and mist nutrients have been suggested.

Embryo Cultures

Somatic embryo culture could be used for secondary metabolite production only if the products are accumulated in the embryos. Somatic embryo cultures may be produced in a number of different ways, by direct or indirect (via callus) embryogenesis. The more readily exploitable system depends upon the differentiation of cells in a suspension culture, which usually requires the imposition of an environmental trigger such as an alteration in hormonal status, e.g. suspensions of *Daucus carota* L. can be induced to produce somatic embryos by the removal of 2,4-D from the medium. This system is exploited for micro-propagation purposes with the production of embryos in bioreactors to generate artificial seeds.[39]

Gene Technology

Genetic engineering of metabolic pathways includes the isolation, characterization and reorganization of genetic material and its transfer to foreign individuals.[40] These procedures have been used to manipulate secondary metabolic pathways, and comprise

the following genetic strategies: increased copy number of selected genes, addition of developmental regulation genes encoding key enzymes but under a plant constitutive transcriptional promoter, addition of novel genes and down-regulation of specific genes by anti-sense RNA techniques.

The aim of producing important levels of special compounds, such as dyes, drugs, flavours, fragrances, and agrochemicals, can be envisaged by engineering the original plant or by introducing its pathway in another plant species. Over the past years, considerable progress has been made to identify genes and to understand how their synthesis is regulated, and in consequence, elaborated gene transfer tools have been developed for its application in a wide variety of plants.[41]

Special interest has been focused on the phenylpropanoid metabolism, which plays an important role since it provides the precursors for antibiotics, furanocoumarins, pterocarpan or stilbene phytoalexins for reinforcement of cell wall and diverse flavonoids that play important roles as flower pigments or UV protectants.[42] Genetic engineering has been used to alter the level of expression of certain genes, silencing genes by anti-sense strategies as in the modification of lignin content and composition,[43] whereas over-expression can be achieved by introducing additional copies of a particular gene or placing it under a strong promoter.[42] Recently, the identification and cloning of transcriptional regulator gene acting in signal transduction pathways has opened up the possibility of manipulating expression of complete biosynthetic pathways. The perspectives of this technology are enormous and include: permanent production of increased amounts of drugs, expansion of the plant´s colour palette, increment of resistance to pathogens, improvement of nutritional quality and composition of crop products.

Bioreactors

Mass cultivation of plant cells is performed in bioreactors, which allow closer control and monitoring conditions than shake flasks. In plant technology, the criteria used in selection of bioreactor depend on the type of culture to be scaled-up: suspension, tissue or organ, and free or immobilized. The main types of bioreactor used in free suspension cultures are stirred tanks, airlift, bubble column and rotating drums.[44] For immobilized cultures, the selection of reactor depends on the immobilization technique. For gel-entrapped systems, stirred tanks, packed bed, airlift and fluidized bed reactors are used.[45] For immobilized material in porous foams and stainless steel matrices, circulating bed reactors are the most suitable.[46] For hairy root cultures, packed bed and a special *in situ* immobilization bioreactor have been used while for embryo cultures, airlift reactors are used.

The suitability of a bioreactor is evaluated by considering the capacity of oxygen supply, as well as the hydrodynamic stress generated, mixing, effect on aggregate size, ability to control temperature, pH and aseptic operation for long periods.[44]

Micropropagation

It involves the massive propagation of a plant from small explant tissue. A range of different explants can be used for this purpose: shoot meristems, stem segments with axillary buds or segments of tissues (hypocotyls, cotyledons) that will form adventitious shoots and/or embryos directly or indirectly via unorganized calluses.[47] The regeneration of plants has been achieved with cells and tissues excised from various medicinal plants with high multiplication factor. A recent work with *Cephaelis ipecacuanha* (Brot.) Tussac yielded 100 plantlets per shoot tip explant per year or 600 plantlets per axenic shoot.[27] Micropropagation is of special interest when applied to plants that require many years to develop. Many plantlets can be produced from a small amount of stock plant in a short time, space requirements are small, plants are free of pathogens and production can be maintained continuously. Some specific plants difficult to propagate *in vivo* are propagated *in vitro*.

The somaclonal variation has been employed to select medicinal plant with altered level of phytochemicals. Important investigations have been carried out with poppy cell cultures to provide plants that produced more thebaine, codeine and morphine than seed born control plants. Segregants with heritable capacity for these alkaloids have been difficult to obtain.[27]

There are many companies engaged in commercial micropropagation of plants that include medicinal and aromatic. Millions of plants are produced by micropropagation in Brazil, Cuba, France, Germany, Israel, Mexico, The Netherlands, the UK, the USA, and elsewhere.

Conclusions

Plant biotechnology is rapidly evolving and will have major impact on obtaining medicinal and aromatic plants and their secondary metabolites, as understanding of plant biochemistry, physiology and molecular biology increases. Many different approaches are being used to obtain higher yields of secondary metabolites in cultures (through elicitors, immobilization, hairy root and shoot cultures, gene technology, etc.), and many of these techniques are completely interactive. The application of biotechnology to medicinal plants include biological and bio-engineering aspects, which consider the design of reactors that will respond to the culture requirements, considering cell suspensions, hairy root or shoot cultures, either free or immobilized. The commercialization of fine chemicals by plant cell cultures will largely depend on product yields as well as socio-political, ecological and health-care considerations.

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Part 5
Trade

Chapter 13
Trade in Herbal Medicinal Products

by Vishavjit Kumar

Introduction

Medicinal plants have been used to alleviate human suffering since time immemorial. Even today, about 80% of world population, mostly in emerging and developing countries of Asia, Africa and Latin America, rely on medicinal plants for their primary health care.[1] Medicinal plants are the major component of traditional and herbal medicines, more recently known as herbal medicinal products. Herbal medicinal products have taken on increasing significance as regards medical and economic importance over the last two decades, and have registered a strong comeback in developed countries in the USA, the European Union (EU), Australia and Canada. For example, over the last two decades one-third of American adults have used alternative treatment; 60% of the population in the Netherlands and Belgium, and 74% of British people are in favour of complementary medicine being available within the framework of their national health services. A survey among member states of the EU in 1991 identified about 1,400 herbal drugs used in the European Economic Community. Consumer interest in natural products, which are considered safe and cost-effective, is responsible for their increased demand in the world market.

The global market for herbal medicines grew from US$ 12.4 bn in 1994 to 19.6 bn in 1999 and is estimated to reach 24.2 bn in 2002.[2,3] Europe is the world leader in retail sale of herbal medicines. The USA is the world's fastest growing market for botanical products. With the emergence of newer product categories like health foods, natural cosmetics and personal hygiene products, demand for medicinal and aromatic plants has increased exponentially in the world market. Overall international trade in medicinal plants and their products was estimated at over US$ 60 bn in 2000, and it is expected to reach 5 trillion by 2050.[4]

The raw material supply of medicinal and aromatic plants to the world market is mainly sourced from emerging and developing countries of Asia, Africa and Latin America and some East European countries. China and India are the world's leading exporters of material of medicinal and aromatic plants.

Trade in medicinal plants is neither regulated nor organized in most parts of the world. Rising global demand of medicinal plants has also created an underground trade in plant materials and has resulted over-harvesting from the wild. This has not only threatened the existence of many commercial medicinal plant species but also resulted in short supply of raw material. There is an urgent need to regulate export and allow only sustainable harvesting of natural resources of medicinal plants. The lack of authentic data on supply and demand of medicinal and aromatic plants and their products, user groups, trade legislations and policies are the major constraints in the development of global herbal industry.

Medicinal Plants Demand

Medicinal and aromatic plants are used by many groups, mainly pharmaceutical and food industries, traditional or alternative practitioners, folk or household users, and cosmetic and flavour industries. The data on demand from these sectors are sparsely available, making it difficult to estimate the exact figures from all the sectors. Only trends can be deduced from the various quarters.

Phytopharmaceuticals

The most significant and important use of medicinal plants is to obtain drug molecules for therapeutic use. A number of important drugs are still obtained either directly from plants or synthesized from their precursor molecules obtained from plants e.g. digitoxin or quinine are obtained from *Digitalis* and *Cinchona* species, respectively, whereas most steroid drugs are semi-synthetically obtained by utilizing a steroid molecule from a plant source. The number of drug molecules obtained or developed industrially from plants and used in modern medicine was estimated to be 121 in 1995 and 130 in 1997.[5,6] Plant-derived pure chemical drug entities accounts for 50% turnover of plant products. Most of these drugs are prescription drugs. The other categories of products derived from plants make up the remaining half. The plant-derived drug molecules used to treat serious ailments include atropine, digoxin, morphine, paclitaxel, pilocarpine, quinine, scopolamine, topotecan and vincristine, and others.

In the USA, about 25% of dispensed prescriptions contain drugs sourced from plants. The sale of these plant-based drugs amounted to some US$ 4.5 bn in 1980 rising to 15.5 bn in 1990.[7,8] With the increasing demand of natural product medicines and interest of pharmaceutical companies in discovery of novel molecules from plants, it is estimated that the share of plant-derived prescription drugs will increase to 30% over the next few decades.[9]

The world market for plant-derived drug molecules was valued at US$ 22.6 bn in 1997, estimated to reach 30.6 bn in 2002, with an average annual growth rate (AAGR) of 6.3% (Table 1).[10] Terpenoids contributed the most to the sale of plant-derived drugs valued at US$ 7.7 bn, followed by glycosides (7.3 bn), alkaloids (3.6 bn) and other plant-derived drugs (4 bn). Their sale value has been estimated to reach US$ 12.4 bn, 9.2 bn, 4 bn and 5 bn respectively in 2002.

Table 1: Worldwide sale of plant-derived drugs, 1997-2002

Plant drug category	Sale value (billion US$)		AAGR %
	1997	2002*	
Terpenoids	7.7	12.4	10.1
Glycosides	7.3	9.2	4.8
Alkaloids	3.6	4.0	2.4
Others	4.0	5.0	4.4
TOTAL	22.6	30.6	6.3

** Estimates*

Herbal Medicines

Herbal medicine is the oldest form of health care known to human beings and has played a dominant role in the development of modern medicine. Medicinal plants are the major component of all indigenous or alternative systems of medicine. For example, they are common elements in Ayurveda, homoeopathy, naturopathy, Oriental and Native American Indian medicine. The World Health Organization (WHO) estimates that about 4 bn people of the world population currently use herbal medicines for their primary health care in one or other way.

The herbal medicine industry is one of the fastest growing industries. Europe leads the world market followed by Asia, North America, and Japan (Table 2).[2,3] Latin America and Eastern Europe have a retail sale of US$ 600 mn and 400 mn, respectively. The share of Africa and Middle East together, and rest of the world is about US$ 200 mn each. The USA is the fastest growing market. It had retail sales of US$ 3.8 bn in 1999, which was estimated to reach 4.5 bn in 2002.

In the late 1990s, the demand for herbal medicines in Europe was almost static, while in North America it steadily increased during this period. In Asia, the demand almost doubled during the same period, partly from increasing pressure from the population.

In Europe, the market is well established in the sale of herbal medicines. These are sold as both licensed and unlicensed products. The herbal market has been described as a leading sector within the dietary supplements and Over-the-Counter (OTC) drugs.[11,12] During 1994, the overall annual sale of OTC herbal medicines amounted to US$ 6 bn, which increased to 7.4 bn in 1999, with an annual growth rate of 10 to 15%. European market for licensed herbal medicines in term of sales stood at more than US$ 475 mn in 1997, and was dominated by products based on ginkgo *Ginkgo biloba* L.), ginseng (*Panax* spp.), garlic (*Allium sativum* L.), St. John's wort (*Hypericum perforatum* L.), evening primrose (*Oenothera biennis* L.) and echinacea (*Echinacea* spp.). Within Europe, Germany leads the market with sale of US$ 3.5 bn, followed by France, Italy, the UK, Spain, Scandinavia and the Netherlands. Germany comprises about half the European market of herbal medicine and its annual per capita consumption of US$ 42.9 is about ten times of any other European country.

Table 2: Sale of herbal medicine in different regions of the world

Region	Sale value (billion US$)			
	1994	1997	1999	2002*
Europe	6.0	7.0	7.0	8.9
North America	1.5	1.6	3.8	4.5
Japan	1.8	2.4	2.2	2.9
Asia	2.7	2.2	5.1	6.0
Austral-Asia	-	-	0.1	0.2
Africa & Middle East	-	-	0.2	0.2
Latin America	-	-	0.6	0.8
Eastern Europe	-	-	0.4	0.4
Rest of world	0.4	0.8	0.2	0.3
TOTAL	12.4	14.0	19.6	24.2

**Estimates*

The North American market for botanicals is considered to be in its developmental phase as compared to European market, and most of the herbal products are sold as dietary supplements. The classification of medicinal herbs and food supplements under the Dietary Supplement Health and Education Act (DSHEA) of 1994, which exempts their approval from the Food and Drug Administration of the United States of America (USFDA), has increased the sale and distribution of medicinal herbs at most major retail channels. The demand for medicinal plants increased significantly during the 1990s and was particularly strong among the aging baby boomer generation. In 1994, the total annual sale value of herbal remedies in North America was only US$ 1.5 bn, which increased to US$ 3.8 bn in 1999, registering an increase of about 160%.[9] The USA is the largest market for herbal products in North America. Twelve botanicals accounted for 94% of market sale and all of these exhibited over 25% growth in 1997 and 1998.[13] Many of the top-selling herbal products in the USA are similar to European products, e.g. ginkgo, ginseng and garlic. Six products from herbs - ginkgo, St. John's wort, ginseng, garlic, echinacea and saw palmetto (*Serenoa repens* (Bartr.) Small) - accounted for 85% of total sales in 1998.

Traditional and Alternative Medicines

The traditional systems of medicine refer to methods of health care that were practised before the modern system of medicine developed. These approaches to maintaining health belong mostly to the traditions of developing countries, and have been handed down from generation to generation. Traditional medicines have fulfilled the needs of the local communities for centuries. A large section of the population of emerging and developing countries still relies on birth attendants, herbalists and bone-settlers, and use medicinal plants to satisfy their primary health-care needs.

Traditional medicines have maintained their popularity in a number of Asian African and Latin American countries. Among the Asian countries Japan, China and India have the highest per capita consumption of traditional medicines. In Japan, there was a 15-fold increase in the sale of Kampo (locally accepted version of Chinese medicine)

medicine from 1974 to 1989 in comparison with an increase of only 2.6-fold for mainstream pharmaceutical products. At present, the annual production of Kampo drugs is worth about US$ 1 bn of which prescription sale accounts for 78.6% and OTC 21.4%.[14] In China, traditional Chinese medicine accounts for 30 to 50% of the total medicinal consumption. Indeed, in the late eighties the annual demand was expected to exceed 700,000 tonnes.[15] In India, the annual turnover of herbal industry was estimated around US$ 300 mn in 1995.[16] According to Chemexcil reports, the export value of Ayurvedic and Unani medicines was about US$ 31.7 mn during 1999-2000. Of a total turnover of US$ 48.8 mn of Ayurvedic and herbal products, the major OTC products contribute around US$ 25.5 mn, ethical formulations around 13.8 mn, and classical Ayurvedic formulations the remaining 9.6 mn.[17] The Malaysian herbal industry has been estimated at about US$ 315 mn per annum, growing at a steady pace of 20%.[18] The Malaysian herbal market has the potential to reach US$ 842 mn by the year 2005 and 1.36 bn by the year 2010.[18,19]

Traditional medicine is an important part of African culture. It varies with cultural groups and regions. The western pharmaceuticals are inaccessible especially to rural-based populations. Therefore, more than 80% of Africans rely on medicinal plants for their health-care needs. About 70 to 90% of the populations in South Africa, Zambia, Nigeria, Mozambique, Ethiopia, and the Democratic Republic of Congo (DR Congo), among others, rely on traditional medicine for their health care. In South Africa, at national level, 20,000 tonnes of medicinal plants material are traded, corresponding to a value of about US$ 60 mn.[20] In Zambia, trade in traditional medicine is worth over US$ 43 mn per annum. Over 90% of Nigerians in rural areas and about 40% in urban areas depend partly or wholly on traditional medicine. In Namibia, medicinal plants are used widely by rural people for their health-care needs. In the Tsumkwe district of the Otjozondjupa region of Namibia alone, more than 80 medicinal plant species are used to treat 30 medical ailments. Traditional medicine is also a predominant medical system in use in Malawian rural areas. Limitations such as drug shortages and inadequate modern medical infrastructures have contributed to reliance on traditional medicine.

Traditional medicine also has a significant presence in most Latin American countries, with different forms of expression depending on the region and location. About 70 to 80% of the Latin American population relies on traditional medicine for their health-care needs, for example, about 80% of Ecuadorians, with consequent reliance on plants or products derived from plants. There is a lack of access to modern drugs in a significantly large part of Latin America. The increasing control of the pharmaceutical industry by international companies and the decreasing participation of national governments in the purchase and distribution of medicaments has exacerbated the problem.

Natural Health Products

In recent years, with the expansion of consumer interest in the health benefits of foods and personal care products, more attention is being paid to health foods (nutraceuticals), cosmetics and personal hygiene products (cosmeceuticals) containing natural ingredients.

Nutraceuticals

Health foods are known under different names throughout the world, i.e. functional foods in oriental and nutraceuticals in the western world. Nutraceutical is the most widely used and cited term in the literature for health food. Nutraceuticals are food products supplemented with herbal ingredients, vitamins, minerals and nutrients or ingredients isolated/ purified from conventional foods. These are the latest products in a succession of health food evolutions constituting dietary supplement, fortified foods, foods and beverages with added bioactive ingredients, and entire food regimes. The strongest market driver for nutraceuticals is the baby boomer generation, which will be the largest buying consumer group in the years ahead.

The nutraceutical industry is a promising sector with enormous growth potential. The USA leads the market, followed by countries of Western Europe and Japan. In 1999, the global nutraceutical market was US$ 6.8 bn, almost thrice the value in 1987 (Table 3).[21,22] It is estimated to grow at the rate of more than 8.3% per annum, to reach US$ 11.2 bn in 2004. The three main constituents of nutraceuticals are herbal extracts, vitamins and mineral nutrients. The global demand for herbal extracts in nutraceuticals grew to US$ 2.8 bn in 1999 from US$ 0.5 bn in 1987, an almost four-fold rise in demand. Freedonia Group Inc. in its report in 2001 has further predicted that herbal extracts will generate the fastest growth in worldwide demand among all nutraceuticals, reflecting their widely perceived health advantages.

Table 3: Global nutraceuticals demand from 1987 to 2002

Item	Demand value (billion US$)				Per cent annual growth	
	1987	1997	1999	2002*	1987/97	1997/02
Herbal extracts	0.5	1.7	2.9	3.0	12.9	11.3
Vitamins	0.7	1.4	2.3	1.9	7.2	7.0
Minerals & nutrients	1.1	2.4	1.6	3.3	7.7	6.7
TOTAL	2.3	5.5	6.8	8.2	8.9	8.3

**Estimates*

Asia and Pacific, Latin America, Africa and Middle East are set to provide the fastest growth for the nutraceutical industry. China will see the most impressive jump in nutraceutical consumption and production. The USA, Japan and major Western European countries will remain the largest global producers and consumers of nutraceuticals owing to higher levels of consumer income, widespread preferences for speciality products, trends promoting preventive medicines, and self treatment. US demand for nutraceuticals will increase to the end-use product market totalling US$ 34 bn.[22]

Cosmeceuticals

Just as with acceptance of nutraceuticals as a valid sector of the food industry, cosmetic and personal care products containing natural ingredients are also finding an increasingly receptive trend in the market. Cosmeceuticals are products that lie on the boundary between drugs and cosmetics, and possess desirable physiological activities such as skin healing, antioxidant, smoothing or conditioning properties. The cosmeceutical

market has grown with the addition of new active ingredients, discovery of enhanced technologies, and the spread of cosmeceuticals ingredients to make-up and hair-care products. Manufacturers are now frequently replacing vitamins with herbal ingredients such as saw palmetto (*Serenoa repens* (Bartr.) Small), ginseng (*Panax* spp.) and ginkgo (*Ginkgo biloba* L.). The *Aloe vera* (L.) Burm. f. is the most demanded plant species in the cosmeceutical industry owing to its soothing, calming and sun-protection properties. Major cosmeceutical categories include skin-care (age-defying and sun-protection) products; hair-care products (hair-growth retardants and hair-growth stimulants); professional products used for appearance-enhancing facial implants, injections, chemical peels and related procedures, and other products.

Globally, the market for cosmeceuticals has been estimated at US$ 22 bn and the fastest growing sector in this market is anti-aging products.[23] The USA, Japan, Australia, and Europe are the most dominant markets for cosmeceuticals and China, Malaysia, Russia and Latin America have strong potential for long-term growth. The baby boomer generation entering their fifties is making anti-aging products the core of the skin-care products, pushing sales over US$ 2 bn in 2000 and expected to top the cosmeceuticals market at US$ 5.4 bn by 2005.[24]

In the USA, the market for cosmeceuticals was estimated at US$ 2.5 bn where the market for botanical ingredients for use in cosmetics and toiletries stood at US$ 345 mn in 1998 forecasted to increase 7.9% annually to reach US$ 505 mn by 2003 and 750 mn by 2008 (Table 4).[25,26]

Table 4: Botanical extract demand in cosmetic and toiletries from 1989 to 2008

Item	Demand value (million US$)				
	1989	1993	1998	2003*	2008*
Aloe extract	38	46	63	86	115
Botanical extract	180	230	345	505	720
Others	22	34	67	113	174
Phyto-chemicals	19	37	65	106	173
Essential oils	101	113	150	200	258
Other natural products	85	115	180	265	385
TOTAL	265	345	525	770	1,105

**Estimates*

Raw Material Supply

In international trade, medicinal plants have been classified under the Standard International Trade Classification (STIC), and the Harmonized Commodity Description and Coding System (HS) or Customs Cooperation Council Nomenclature (CCCN) codes. The HS or CCCN Code 1211, which is widely accepted by the World Trade Organization (WTO), relates to botanical drugs (plants and plant-parts of a kind used primarily in perfumery, pharmacy, or for insecticidal, fungicidal or similar purposes). Its sub-sections are further classified into three main categories, i.e. other medicinal plants (HS 1211.90),

liquorice roots (HS 1211.10) and ginseng roots (HS 1211.20). Liquorice and ginseng roots are in high demand in international market and have therefore been kept under separate categories.

Medicinal plants are traded in a variety of forms, for example: entire plant parts such as leaves, bark, and roots; chopped or sliced plant parts; derivatives semi-processed or manufactured material such as powders, extracts, tonics, pills, teas and other products; and finished pharmaceutical products.

Throughout the world, about 35,000 to 70,000 species of plants have been used at one time or another for medicinal purposes.[27] In India, more than 1,000 plant species, in Nepal 700 species, approximately 7,000 species in Peninsular Malaysia and its neighbouring islands and over 1,800 species in Vietnam are reported to have medicinal value. However, only a relatively very small number of them are used in any significant volume, e.g. in traditional Chinese medicines, 9,905 botanical materials are used but only an estimated 500 are commonly used in any significant volume.[28]

In the early 1980s, about 400 species were reported to be used in Europe, though according to recent estimates this has increased to about 1,500 species.[29,30] It has been estimated that 500, and possibly as many as 600 species of medicinal plants are traded through Hamburg, Germany, which lies at the heart of the import business in Europe.[31]

Trends in Global Trade of Medicinal Plants

According to the International Trade Center (ITC), as far back as 1967, the total value of global import of starting materials of plant origin for the pharmaceutical and cosmetic industry was of the order of US$ 52.9 mn. From this amount the total value grew to US$ 71.2 mn in 1971, and then showed a steady annual growth rate of approximately 5 to 7% through to the mid-1980s. From 1987 to 1991, the average value of trade in medicinal plants increased to US$ 853 mn. It generally showed an upward trend except for 1990, when it dipped slightly before rising again to US$ 1.08 bn in 1991.[32] The world trade in medicinal plants and plant-parts averaged US$ 1.28 bn during 1995 to 1999. During this period, world imports rose slightly and subsequently decreased to US$ 1.1 bn in 1999. In 1996, the volume of traded material was 440,000 tonnes, valued at US$ 1.3 bn.[33]

In terms of value, the HS category of other medicinal plants represented three-quarters of the total imports, ginseng roots covered one-fifth, and the rest was liquorice roots. The six leading importers (volume-wise) were Hong Kong, Japan, Germany, the USA, South Korea and France during the late 1990s. The world trade in medicinal plants and their products has now been put at over US$ 60 bn, with annual average growth rate of 7%; the figure is expected to reach US$ 5 tn by 2050.[4,34]

The major international trade in medicinal plants is from developing to industrial countries. China is the leading export country for botanical drugs, exporting about 140,000 tonnes from 1991 to 1998. India is the second largest exporter of medicinal plant material.

Supply Sources of Medicinal Plants

Medicinal plants material generally comes from two sources, viz., wild and cultivated. Surprisingly, the bulk of the material traded in the world market is wild-harvested and constitutes more than 80% of total supply. Only a very small number of species are cultivated.

Wild-harvested Material

Wild harvesting is the collection of plant species from natural habitat. In many traditions, wild harvested material is generally considered to have higher therapeutic activity, and therefore fetches higher prices. In Asia and Africa more than 80% of supply comes from the wild sources. For example, in China the figure is about 60%, and in India about 90%. About 100 species in Nepal are collected from the wild. The situation is the same in Latin America. The major part of wild-harvested material is sourced from developing countries, but a high amount is also wild-harvested in developed countries. Of 1,200 to 1,300 traded plants in Europe, at least 90% are collected from the wild, with overall volume of at least 20,000 to 30,000 tonnes annually.[35]

Cultivated Material

Countries like China, India, Spain, Argentina, Hungary and Poland cultivate medicinal plants on a large scale. In China, more than 250 species of medicinal value are commercially cultivated and among them 60 species have performed well. In India, about 40 species of medicinal value have huge demand and have been brought under commercial cultivation. In Europe, 130 to 140 medicinal and aromatic plants are cultivated on an estimated area of 70,000 hectares. France, Hungary and Spain have the largest areas under medicinal plant cultivation. In Latin America, several exotic and introduced species are cultivated. Medicinal plants such as *Warburgia salutaris* (Bertol.f.) Chiov., *Agasthosma* spp. and *Siphonochilus aethiopicus* (Schweif.) B.L. Burt are cultivated in South Africa, and *Harpagophytum procumbens* (Burch.) DC. ex Meisn. in Namibia.

Channels of Supply

Trade in medicinal plants generally takes place at three levels. At first level, there is national trade involving hundreds of species in regional markets. The second level is informal international trade consisting of trade of a few species within the same continent. The third level comprises formal export, which consists of trade of medicinal plant species of high demand across international borders.

In most emerging and developing countries, collections are also carried out directly by the consumers. For trade, the material is gathered by individual farm households and sold following first post-harvest treatment to local collectors/traders, who sell the produce to licensed export companies or pharmaceutical processing factories. For developed countries, supply of medicinal plant material is more organized and passes from the source of collection, through a network of buyers including collectors' organizations and

state-run organizations, and agents or subsidiaries of the plant traders. The traders sell the plant material to trading companies located in Hamburg, New York, Tokyo and Hong Kong. They play a powerful role in the trade by dictating prices.

Major Importing Regions and Countries

The EU, the USA and Japan are the largest consumer markets of medicinal plants. In 1980, Europe imported 80,738 tonnes of medicinal plants material from India and countries of Eastern Europe. During the same year, Europe exported about 70,000 tonnes of plant material, mainly to the USA. Among the EU countries, Germany, France, Italy and Spain are the major markets for medicinal herbs. Germany dominates European trade in medicinal plants and the European market for phytopharmaceuticals. During 1991 to 1997 about 46,000 tonnes of material was imported annually from more than hundred countries into Germany, amounting to about US$ 142 mn.[33] One-third of the imported material was re-exported as finished products, primarily to Western Europe and the USA.

In North America, the USA is an important market for medicinal plants. In 1988, the annual turnover of the plant-derived pharmaceutical industry in the USA was US$ 10 bn.[36] The major part of the material is sourced from Europe (Eastern Europe) and Asia. Over the last decade, demand in North America for medicinal plants from Latin America, China and India has increased significantly.

The major importers of medicinal plants in Asia are Hong Kong, Japan, Singapore and Malaysia. The volume of material used in traditional systems of medicine in Asia is huge and of great concern when considering the supply and demand for medicinal plants. China also imports significant volumes of medicinal herbs, as well as being the largest producer and exporter of medicinal herbs. Among others, leading importers are the Republic of Korea and Pakistan.

Major Exporting Regions and Countries

China and India are the leading exporting countries. The average annual export during 1991 to 1997 of China was 140,000 tonnes and of India about 35,000 tonnes. China's total output of medicinal plants from both cultivated and wild-harvested sources was estimated about 1.6 mn tonnes. The Ayurvedic and Unani herbs are also traded in large quantities and over a very wide geographical area. For example, in 1992, an estimated 4,117 tonnes of material were exported, largely to Bangladesh, Japan, Pakistan, Saudi Arabia, the USA and the United Arab Emirates.[37] Other major exporters of medicinal plants in the top 12 are: Germany, Singapore, Egypt, Chile, the USA, Morocco, Mexico, Pakistan, France and Thailand. Significant quantities are also exported by Albania, Brazil, Bulgaria, Hungary, Korea, Turkey and smaller amounts by Kenya, Mauritius and Indonesia. Singapore and Hong Kong are the main re-exporters of medicinal plants to the world market.

As mentioned, Hamburg in Germany is the world's leading trade centre in medicinal plants, where more than hundred countries export their produce. The most important exporters to Germany are Albania, Argentina, China, Egypt, France, Greece, Hungary, India, The Netherlands, Poland, former Yugoslavia and DR Congo.

Plant Extracts

A significant percentage of medicinal plant material is used to make plant extracts. This process is carried out by either the end-product manufacturer or the extract company. Sale of plant extracts is undoubtedly increasing as evidenced by the growth of Indena, Europe's leading extract supplier.

The US market for extracts is alone estimated to be approximately US$ 500 mn, equivalent to about 25% of the global market. The extract market is forecasted to grow to US$ 1.5 bn over the next five years. The proportion of extract market to crude herbs market is forecasted to rise as much as 75%, reflecting the increased emphasis on consistency and quality.[38] The demand for phytochemicals in the USA has been projected to advance at a rate of 7.1% per annum to reach US$ 2.9 bn in 2005.[39,40] The new plant-based pharmaceuticals and beverage sector with natural flavour will push the demand for phytopharmaceuticals.

Developments in Herbal Industry

The herbal industry has been developing rapidly over the last two decades. Europe has a long history of R&D in herbal drugs, and has tighter regulations, established quality control procedures, and decades of clinical data to support its products. The majority of leading herbal companies are located in Germany, France, Italy and Switzerland. Some of them are over 100 years old and many are privately owned.

In the last decade, there was a tendency of acquisition of smaller herbal companies in Europe by multinational pharmaceutical companies and establishment of joint-ventures between European herbal companies and American partners. There is an increasing consolidation in the herbal industry at wholesale, retail and suppliers level. Beginning with the merger of Twin Labs and Natures Herbs in 1989, many important mergers and acquisitions have taken place (Table 5). Celestial Seasonings, one of the largest producers of herbal drinks, was acquired by the Hain Food Group for US$ 390 mn, to form the largest natural foods company in the USA.[39] Most of the large food and pharmaceutical companies have also entered the business, e.g. Warner Lambert, American Home Products, Bayer and SmithKline Beecham, have all introduced herbal products.

The nutraceutical industry is also developing very fast. The large food and pharmaceutical companies, such as Kellog, Heinz, Quaker, Unilever, Dupont, Novartis, Cargill, Hormel, Abott Laboratories, Royal Numico, Amway and American Home Products are active in the field since they view nutraceutical market as an emerging sector. In general, the pharmaceutical industry is better positioned to produce nutraceuticals, although there

are companies that operate in both areas through strategic alliances. The largest Australian-owned nurtaceutical company, Goodman Fielder, had a total turnover of around US$ 2.2 bn in 1998-1999 and 10% of this corresponded to health foods.

Table 5: Acquisitions of herbal companies by multinational pharmaceutical companies

Multinational company	Herbal company acquired
American Home Products	Dr. Much (Germany)
Boehringer Ingleheim	Pharmaton (Switzerland) & Quest (Canada)
Boots	Kanold (Germany)
Bausch & Lomb	Dr. Mann (Germany)
Hain Celestial Group Inc.	Celestial Seasonings (USA)
Degussa	Asta Medica (Germany)
Fujisawa	Klinge (Germany)
Johnson & Johnson/ Merck	Woelm Pharma (Germany)
Pfizer	Mack (Germany)
Rhone Poulenc Rohrer	Natterman (Germany)
Sanofi	Plant Organ (Germany)
Searle	Heumann (Germany)
SmithKline Beecham	Fink (Germany)
Solvay	Kali Chemie (Germany)

Market leaders in cosmeceuticals are Johnson & Johnson, L'Oreal, Unilever, Proctor and Gamble, and Estée Lauder.

In the raw materials sector, the leading herbal companies supplying material to the world market are Martin and Bauer Group with a global turnover of US$ 250 mn followed by Indena and Scheizerhall, each at US$ 200 mn and SKW Trostburg, Arkopharma each with US$ 100 mn in 1998. Indena is the world's largest botanical extract supplier, with a wide range of extracts of medicinal and cosmetic value.

Policies and Regulations in Medicinal Plants Trade

Trade in medicinal and aromatic plants is unregulated in most parts of the world. There is an urgent need to formulate a uniform policy at international level to control trade in these plants. International supplies of medicinal plants are regulated by tariff and non-tariff measures and restrictions varying from country to country.

Tariff Measures

Both import and export tariff measures are adopted in medicinal plants trade. The import tariffs are imposed to provide protection to domestic products. Developed countries tend to maintain low tariffs on import to ensure sustained supply of raw material. In the EU markets, special tariff rates apply to products from African, Caribbean, Pacific, Andean and countries of the European Free Trade Association. In the US market, special rates apply to products from the Caribbean or other countries in free trade areas. Import tariffs in emerging and developing countries are considerably higher. For example, im-

port tariffs in China range from 12 to 65%, and from 30 to 60% in India. Export tariffs are levied on medicinal plants exported from most developing countries. For example, the export duty levied on medicinal plants is 15% in Cameroon.[41]

In several countries, most medicinal plants and crude drugs are traded without any tariff restrictions, e.g. in Canada, Japan, the EU and the USA. However, tariff charges in China and South Africa vary between 10 to 20% of the value of goods, depending on the product. Tariff regulations applicable to drug import in the EU include associated implications of revenue law and conservation legislation. Dried and fresh botanical material is subject to a tariff codex when imported from emerging and developing countries into the EU. This codex consists of tariff regulations and associated implications of revenue law. These comprise Custom Law, Law on Market Organization and Countervailing Duty Law. Trade within the EU is unrestricted and exempt from customs duty.

Non-tariff Measures

The important non-tariff measures applicable to medicinal plants and their products in trade are species protection control, health and safety regulations, and quality and technical standards.

Species Protection Control

After recognizing the fact that the threat of extinction of a species is directly related to its global market demand, nations of the world worked together to formulate an international treaty known as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This treaty came into effect on 1 July 1975 and at present has 154 signatories. It regulates the international trade of rare and endangered species of plants (including medicinal) and animals through establishment of protocols for regulating the international trade of plants that are facing danger of extinction due to over-exploitation. Medicinal plants that have become endangered are listed under three appendices, according to their risk of extinction. Appendix I includes plant species that are currently threatened with extinction. Trade in Appendix I species is most heavily restricted and is normally prohibited. However, under special circumstances the movement can be allowed and requires both an export permit from the country of origin and an import permit from the country of destination. Medicinal plant species like *Nepenthes distillattoria* L., *Saussurea costus* (Falc.) Lipschitz and *Stangeria eriopus* (Kunze) Nash. are included in this category. Appendix II includes plant species that are not necessarily threatened with extinction at present but may become so if not carefully monitored. Trade in Appendix II species requires only an export permit. Appendix III includes plant species that individual nations wish to regulate through international cooperation in order to prevent or restrict their exploitation. At present, an estimated 230 plant species included in CITES are traded for medicinal purposes. Very recently, a list of 47 medicinal and aromatic plants traded in Germany has been included in Appendix II of CITES. From India, 10 medicinal plant species in trade are included in Appendix II and one in Appendix I. A few countries have also imposed bans on export of wild plants, e.g. Australia has developed a comprehensive system of export control for all its native plants. Some indi-

vidual countries also control trade in certain species by controlling their export, e.g. *Harpagophytum procumbens* (Burch.) DC. ex Meisn. in Botswana, many wild orchids in Costa Rica, and *Rauvolfia serpentina* (L.) Benth. ex Kurz and wild orchids in India.

Health and Safety Regulations

As regulatory requirements for health products in many countries are becoming stricter, many industrialized countries refuse admission for consignments of plant material that show signs of pesticide residues. For example, Germany has regulations concerning the maximum allowable residue level in phytogenic foodstuffs. Exporting countries are required to furnish phyto-sanitary certificates of pesticide-residue-free products. It is also essential that the plant material in trade should be free from microbial contamination, dirt, dust and other undesired matter.

Quality and Technical Standards

Quality considerations are of primary importance in the trade of medicinal and culinary herbs. The quality and technical standards are becoming increasingly strict. The main factors considered by importers and buyers are cleanliness, flavour, colour and aroma of the herb. Quality criteria vary from country to country and from herb to herb, and are usually imposed by large importing and processing companies. The regulations and requirements regarding quality parameters, i.e. identification, medicinal qualities, characteristics and storage of medicinal plants and their derivatives, are well-defined in national pharmacopoeias and formularies. The EU follows unified standards laid down in the European Pharmacopoeia while specifications for Japan and the USA are listed in the Pharmacopoeia of Japan and the United States Pharmacopoeia, respectively. Emerging and developing countries have also developed national pharmacopoeia, e.g. the Ayurvedic Pharmacopoeia of India and the Indian Pharmacopoeia, and the Pharmacopoeia of the People's Republic of China.

Problems and Constraints in Medicinal Plants Trade and Market Development

Development of the medicinal plants market has been held back by many problems such as lack of species-specific trade statistics, lack of clear distinction between medicinal, food, spice and aromatic usages, and grouping of medicinal plants in one broad category in international trade classification systems. In most emerging and developing countries, medicinal plants are considered as minor crops and receive low priority in national investment programmes for research and export development. The growth of export from these countries is hampered by the lack of R&D, production technologies, and the lack of information on intellectual property rights, market access, supply and demand.

Most countries do not have legislation and policies to regulate trade in medicinal plants. Countries with such legislation, do not ban collection of rare or endangered plants from private land. Many medicinal plants grow remotely from the protected areas of domain, and many disappear without anyone's knowledge. International treaties like CITES do not have enforcement powers of their own. It is up to individual member nations to

enforce the regulations suggested by CITES. However, the nation is not bound by CITES trade restrictions if it simply enters a reservation on a species. This loophole in the CITES agreement ignores the protection of several threatened plant species.

Conclusions

Medicinal plants and their products have taken on increasing medical and economic importance. With product categories like health foods, cosmetics and personal-care products containing natural ingredients, the demand for medicinal plants is growing exponentially. The use of herbal medicines is becoming ever more popular with rising green consumerism. Most medicinal plants material is sourced from the wild and from developing countries. The booming world market is opening up invaluable opportunities for these countries to benefit from the rising demand. However, international trade of medicinal plants is unregulated, and statistics on supply and demand of heavily demanded plants are scarce. Over-harvesting from wild sources is rampant and cultivation efforts are few.

The situation, however, shows promise for emerging and developing countries, which are blessed with both rich biodiversity and diverse agro-climatic conditions that can encourage sustainable harvesting from wild and cultivation.

With the increased demand of medicinal plants in the world market, the emerging and developing countries have great opportunities to develop their export potential. The unregulated nature of trade coupled with over-exploitation of medicinal plant resources from the wild has threatened the existence of many species of commercial importance. To date, the only international legislation that provides species-specific information and regulate international trade in medicinal plants is CITES. However, it does not have a complete control of the voluminous trade in medicinal plants.

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Contributors

Name	Affiliation
Abdurazag AUZI	Pharmacognosy Department Faculty of Pharmacy Elfateh University P. O. Box 9311 Tripoli Libya Tel.: +218-21-3502106 Fax: +218-21-3501505 E-mail: aauzi@yahoo.co.uk
Armando CÁCERES	Iberoamerican Network on Phytotherapeutic Products (RIPROFITO) Laboratorio Farmaya Av. Centroamericana 18-92, Zona 1 Guatemala City Guatemala Tel.: +502-2-214967 Tel./fax: +502-2-305006 E-mail: farmaya@explonet.com
M. Iqbal CHOUDHARY	HEJ Research Institute of Chemistry International Centre for Chemical Sciences University of Karachi 75270 Karachi Pakistan Tel.: +92-21-9243224/11/35 Fax: +92-21-9243190/91 E-mail: zainraa@digicom.net.pk or hej@cyber.net.pk
Ermias DAGNE	African Laboratory for Natural Products (ALNAP) Department of Chemistry Addis Ababa University Addis Ababa Ethiopia Tel.: +251-1-553499 Fax: +251-1-551244 E-mail: erda@chem.aau.edu.et or edagne@yahoo.com
Mahabir P. GUPTA	Fine Pharmaceutical Chemistry Subprogramme (CYTED) University of Panama Estafeta Universitaria, Apartado 10767 Panama City Panama Tel.: +507-2697655 Fax: +507-2640789 E-mail: cytedqff@ancon.up.ac.pa

Name	Affiliation
Sukhdev Swami HANDA	Zandu Pharmaceutical Works Limited 70, Gokhale Road South, Dadar Mumbai IND-400025 India Tel.: +91-22-4307021 Fax: +91-22-4375491 E-mail: zanduho@giasbm01.vsnl.net.in
Maninder KARAN	University Institute of Pharmaceutical Sciences Panjab University Chandigarh India Tel.: +91-172-534113 Fax: +91-172-541142 E-mail: maninderkaran@hotmail.com
Krisana KRAISINTU	Research and Development Institute Government Pharmaceutical Organization 75/1, Rama VI Road, Ratchathevi 10400 Bangkok Thailand Tel.: +662-2457164 Fax: +662-2462134 E-mail: krisana@mozart.inet.co.th or kraisintu@hotmail.com
Vishavjit KUMAR	Industrial Utilization of Medicinal and Aromatic Plants Earth, Environmental and Marine Sciences and Technologies ICS-UNIDO AREA Science Park, Bldg. L2, Padriciano 99 34012 Trieste Italy Tel.: +39-040-9228106 Fax: +39-040-9228136 E-mail: vishavjit.kumar@ics.trieste.it or vishavjitkumar@hotmail.com
Bambang MURSITO	Directorate of Indonesian Indigenous Drugs National Agency of Drugs and Foods Control Percetakan Negara 23 10560 Jakarta Indonesia Tel.: +62-21-4245075 Fax: +62-21-4245150, 8644916 E-mail: bmursito@astaga.com

Name	Affiliation
Marianne J. NGOULLA	World Health Organization for African Region (WHO/AFRO) P. O. Box Be 733, Belvedere Medical Schools, Parirenyatwa Hospital Harare Zimbabwe Tel.: +1-321-7339326 Fax: +1-321-7339160 or +263-4-700742 E-mail: ngoullam@whoafr.org or ngoullam@hotmail.com
Rodolfo QUINTERO	Instituto Mexicano del Petróleo Eje Central Lázaro Cárdenas 152 Col. San Bartolo Atepehuacan 07730 Mexico City Mexico Tel.: +52-55-30036000 Fax: +52-55-30038000 E-mail: quintero@imp.mx
Atta-ur-RAHMAN	HEJ Research Institute of Chemistry International Centre for Chemical Sciences University of Karachi 75270 Karachi Pakistan Tel.: +92-21-9243224 Fax: +92-21-9243190, 9243191 E-mail: hejric@digicom.net.pk
Farzana SHAHEEN	HEJ Research Institute of Chemistry International Centre for Chemical Sciences University of Karachi 75270 Karachi Pakistan Tel.: +92-21-9243224/11 Fax: +92-21-9243190/91 E-mail: zainraa@digicom.net.pk or farzanailyas@yahoo.com
Chika UKWE	SES/PEM UNIDO P. O. Box 300 A-1400 Vienna Austria Tel.: +43-1-260263895 Fax: +43-1-260266819 E-mail: c.ukwe@unido.org or chikaukwe@yahoo.com

Name	Affiliation
Karan VASISHT	Industrial Utilization of Medicinal and Aromatic Plants Earth,Environmental and Marine Sciences and Technologies ICS-UNIDO AREA Science Park, Bldg. L2, Padriciano 99 34012 Trieste Italy Tel.: +39-040-9228106 Fax: +39-040-9228136 E-mail: karan.vasisht@ics.trieste.it or kvasisht@hotmail.com
Maria Luisa VILLARREAL	Centro de Investigación de Biotecnología Universidad Autónoma del Estado de Morelos Av. Universidad 1001, Col. Chamilpa Cuernavaca Morelos Mexico Tel.: +52-73-297057 Fax: +52-73-297030 E-mail: luisav@cib.uaem.mx
Arnold VLIETINCK	Department Farmaceutische Wetenschappen Universitaire Instelling Antwerpen Universiteitsplein 1-B-2610 Antwerpen (Wilrijk) Belgium Tel.: +32-3-8202733/2020 Fax: +32-3-8202734 E-mail: vlietinck@ua.ac.be

Coverpage insets include pictures of:
Echinacea purpurea (L.) Moench,
Hypericum perforatum L., and
Papaver bracteatum Lindl.