MEDICINAL AND AROMATIC PLANTS

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Summary

The natural environment has been a location for the growth and development of medicinal plants for thousands of years. Healing with plant extracts dates back to the appearance on earth of *Homo sapiens*. Even to date, about 80% of the world population relies on traditional medicines for their primary health care, while medicinal plants continue to play an important role for the remaining 20%.

The botanical characteristics of medicinal plants are rather diverse. They belong to various plant families and are the source of crude drugs or simply drugs i.e. specific

plant parts of medicinal plants, as described in the *Pharmacopoeias* in terms of European and/or national standards. Frequently, plant parts containing special ingredients are processed prior to utilization. Drying is the simplest methods of processing (primary processing), making it possible to store crude drugs. Other methods include extraction, extraction of essential oils, etc.

The pharmacological activity of medicinal and aromatic plants (MAPs) is due to their biologically active ingredients classified into four groups: alkaloids, glycosides, essential oils and other miscellaneous active substances. Secondary metabolites, being end products of metabolic processes, can be observed through color, taste, or odor, and be determined by chemical analysis. Growth and development of MAPs and their metabolites are influenced by the physical environment, including light, temperature, rainfall, and soil properties. Changes can occur in the course of the plant cycle and even during one single day (diurnal variations).

Production of quality crude drugs with high amounts of active substances requires expert collection practices, proper processing, drying, packaging and correct storage. The increasing demand for wild plants – as ingredients for food, cosmetics, well-being and medicinal products – poses ecological and social challenges. Specific production strategies, production guidelines (Good Agricultural Practices - GAP) are meant to provide well-defined and reproducible production conditions for MAP producers.

1. Introduction

Natural environment has been a source of medicinal agents for thousands of years, since healing with plants dates back probably to the evolution of *Homo sapiens*. Even to date, about 80% of the world's inhabitants rely mainly on traditional medicines for their primary health care, while medicinal plants continue to play an important role in the health care systems of the remaining 20%. Partly based on their use in traditional medicine, an impressive number of modern drugs have also been isolated from natural plant species. Remarkably, even today there is no real definition for this special group of plants that has been accompanying mankind throughout history.

Most frequently, medicinal plants are defined as feral and/or cultivated plants that, based on tradition and literature records, can be directly or indirectly used for medical purposes. The basis for this use is that these plants contain so called active ingredients (active principles or biologically active principles) that affect physiological (metabolic) processes of living organisms, including human beings.

The notion of aromatic plants is even less definite. The attribute aromatic indicates plants having an aroma; being fragrant or sweet-smelling, while the word aroma is supposed to imply also the taste of the material (*aromatic herbs).*

Spice plants are plants used for seasoning, spicing, flavoring and coloring foods, drinks and different products of the food processing industry, i.e. making a product more enjoyable. Frequently, we also speak of essential oil plants, that accumulate oils in certain specific organs or plant parts which are then used for the production of essential (ethereal) oils.

Due to the complexity and overlapping uses of active ingredients, and the great number of plant species involved, it is impossible to establish rigid categories or a practical classification for medicinal and aromatic plants. Anise, dill, coriander, thyme, etc. are equally known as medicinal, spice and essential oil crops. Thus, frequently these plants are simply referred to as medicinal plants, disregarding their specific features.

More recently, the term “Medicinal and Aromatic Plants” (MAPs) has been used in a slightly broader sense, distinguishing the fragrant (aromatic, ethereal) ingredients-containing group of medicinal plants.

2. Botanical Characteristics and Taxonomy

With regards to their botanical characteristics, medicinal plants are rather diverse. They belong to various plant families which, frequently, comprise characteristic similar active ingredients (as a result of similarities in the biosynthetic pathways). As an example, the plant-family Labiateae (Lamiaceae) comprises a large number of essential oil-containing species (lavender, thyme, rosemary, sage, etc.) whereas other plant families, like the Solanaceae are characterized by the occurrence of several alkaloid-containing species (Belladonna, thorn apple, tobacco, etc.).

Phylogenetic systems classify medicinal and aromatic plants according to their purported evolutionary relationships or heredity, although remarkably even to date, phylogenetic systems are to a large extent based on the former artificial system of Linneaus. More refined morphological systems take into consideration the morphological traits of plants and evaluate them according to the principles of evolution and inheritance.

In recent decades, more and more attention has been paid to the use of plant-derived chemical information giving rise to chemo-taxonomy or phytochemical plant systems. Similarly to other domains of plant systematics, the recent trends to use cytological and molecular biological traits are expected to bring about changes in the already established phylogenetic systems.

The basic taxonomic unit of MAPs remains the *species* (sp.), with related species constituting a *genus*. The categories *subspecies* (subsp.), *variety* (var.) and *form* (f.) are used to differentiate among dissimilar populations of wild-growing species. In an econo-botanical sense, both natural and cultivated species are divided into well distinguished *infraspecific varieties* (Terpó, 1992). Cultivars are differentiated according to their features valued by human societies.

A special feature of MAPs is that a number of characteristic chemical, cytological, morphological, and occasionally even ecological properties may be used for their correct description. In these cases the species represents either a homogenous taxon of plants with little variation from one specimen to another, or it may include varieties or races with distinctive features. Often, such varieties represent single gene mutations and are morphologically recognizable. In other cases the mutation gives rise to a variant having a different secondary metabolite profile, which is not necessarily noticeable in the morphological form. These are termed *chemical races* or *chemodemes*.

In certain instances, there are also other genetic variations that affect the chemical constituents of the species, e.g. the appearance of polyploids, the addition of one or a few chromosomes above the normal complement (extra chromosomal types), gross structural changes to the chromosome, biotechnologically produced genetically modified plants.

Chemical races have been detected in numerous species and chemical substances, e.g. cyanogenetic glycosides in *Prunus communis*, alkaloids in *Duboisia* species, cardiac glycosides in *Digitalis purpurea*, essential oils in *Ocimum* spp, *Melissa* spp., *Thymus* spp., etc. (Trease and Evans, 2002).

3. Biochemical and Plant Physiological Features

In a simplified form, the compounds produced by living organisms are divided into two major groups: primary metabolites and secondary metabolites. The primary metabolites are produced in the basic metabolic process (primary metabolism), such as photosynthesis and respiration, and are considered essential, functional, operating components of all living organisms. Secondary metabolites are mostly derived from the precursors produced by the primary metabolic processes.

Secondary metabolites have no generally recognized, direct roles in the processes of photosynthesis, respiration and other major metabolic processes of the plants. Secondary metabolites also differ from primary metabolites (amino acids, nucleotides, sugars, acyl lipids) in having a restricted distribution in the plant kingdom (Ziegler and Taiz, 2006). In other words, particular secondary metabolites are often found in only one plant species or related group of species, whereas primary metabolites are often found throughout the plant kingdom.

More recently, many secondary metabolites have been suggested to have important ecological functions in plants, e.g.:

- They protect plants against being eaten by herbivores and/or being infected by microbial pathogens.
- They serve as attractants (smell, color, taste) for pollinators and seed-dispersing animals,
- They function as agents of plant-plant competition and plant-microbe symbioses.

4. The Crude Drug

Crude drugs or simply drugs are specific plant parts of medicinal plants, as described in the *Pharmacopoeias* (European and/or national standards), or their products produced according to a definite technology. As a rule, not the entire plant is used, but only those portions that contain the active ingredients, e.g. the root, leaf or fruit. The “queen” of medicinal plants is *Chamomilla recutita L*. (Photo 1).

The connotation of “drugs” is controlled by the relevant rules of *Geneva Nomenclature*. In most instances the Latin name of the medicinal plants (either the binominal name or only the species name) in singular genitive case is followed by the authorized name of the processed plant part in the nominative case, e.g. *Vincae minoris herba*, *Daturae innoxiae folium, Lavandulae flos*, *Belladonnae radix*, etc. Sometimes, especially in the case of plant extracts, the plant part in nominative case is followed by the name of the plant in genitive case, e.g. *Aetheroleum Menthae piperitae*, *Amylum Ricini*, etc. Common trade names of frequently occurring drugs are contained in Table 1.

Photo 1. The queen of medicinal plants, *Chamomilla recutita L.*

Frequently, the plants are not utilized (consumed) in the fresh state, but the plant parts containing the special ingredients are first processed. Drying is the simplest, at the same time, one of the important methods of processing (primary processing), making it possible to store crude drugs. Other methods include extraction, extraction of essential oils, etc.

Latin name	**English name**	**Latin name**	**English name**
amentum, -i	catkin, inflorescence	*herba, ae*	herb
amylum, -i	starch	*lichen, -es*	lichen
anthodium, -i	inflorescence	*lignum, -i*	woody parts
bacca, -ae	berry	*oleum, -i*	oil
bulbus, -i	bulb	*pericarpium, -ii*	fruit skin
capsula, -ae	capsule, fruit	*petalum, -a*	flower petals
caput, -itis	head	*radix, -icis*	root
cortex, icis	bark	*resina, -ae*	resin
flos, -ris	flower	*rhizoma, -ae*	rhizome
folium, -ii	leaf	*semen, -inis*	seeds
frons, -des	branch-tip	*stigma, -ae*	stigma
fructus, -es	fruit	*stipes, -itis*	stem, stalk,
galbulus, -i	strobilus, cone	*stolo, -onis*	runner
galla, -ae	gall	*strobulus, -i*	cone
gemma, -ae	bud	*summitas, -atis*	shoot-tip
granum, -i	seed corn	*tuber, -ecis*	tuber

Table 1. Trade names of frequent crude drugs

5. Active Ingredients

MAPs contain chemical substances of different composition and activity. These are referred to as active or biologically active substances, implying their effect on living organisms. These substances play an important physiological and ecological role for the plant itself and are the basis for their utilization as MAPs. It should, however, be underlined that plant metabolism cannot artificially be divided, as it involves both universal and special processes.

In the scientific literature, active ingredients of plants are often still classified into four traditionally accepted groups: alkaloids, glycosides, essential oils and other miscellaneous active substances (Hornok, 1992). These categories are mainly based on practical, diagnostic considerations.

- **Alkaloids** are a group of nitrogen-containing substances of basic chemical reaction; they frequently form salts and have strong physiological effects on living organisms. The alkaloids are very variable in their composition.

- **Glycosides** are compounds of various chemical structures and physiological effect, and of divergent metabolic origin. Although generally not regarded as a uniform group of compounds, their common feature is that one or more identical sugar molecules are bound to a non-sugar-type compound (aglycone). The aglycones, in turn, can be also most varied.

- **Essential oils**. The term refers to a mixture of various compounds, mainly terpenes and terpene derivatives that evaporate at room temperature without residues. Frequently they have characteristic and a strong odor and taste (aroma). Generally they are extracted (isolated) by steam distillation. They do not or only poorly dissolve in water.

- **Miscellaneous substances** like aromatic acids, bitter substances carbohydrates, mucilaginous substances, plant pigments, rubber, sterols, tannins, vitamins cannot be classified into the above groups; they are of diverse chemical composition and physiological effectiveness.

In contrast to the above classification, the biogenetic system of natural substances is based on the main pathways of the universal metabolism and connects special metabolic pathways, e.g. sacharides, phenoloids, polyketides, terpenoids and azotoids.

6. Heredity and Variability

At different levels of evolution, the chemistry of living organisms including medicinal and aromatic plants is different. The rise of chemical taxa can be considered as the result of biochemical and metabolic processes mostly under genetic control. It is accepted that differentiation in cells is mostly manifested in chemo-differentiation at a molecular level and the fundamental differences in the course of ontogeny manifest themselves mainly in the differences of proteins present in the organism, i.e. ultimately in differences between the enzyme systems (Tétényi, 1992). All other (morphological, anatomical) differences are only the consequences of these.

The secondary metabolites of MAPs, the end products of metabolic processes, if accumulated, can be directly observed by sensing (through color, taste, odor) and can be revealed by chemical analysis. Frequently, however, these chemical characters are hidden. It is recognized that they are accompanied by morphological divergence, e.g. cyanogenic glycosides in *Trifolium repens* and the presence or absence of a white spot on leaflets.

Differences in plant chemistry, i.e. in the special chemical features of MAPs, are attributed to dissimilarities in the metabolism. Since they are manifestations of the genetic background, they should be determined in a possibly most complex way, when characterizing this special group of plants. This chemical fingerprint - the complexity of chemical traits - is called *chemosyndrome*. The accumulation of identical materials does not imply any relationship in chemism, e.g. the occurrence of the alkaloid bufotedine, in both the flowering plant *Piptadenia falcata* Benth and toads. It is known that both rare (e.g. thebaine in certain *Papaver* species) and ubiquitous substances (e.g. chlorophyll) may also have homologous biosynthetic pathways. Therefore, their frequency of occurrence cannot be regarded as proof of relationship.

It has also been found that chemical changes - e.g. infra-specific chemical modifications - can be caused by ecological and geographical conditions. These chemical differences are known as *polychemism*. According to Tétényi (1992) polychemism is the materialized result of all chemical processes of the plant. It results from differences between the chemism and taxonomic units, i.e. chemotaxa that have been established during that chemical differentiation. Polychemism is known to be frequent in autogamous species (where a sudden chemical change can easily be inherited) and has been frequently described in cross-fertilized species, provided they are isolated.

Chemical characters and their differences are as important characteristics in plants as other features. Their inheritance and variability are governed by the same rules. They are especially important in the case of medicinal and aromatic plants, since they serve as a real biological base for breeding. The efficiency of cultivation of these species is fundamentally dependent on the productivity of the plant material within which these compounds are accumulated.

Recent research trends seem to provide new opportunities for revealing the reality of DNA and biosynthetic causes of chemo-differentiation. They are opening great perspectives for the breeding of new, highly powerful chemo-cultivars of medicinal and aromatic taxa.

7. Genetic Improvement and Breeding

In medicinal and aromatic plant breeding, besides the usual breeding goals - e.g. to increase plant yields - the quality of active principle content plays an important role. The amount and quality (composition) of these metabolites is, however, influenced by various ecological factors. It can undergo changes in the course of the plant cycle and even during one single day (diurnal variations). It is accompanied by the translocation of metabolites between various organs, occasionally even between above- and below-ground organs. To avoid false conclusions, the effect of these factors must therefore be investigated in the course of breeding. Due to the high costs of chemical analyses the breeding of MAPs can be rather expensive as compared to other crops.

Morphological differences that are important parameters in other crops could be also misleading as was determined, for example, in the case of *Digitalis lanata*, where no correlation could be found with leaf sizes. Nonetheless, the sizes of certain plant organs (as for example fruits of coriander, anis, or caraway) are important traits from the viewpoint of customers.

The breeding of MAPS usually starts from populations, possibly by selecting plant individuals with favorable traits. As a rule, the variability of MAPs is higher than in other species. Therefore, at the first level of breeding the commercial propagating material taken from these types is selected frequently at random with almost no guarantee for the inheritance of compositional properties (Tétényi, 1992). Landraces, with less variability in their regional features or chemical characteristics represent the next level of breeding. A number of poppy cultivars of this level used to be grown in Hungary (Photo 2).

Photo 2. Capsules of opium poppy (*Papaver somniferum L*) ripe for harvest

Breeders of MAPs use well established traditional and biotechnological methods of plant breeding. Selection breeding is generally important to retain fitness while inbreeding is used mostly in increasing uniformity. The latter is frequently accompanied by the deterioration of certain traits, e.g. vitality in *Digitalis* sp.

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The special literature on medicinal and aromatic plants is rather vast. Especially, due to the involvement of several basic and applied sciences it is hard to assess. The above list of references is meant to offer some assistance for those wishing to get a deeper insight

Biographical Sketch

Habil. Prof. Dr. Ákos Máthé graduated from the University of Horticulture, Budapest. He earned his Ph. D. in experimental plant sciences, Doctor of Sciences degree of the Hungarian Academy of Sciences, in agricultural sciences, Habilitation at the Szent István University, Gödöllő (Hungary), agricultural sciences.He is member of International Society for Horticultural Science (ISHS) since 1977, and is presently chair of the Section Medicinal and Aromatic Plants. He is Vice President of International Council of Medicinal and Aromatic Plants (member of IUBS) and President of the Hungarian Horticultural Society. He is former editor of Herba Hungarica, Acta Agronomica Hungarica, and presently editor of ICMAP Newsletter, member of the board of editors of Journal of Medicinal and Aromatic Plants, Haworth, Journal of Horticultural Science and Biotechnology.Prof. Mathe was a Fulbright scholar to UC Davis, Purdue University and UMASS, in 1986 and 1995. He was Lecturer and visiting professor at University of Massachusetts, Amherst, and University of Veterinary Medicine, Vienna. Presently, he is Professor and Head of Department of Botany, University of West Hungary, Faculty of Agriculture and Food Science, Mosonmagyaróvár, Hungary. His main research areas include: botany and ecophysiology of medicinal and aromatic plants, diversification of horticultural production.