1. BOTANICAL ASPECTS OF MEDICINAL AND AROMATIC PLANTS

1. Botany of Aromatic and Medicinal Plants

The vast diversity of the plant kingdom, the approximately 40,000 plant species used for ethnomedicinal purposes, since the beginnings of recorded history, have traditionally been collected and gathered from the wild. This activity is also called **wild-crafting**. Even at the present time large quantities are foraged from native ecosystems.

With regards to their botanical characteristics, MAPs plants are both rather specialized and also diverse. Their differentiating characters are studied by 5 main branches of botany, i.e.: morphology/anatomy, systematics (taxonomy), physiology, genetics and ecology.

Botany, also called **plant science(s)** or **plant biology**, is the science of plant life, a branch of biology. Until the 18th century, botany was involved mainly with the description of plants and their classification. As a *quasi contrast*, the modern science of Botany is dealing with plants in a broad, multidisciplinary way and is based on inputs from numerous other areas of science and technology.

Pharmacobotany or **Medical Botany,** a special domain of botany, covers all pharmaceutical aspects of botany, including cytology, histology, morphology and taxonomy of plants used in the pharmacological practice, i.e. it deals with the botanical aspects of plants affecting man's health (Medicinal and Aromatic Plants).

2. Plant Morphology/Anatomy

The aromatic as well as medicinal properties of herbs can come from various organs of a plant: leaves, roots, barks, fruits, seeds, flowers. The biologically active substances that are responsible for these effects are produced and frequently also accumulated in the tissues of these organs. As a consequence, they are harvested/collected for the purpose of utilization. Frequently, however, these substances are translocated between organs, so that – in certain cases - it can happen that one part of the plant could be toxic while another organ of the same plant could be harmless.

The discipline of **Pharmacognosy** (the knowledge of herbs), relies greatly on the morpho-anatomic characteristics of plants, i.e. on the presence or absence of morphological traits. Well identifiable morphological/structural traits are used both to determine the identity of crude drugs, and to eliminate adulterations. In pharmacognosy, dried forms of these plant organs are called (crude)

drugs.

They are generally denominated by using the binominal Latin name of the plants (e.g.: Flores tiliae, Folium menthae, etc.).

2.1 Plant organs utilized for obtaining culinary herbs

The most frequently collected and used plant organs are the following:

Bark: The protective outer layer of a tree trunk, e.g.: cinnamon bark.

Bulb: a compacted underground shoot, a fleshy structure comprised of numerous layers of leaf bases (known as bulb scales), e.g.: onion species and garlic.

Flowers: The flowers of plants have always been popular in traditional medicine. Examples include clove and chamomile flowers. Flower parts are also used such as saffron stamens, the stigmas of maize, or pollen.

Fruit: Fruits have been heavily used for medicinal purposes. Dried whole fruits or portions of fruits can be used. Many members of the carrot family have fruits that are used in medicine including fennel fruit and anise.

Gum: Gums are solids that are mixtures of polysaccharides (sugars). They are water-soluble and are in part digestible by humans.

Leaf/herbs: the leaves of plants, shrubs, and trees, in either fresh or dried state, can be used for seasoning purposes, e.g.: peppermint, lemon balm, sage, etc.

Roots: the fleshy or woody roots are frequently used for also medicinal purposes, e.g.: ginseng, licorice.

Rhizome: A rhizome is defined as a fleshy or woody elongated stem that usually grows horizontally below the ground. Rhizomes often produce leaves above the ground and roots into the ground, e.g.: ginger.

Seed: The seeds of many plants are used for their medicinal properties. Seeds may be contained within a fruit or are sometimes used on their own. Juniper berries look like fruits but they are actually seeds surrounded by beautiful woody cones.

Tuber: A tuber is defined as a swollen, fleshy structure below ground. Tubers are usually of stem origin but can be partly stem and root in origin. Tubers used for medicinal properties include African potato and autumn crocus.

Wood: Thick stems or the wood of trees or shrubs are used for medicinal properties. Sandalwood and quassia wood are popular examples.

The science of pharmacognosy ranks also essential oils and fatty oils among the plant drugs. Characteristically these are the products of extraction processes from various plant organs.

Essential Oils: These are defined as volatile oils that are generally extracted from plants using a steam distillation process. Examples include camphor and peppermint oil.

Fatty Oil: These are defined as non-volatile vegetable oils that are pressed from the seeds or fruits of plants and are insoluble in water. Examples of fatty oils used in medicine are castor oil, olive oil, and safflower oil. Some fatty oils have direct medicinal properties while others are used as carriers in liquid formations and ointments.

3. Plant systematics

MAPs belong to various plant families which, frequently, produce characteristical active ingredients with similar biological activity (this is regarded as the result of similarities in the biosynthetic pathways**Plant systems** classify medicinal and aromatic plants according to their morphological and also purported evolutionary relationships or heredity. Remarkably, however, even to date, they are to a large extent based on the former, so called artificial system of Linneaus (Linneaeus, 1758). In the second half of the last century, however, more and more emphasis was paid to the use of plant-derived chemical information. This gave rise to the science of **chemo-taxonomy** or **phytochemical plant systematics** (Hegnauer, 1986, (Swain, 1977).

3.1 Biological diversity of MAPs

Over ninety percent of the traditionally used MAPs in economically poor countries are traditionally gathered. The natural resources (the natural diversity) of MAPs are, however, limited. If the biological equilibrium of natural ecosystems is impaired by irrational exploitation, this action could have disastrous repercussions also on the entire ecosystem (Bojor 1991). To date, the unthoughtful utilization has already lead to the overexploitation of natural resources of MAPs, thus endangering the survival of an increasing number of species.

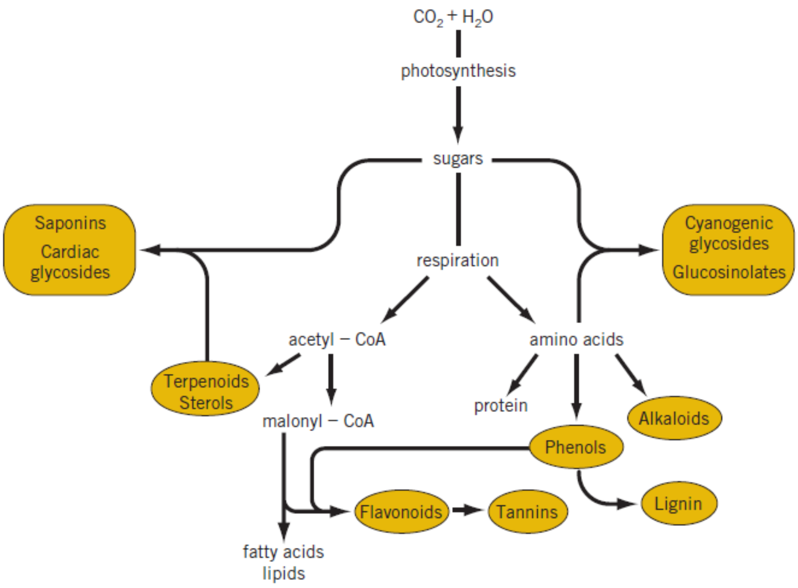
The need for the **sustainable use** of natural resources was recognized by the Chiang Mai Declaration (1988) that had expressed alarm over the consequences in the loss of plant diversity

(WHO 1991). The Declaration highlighted "the urgent need for international cooperation and coordination to establish programs for the conservation of medicinal plants to ensure that adequate quantities are available for future generations". It has also called for a need to coordinate **conservation** actions based on both ***in situ*** and ***ex situ*** strategies.

Ex situ conservation is the process of protecting an endangered plant species outside its natural habitat, e.g.: seed bank, gene bank. *In situ* conservation, as an opposite, means the process of protecting an endangered plant species in their natural habitats.

4. Plant physiology

The biologically active substances (principles) of plants are produced by multitude forms of biochemical processes studied also by the science of plant biochemistry and plant physiology. Photosynthesis, the capture of light energy converts water, CO_2 and mineral nutrients into organic matters. Carbohydrates and subsequently a wide range of farther organic principles are synthesized in the primary and secondary metabolic processes of plants (Figure 1).



1. *Figure* Interrelatedness of primary and metabolism *(Hopkins & Norman, 2009)* *(Hopkins & Norman, 2009)*

While primary metabolism takes place in most cells, the secondary metabolic processes are frequently related to specialized cells and tissues. In the case of MAPs it is mainly the secondary metabolites that we utilize.

The **yield** (production) **of biologically active principles** in plants is determined by both the biomass of the plant (generally expressed as dry mass) and the quantity of active principles (substances) that are contained in it.

Frequently these substances are regarded as **metabolic end products**, with no relevant role in the metabolism, but rather with various ecological functions (defense, attractant, etc.). Some important ecological functions are:

- They protect plants against being eaten by herbivores and/or being infected by microbial pathogens.

The secondary metabolites of MAPs have an importance in the chemical defense against predators, pathogens, allelopatic agents and help also in pollination, dispersal, etc., their importance has somewhat eased (Gershenzon & Mabry, 1983) (Singh, 2004).

- 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
- These compounds are also used by plants for farther various purposes (e.g. nutrition, maintenance, reproduction, defense, healing). Similarly, the plants consumed by man can serve important basic dietary purposes (food, vitamins), they can also contribute to our wellbeing (as condiments and spices) and finally, they can also serve as important sources of medication (plant derived medicines or herbal medicines).

5. Taxonomy and Plant classification

The basic taxonomic unit of MAPs is the *species* (sp.), with the 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 economic-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 sometimes a number of characteristic chemical, cytological, morphological, and occasionally even ecological properties may be used for their correct identification (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 various varieties or races with distinctive features.

In certain instances, there are also other genetic variations that affect the chemical constituents of the species. Such *chemical races* have been detected in the case of numerous species and chemical substances. E.g.: essential oils in *Ocimum* spp, *Melissa* spp., *Thymus* spp., etc. (Trease and Evans, 2000).

6. Genetics (Heredity and Variability)

At the various 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.

The secondary metabolites of MAPs, the end products of metabolic processes, if accumulated, can be directly observed by sensing (through color, taste and odor) and can be revealed by chemical analysis. Frequently, however, these chemical characters are hidden.

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.*

Chemical characters are especially important in the case of medicinal and aromatic plants, since they can serve as a real biological base for plant breeding. The efficiency of cultivation of these species is fundamentally dependent on the productivity of the plant organic matter (phytomass) 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. Variability of active principle accumulation

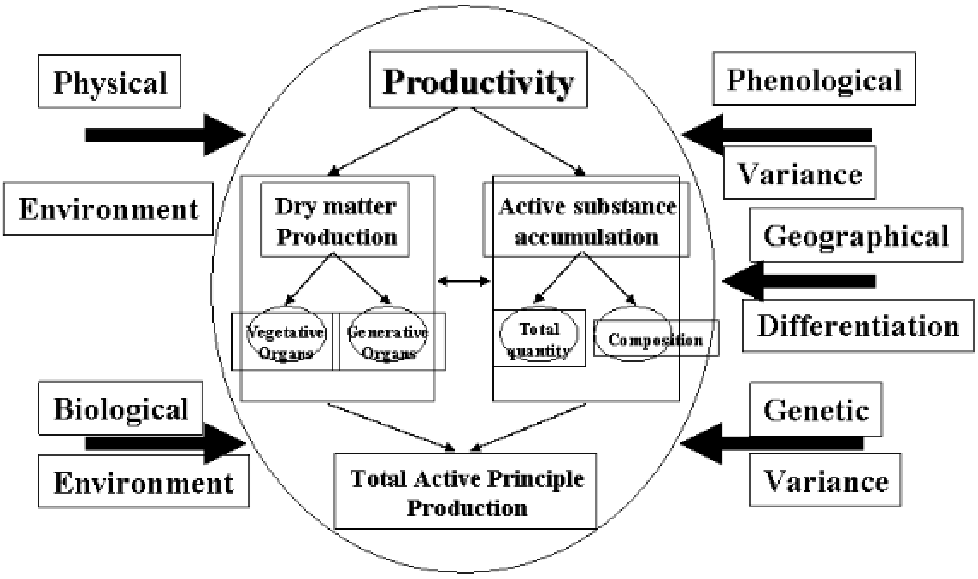
The amount (quantity) and quality (composition) of secondary metabolites as influenced by various factors that can be ranked into the following main groups:

7.1 Ecological variability

As a rule, growth and development of MAPs, including the production of their (secondary) metabolites can be affected by the physical environment, including light, temperature, rainfall, and soil properties. The impact of these ecological factors can be studied by growing various species under different climatic conditions, occasionally in a controlled environment (phytotron). In certain cases the effect of biotic factors can be also remarkable (e.g. in the case of allelopathy).

The productivity of medicinal and aromatic plants, either in natural or cultural ecosystems, is determined by both primary and secondary metabolites. Factors influencing the primary metabolism are likely to affect also the secondary metabolism. It appears, however, that in the production of secondary metabolites also farther special circumstances play a role. These are frequently attributed to their special ecological role and function.

Figure 2 gives an overview of the major factors influencing the biomass and active substance production in MAPs.



2. FigureMajor factors influencing biomass, yield and active substance production in medicinal and aromatic plants (Máthé, Á, 2000)

7.2 Life-cycle related variability of MAPs

It should be noted that the synthesis, accumulation or translocation of secondary metabolites undergoes changes in the course of the plant life cycle. Consequently, their presence and/or optimal concentrations must be determined specifically. These aspects are especially important and are taken into consideration when determining the harvest and collection dates of the relevant species. The chemical reactions related to the build-up of their particular metabolites are frequently related to the occurrence and functions of **special cells, tissues or plant organs**. Certain substances are secreted and accumulated by the plant in various secretor structures, like the oil glands in essential oil species of *Mentha* sp., or in the inflorescences in *Salvia sclarea*. This means that these substances do not take part in the plant metabolism any more. Essential oils are also known to accumulate in other anatomical structures, tissues and forms, like in the passage of the anise and caraway fruits, the roots of *Angelica archangelica*, etc.

7.3 Diurnal variations

Biochemical processes in a plant can undergo changes both in the course of the plant life-cycle (developmental phases in the course of plant life) and even during one single day (diurnal variations). These can be accompanied by the translocation of metabolites between various organs, occasionally even between above- and under-ground organs.

Secondary metabolites like alkaloids have been found to move between various organs within the plant. This is the case for the translocation from root to shoot of the tropane alkaloid hyosciamine in *Hyoscyamus officinalis*.

To avoid false conclusions, the effect of these factors must therefore be investigated in the course of breeding.

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