O. O. BOGOMOLETS NATIONAL MEDICAL UNIVERSITY

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MEDICINAL PLANT RESOURCES

Textbook

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The textbook contains information on current trends of evaluation, using and conservation of resources of medicinal plants, lichens and fungi at the international and national levels. The basic concepts of both national and international legislation concerning the uses and protection of medicinal plants are outlined; the status and conditions of wild resources of these species in Ukraine are regarded, as well as accumulation of biologically active substances by these species; the application of medicinal plants in various regions of the world in the official and traditional medicine is analyzed, as well medicinal plants of Ukraine and their biologically active substances, which are sources of the foreign and native herbal drugs and medicinal remedies. The textbook includes the methodological materials for evaluation (assessment) of medicinal plant resources. Examples of medicinal plant resources evaluation are provided. Some of information data, including the calculation forms for determination of the plant stock density, are presented in appendices.

The textbook can be used for teaching medicinal plant resources science at higher educational institutions, according to academic curricula, for teaching biological and environmental sciences at high school, as well as for evaluation of the plant resources.

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PREFACE

On the one hand, the course «Medicinal plant resources» as an important component of pharmaceutical sciences is a continuation and the final stage of botanical and pharmacognostical education for a pharmacist. On the other hand, it is the basic discipline used as a baseline for all scientific discoveries in pharmacognosy, since the development of new efficient herbal remedies and their implementation into medical practice is impossible without further examination of the resource base of raw material of corresponding plants.

The studies of the plant resources science are being conducted all around the world, but their specialization and characteristics have their own specificities in various countries. These differences are related to economic peculiarities of a country, demographic characteristics, diversity of herbal resources, as well as the availability and development of the area concerned.

Considering that the pharmaceutical purpose of research lies in studying the resources of species of plants and fungi that have recognized health care properties, the present textbook outlines mainly the aspects of the medicinal plants resource science as a part of the botanical resource science among, other pharmaceutical disciplines. The materials contained in the textbook are aimed at acquaintance of future professionals with the international priorities in the field of this research, the use and protection (including conservation and restoration) of medicinal plants, and the participation of Ukraine in the international market of herbal substances and drug preparations.

Keeping in mind the current priorities in the sphere of medicinal plants and fungi research, the medicinal plants resource science as the academic subject studies the species of

the medicinal flora of the world and Ukraine – especially of the European region, the raw materials of which is included into the State Pharmacopoeia of Ukraine, the European Pharmacopoeia, and the British Herbal Pharmacopoeia. Special attention is paid to the analysis of natural resources of these species and their cultivation, as well as to the use of medicinal plants in various regions of the world in scientific and traditional medicine; and to the study of medicinal plants of Ukraine, biologically active compounds of which constitute a considerable share of the medications that are produced domestically and/or abroad.

The textbook briefly outlines the history of the medicinal plants resource science in Ukraine, its basic terminology, the rules and regulations of harvesting and primary processing of raw materials collected in the wild. Much attention is paid to the order and methods for evaluation (assessment) of wild medicinal plants resources, as well as determination of the biological and exploitation stocks of raw materials and their annual amount of harvest. Current issues of the legal framework of the natural plant resources use in Ukraine and abroad are also described.

Taking into consideration the purpose of the textbook that is recommended primarily for students of the specialty Pharmacy, it is focused on investigation of medicinal plants and peculiarities of their accumulation of biologically active compounds, which are valuable for further production of drug preparations based on them or their active ingredients.

The Appendix provides the tables for express resource evaluation of the most important species of medicinal plants, as well as other information needed for the accurate conducting the resource science research.

While developing the textbook, original materials of the resource science case studies, the legislative acts, and available literary methodological sources were used.

CONTENTS

CHAPTER 1

MEDICINAL PLANT RESOURCES STUDY AS A SCIENCE AND AN ACADEMIC DISCIPLINE

Medicinal plant resources study is the science, which aims at investigation of the natural resources, as well as their diversity, ecology, spreading, status, usage and protection. The study of medicinal plant resources is a part of the **botanical resource science. The medicinal plant resources study** is included into the botanical resource science as the science of plant resources. **The medicinal plant resources science is essentially the science of the plant and fungi diverse resources, which are to be used in medicine and pharmacy**. Thus, the medicinal plant resources study occupies an intermediary position in the system of sciences, combining the elements of botany, pharmacy and medicine. The medicinal plant resources study as a discipline is included into the ecological and biological subject programs in universities and higher educational medical establishments (pharmaceutical departments). Medicinal mushrooms are traditionally considered to be the botanical objects and are studied along with medicinal plants.

Research of the medicinal plant resources is based on their taxonomic categorization and available bioactive compounds making it possible to generalize and systematize the knowledge gained in the study of pharmaceutical botany and pharmacognosy. In the pharmaceutical industry, the medical drugs are either made from the compounds extracted from the plant material, or substances of herbal origin are used as the starting materials for the production of semi-synthetic medications. The wild and cultivated plants are often used as the raw material; lichens and fungi can also substitute them, although such practice is not a widespread one. Various national priorities for research and use of medicinal plant resources were formed in different countries; however, the need of the balanced and sustainable use of natural resources unites them with a purpose of the resource protection.

The purpose of medicinal plant resources study is a search and comprehensive study of the flora and fungi resources for the needs of health care. The purpose of the discipline *Medicinal plant resources study* is to analyze the local and global resources of medicinal plants and fungi as the primary sources of biologically active compounds, as well as to study the current conditions and prospects of their usage.

The object of medicinal plant resources study is the particular species of medicinal plants and fungi, which are the primary sources of medicinal raw materials.

One of the main tasks of medicinal plant resources study is the identification among the wild flora of the species with the biologically active compounds which exhibit the distinctive pharmacological properties and therapeutic effects, as well as the assessment of their resources. In other words, it is the compilation of the outline (plant checklist formation) of the medicinal plants grown on

the territory taking into account the natural resources of selected species. These major tasks are closely related to pharmacognosy since the analysis of the flora for certain groups of biologically active compounds occurs, followed by the assessment of resources for each species to provide the pharmaceutical industry and phytotherapeutical practice with the medicinal plant materials.

The development of the pharmaceutical drug based on the raw medicinal plants or fungi and its implementation in the clinical practice requires the joint efforts of a number of experts, as well as the detailed analysis of the conditions and the needs of the pharmaceutical market. In case the species under consideration are confirmed to be prospective for use in medicine, the technology experts are being included into the further development of the drug in order to bring it to the final stage of development.

Resolutions of any issues related to the use of a particular plant species as a source of plant material eventually is encountered with the establishment of the resource conditions in nature or possibilities of its cultivation. The species, the raw material of which is highly estimated on the pharmaceutical market and the resources of which are limited, deserve to have the first and most detailed survey. It is sometimes necessary to study stocks of food, vitamin and industrial plants with a purpose of their application in medical or food industries, as well as for export. Depending on the areas of their uses, the economically important (useful) plants are divided into oil, honey, tanning, medicinal, technical, food, aromatic, forage, dye, decorative plants and others. Numerous species may simultaneously belong to different groups because of being valued as the medicinal, food, decorative plants, etc. Many of them are being used in an integrated manner. For example, Tilia is a medicinal plant, which is also a honey plant grown for landscaping and widely used in the wood industry.

1.1. Terms and definitions

Medicinal plants are considered the plant species that contain biologically active compounds and are used or can be used in medicine as sources of medicinal plant materials. Their Latin names are given in accordance with the binary system (*Urtica dioica, Hypericum perforatum, Melissa officinalis*). If as the raw material are used the parts of all the closely related species, only genera name is given (*Crataegus spp., Tilia spp., Rosa spp.*); if only certain plant species, the name of each of them is nominated. The name of the medicinal plant materials does not always display the generic names of the plants; for instance, the raw material of Eucalyptus globulus are leaves, and the name of the material is *Eucalypti folium; the roots of Althaea officinalis are sources of Radices Althaeae or Althaeae radices (radix); the fruits of Crataegus monogyna – Crataegi fructus; the herb Achillea millefolium – Millefolii herba.*

The plant raw material are the whole plants or their parts, which are used in a fresh or dried form for their direct application or processing (dosage forms, herbal formulations, biologically active food supplements, i.e., parapharmaceuticals); algae, fungi, lichens in the freshly or processed condition. The medicinal plant part is clearly identified, as well as its botanical name according to the binary system. The main types of the plant materials are: tubers (*Tubera*), bulbotubers (*Bulbotubera*), roots (*Radices*), rhizomes (*Rhizomata*), bulbs (*Bulbi*), rhizomes with roots (*Rhizomata cum radicibus*), barks (*Cortices*), leaves (*Folia*), fruits (*Fructus*), buds (*Gemma*), seeds (*Semina*), herbs (*Herba*), flowers (*Flos*), flower buds (*Alabastra*), strobiles (*Strobili*), styles with stigmas (Styli cum stigmatis), galls (*Gallae*), corms (*Cormi*), resins (*Resina*), oleoresins (*Oleoresina*), balsams (*Balsamum*), gum oleoresins (*Gummiresina*). In addition, there may be the cones (juniper), pollen,

etc. The majority of the medicinal plant raw materials are applied in the dry form (air-dry raw material). The freshly gathered raw material is used only for the certain plant materials (*Aloe arborescentis folia recens, Plantaginis majoris folia recens, etc.*). In the international trade, the raw material of medicinal plants is traditionally crushed or – less frequently – accepted in the form of plants or their organs (tubers, roots, fruits, seeds).

The checklists of medicinal plant species are listed in the Appendix (Tables 1- 3). It should be noted that some of the terms used in pharmacognosy and resource science do not correspond to their botanical interpretation. Thus, the term «herb» as a medicinal plant raw material usually means the leafy flowering shoots of the herbaceous plants or sometimes the stalks of horsetails and club mosses. The same term is sometimes used in pharmacy for designating the corms of *Ledum palustre*. In Pharmacognosy, the concept of «flower» means both a single flower (lily of the valley, blue cornflower (the marginal flowers) and a inflorescence (the wild chamomile, yellow everlasting, tansy).

Density of the raw materials stock is the weight of a certain type of plant raw material per area unit (g/m^2, kg/ha), determined in fresh conditions or in terms of air-dry raw material.

While evaluation the resources, the concept of «yield», «yield capacity» and «productivity» are used.

Yield is a specific amount of the raw material collected in a particular area in a current year; is measured in kg, c, t.

Yield capacity is the mean value (for 2-5 years) of yields per area unit.

Productivity (in resource science) is the amount of the raw material produced by plants during a certain period of time in a particular area.

It should be pointed out that the term «**yield capacity**» is not identical to the term «**productivity**».

An inventory area is a certain area, which is set in order to determine the resource characteristics of the plant species under consideration (mass of the raw materials, the number of plants or the projective cover).

For the species resource characterization are applied geobotanical terms concerning the phytocenotic structural organization: **phytocenosis, plant abundance scale, the projective cover and layering**. The first three characteristics are the most widespread in the plant resource science.

Phytocenosis, otherwise called **plant community**, is a set of plants that grow in a homogeneous area and are characterized by a certain species composition, structure and relationship of plants between one another and environmental conditions.

The newly formed phytocenosis is characterized by a certain floristic composition having a predominance of one or more species, layering, representation in phytocoenoses of plants (their abundance and cover) and others. The number of species in plant communities registered in a particular area is **called the species abundance** of a given phytocenosis.

In the plant resource science, it is useful to combine abundance degree (according to the Drudes scale) and the projective cover, and to express them in coefficients (1 – to 1 %, un, sol; 2 – 1–5 %, sp; 3 – 6–20 %, cop1; 4 – 21–50 %, cop 2, 5 – ≥ 50 %, soc) [4]. The abbreviations in accordance

with the Drude scale are as follows: soc (socialis) – the plants are closed up with their aerial parts; cop1, cop2 (copiosae) – the plants grow abundantly; sp (sparsae) – the plants are scattered or rarely; sol (solitaries) – solitarily; un (unicum) – one plant in the area of detection.

Projective cover is a part of the area of the projections of plant aerial parts onto the ground (or other surface). The term is usually used for herbaceous plants, sub shrubs, shrubs and dwarf shrubs. Within preparation of geobotanical description report, *the general projective cover* of the plant community or *the projective cover of the studied species* are traditionally considered, both are expressed in percent.

The biological stock is determined multiplying the area and the density of stock. The biological stock value is expressed in terms of the dry plant material weight. The output of the air-dried material from of the fresh one is already set for most of the raw materials (see Appendix, Tab. 1). If this information is unavailable, the raw material in being dried from the inventory areas according to the rules of the drying material of useful plants, collected from 10 to 50 species samples. The dried material is being weighed again, and the output coefficient for the dry raw material from the fresh one is being set. While processing the materials from the field studies, the coefficient, by which the output of dry material has been determined, is pointed out.

Calculation of the biological stock of the raw material is usually carried out according to the upper limit of the yield capacity.

The exploitation stock of raw materials is a maximum part of the biological stock that is the allowable to collect, which ensures that the recovery capacity of populations after harvesting the raw materials. It is set for all groups of economically important plants regardless of the type of raw

material. The exploitation stock for plants, the raw material of which comprise their generative organs (fruits, flowers, buds), constitute up to 90 % of the biological stock; in case of the aerial parts of the plants, used as the material, it constitutes 50 % for herbaceous plants, 25–30 % for biennials and perennials, 25 % for bushes, sub shrubs and shrubs, 10–25 % for trees; in case of the underground portions – 25 % for herbaceous plants, 10 % for trees, shrubs, bushes and sub shrubs. Calculation of the exploitation stock is set according to the lower limit for the conservation of available resources (in terms of dry weight, unless otherwise stated).

The amount of allowable annual use is a part of the **exploitation** stock of raw materials, which considers the period for population recovery of the species after harvesting the raw materials (Appendix, Tab. 1). It is set for the species of useful plants, the volume of collection for which are subjected to regulation in the order of specialized usage of plant resources [14]. For the plant species, the raw material of which are fruits, the amount may be equal to the exploitation stock of the raw materials.

$$\textbf{The amount of allowable annual use (kg, t)} = \frac{\text{Exploitative stock of raw material}}{\text{Period of recovery}}$$

Special usage of natural plant resources is the type of usage, which is conducted by legal or individual persons to meet the industrial and scientific purposes, to receive profit from the sale of these resources or their products, carried out with a permission of the specially authorized central executive authority on ecology and natural resources issues.

Collection of the plant raw materials is the harvesting or purchase of the raw materials for needs of industrial and commercial activities.

Management in planning of the natural plant resources collection involves determining the **standards and setting of limits** for their uses.

Normative of special usage of the natural plant resources are the allowable average amounts of natural plant resources, after considering the possibilities of their reproduction, which are approved for a period of 5–10 years by the Ministry of Ecology and Natural Resources of Ukraine (a governmental executive authority in the area of environmental protection) on the basis of evaluations materials of the natural plant resources, the raw materials of which are being harvested.

Limits of the special usage of natural plant resources comprise the amount of the allowable annual use of the plant resources.

Limits of the special usage of natural flora resources are set for the resources of both national and local importance for a year by the executive branch (the Ministry of Ecology) or other local authorities (the regional councils of people's deputies in consultation with the local departments of the Ministry of Ecology).

Limits of the special usage of natural plant resources of the national and local importance are based on the standards approved by the principal governmental authority in the field of environmental protection.

The plant resource science includes a number of other terms taken from geobotanical, plant geography and cartography, which are used to characterize the resources of biological objects, located on a particular area. Some terms related to the methodological aspects considering evaluation of medicinal plant resources are discussed in the corresponding chapters.

CHAPTER 2

CLASSIFICATION OF MEDICINAL PLANTS

Classification of medicinal plants is organized in different ways depending on the objective. In pharmacognosy the most commonly used classification of medicinal plants is based on the following criteria:

– Taxonomic (considering a taxonomic rank);
– Chemical (occurrence of major active principles);
– Pharmaco-therapeutic (significant biological effects on humans);
– Morphological (according to the type of medicinal plant material).

The following types of classifications are used less frequently: classification according to the biological characters (e.g. life forms: trees, shrubs, vines, herbaceous plants), growth environment (forest, meadow, marsh, water) and habitat type (arctic, tropical, etc.). These categories are important for the search of the new sources of biologically active compounds.

2.1. Pharmaco-therapeutic classification of medicinal plants

This type of classification is important for phytotherapeutists and for pharmacists since a pharmacist has to know the effects of the herbal remedies, as well as of the herbal ingredients in medications. According to the principle of pharmacological effects, the herbal substances are divided into the pharmaco-therapeutic groups of the following types of action:

> Anti-inflammatory,
> Bactericidal,
> Cardiotonic,
> Laxative and astringent,
> Hypotensive and hypertensive,
> Sedative and tonic,
> Choleretic,
> Diuretic,
> Immunostimulatory, etc.

Based on the pharmaco-therapeutic classification, drugs of herbal origin are placed on the shelves of pharmacies, as well as arranged in encyclopedias concerning phytotherapy and medicinal plants.

2.2. Classification of the medicinal plants according to their content of biologically active substances

This classification is a basic for studying in the course of pharmacognosy in the higher pharmaceutical education. It is based on the principle of division of medicinal plants and materials depending on the chemical nature of the leading group of biologically active substances (BAS) that are accumulated.

In the process of assimilation, the medicinal plants synthesize various organic compounds including many biologically active compounds that affect humans and animals. By the chemical nature of the bioactive principles plant constituents may be classified into carbohydrates, acyclic, aromatic and heterocyclic compounds, including polymeric compounds: polysaccharides, proteins, and enzymes.

The chemical composition of many medicinal plants is still understudied, and the information on their composition is constantly added. The biologically active substances, the composition of which is already sufficiently studied, include glycosides, alkaloids, carbohydrates, essential and fatty oils, tannins, organic acids, coumarins, vitamins, etc. Less number of investigations is conducted on phytoncides, enzymes, polysaccharides, polypeptides, hormones, resinous substances, mucilage's, and gums.

The medicinal plant species usually contain many groups of biologically active compounds, and it complicates their classification. Therefore, it is sometimes difficult to refer the plant material into some particular group, e.g. to the one containing alkaloids or glycosides. However, considering that the criterion is highly important in the process of classification of plants in order to find the alternative sources of medicinal plants, they are conventionally divided according to the major groups of biologically active substances.

The value of each plant depends on the content and nature of its active ingredients and their combinations; their pharmacological activity often depends on the quantity of the active substances, presence of concomitant substances, as well as the quality of the medication made from the plant raw material.

Among the complex of biologically active compounds of plants, two main groups are distinguished: the products of the primary and secondary metabolism. The former include proteins, carbohydrates, fats (lipids), vitamins, and enzymes;

the latter's are exemplified by alkaloids, glycosides, phenolic compounds (phenols, lignans, coumarins, flavonoids, tannins), essential oils, resins, organic acids, and others.

According to the content of the main groups of bioactive compounds, the medicinal plants are divided into the following groups, containing:

> Vitamins
> Lipids (fats),
> Terpenoids,
> Carbohydrates,
> Cardiac glycosides,
> Sapponines,
> Alkaloids,
> Flavonoids,
> Tannins,
> Anthracene derivatives,
> Coumarins,
> Chromone, xanthones,
> Simple phenols, phenolic glycosides,
> Lignans,
> Various chemical compositions.

This classification is the most appropriate for the purposes of pharmacognosy and is taught in details. Knowledge of the nature of biologically active compounds allows developing of ways for preserving the active ingredients during harvesting, drying, transportation, storage and processing of the raw materials of medicinal plants.

2.3. Classification of medicinal plants according to their taxonomic classification

The study of the medicinal plants in pharmacognosy is conducted according to the botanical classification,

meanwhile focusing on such major taxonomic categories as species – genera – family. It is conditioned by the presence of the qualitatively similar bioactive compounds in closely related taxa of the genera, or family (the latter occurs less frequently). For example, the species of yarrow genera (*Achillea*), thyme (*Thymus*), St.John's wort (*Hypericum*) in Ukraine have many species that are similar to each other in their active principle composition. Most species of the Lamiaceae family are the source of essential oils; the ones of the Solanaceae family are alkaloids. The higher taxonomic categories (class, order, and division) are traditionally used in the study of the pharmaceutical botany.

The greatest diversity of the medicinal plants in Ukraine is studied for the following families: *Asteraceae* (Compositae), *Lamiaceae* (Labiatae), *Brassicaceae* (Cruciferae), *Fabaceae* (*Leguminosae*) and Apiaceae (*Umbelliferae*) (Fig. 1).

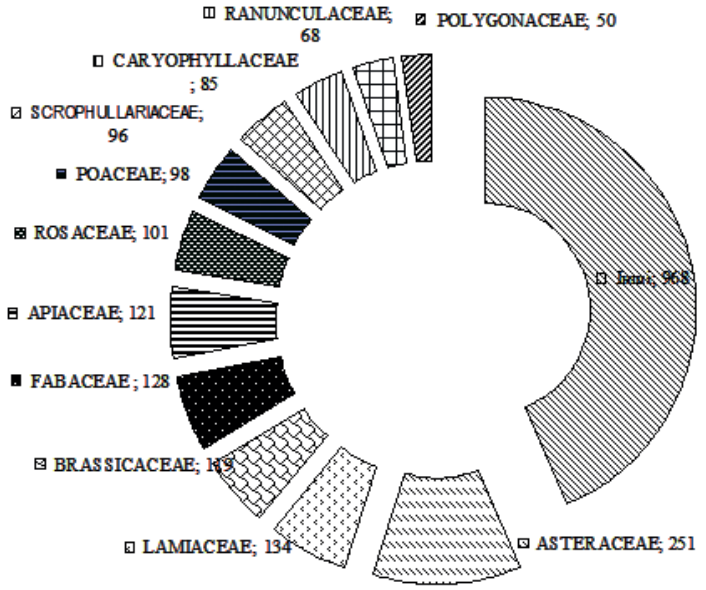


Figure 1. The differentiation of the medicinal plant species of Ukraine according to their taxonomic classification

The Asteraceae (Compositae) includes the largest number of the medicinal plants of Ukraine (251), containing various biologically active substances.

Table 1

The major medicinal plants of the Asteraceae family

The plant species	The main active substances	*Availability of resources
Arnica montana	sesquiterpenes, flavonoids, furanocoumarins	–
Cynara cardunculus	phenolic acids, cynarines	c
Centaurea cyanus	anthocyanins, flavonoids	+
Achillea millefolium	essential oils, flavonoids, vitamins	+
Echinacea purpurea	polysaccharides, phenolic compounds and glycosides	c
Taraxacum officinale	Carbohydrates, triterpenoids, phenolic compounds	+
Calendula officinalis	Flavonoids, carotenoids, saponins	c
Artemisia absinthium	Essential oil, bitter glycosides, sesquiterpenes	+
Silybum marianum	Flavonolignans	c
Chamomilla recutita	Essential oils, sesquiterpenoids, flavonoids	+, c
Cichorium intybus	Fructosan, bitter glycosides, phenolic acids	+, c
Helichrysum arenarium	Flavones, essential oil, bitters, tannins	+, c

Note*: c – the plant is cultivated for the raw material; + – the natural resources are sufficient to applications; – the natural resources are limited; p – the species is under protection

The Lamiaceae (Labiatae) species in Ukraine are mostly perennial plants and bushes (the latter may be found less

frequently). Many species of the family are known for being the source of essential oils:

– Species of the genera *Mentha* (*Mentha aquatica, M. longifolia, M. piperita, M. spicata*),

– Species of the genera *Thymus* (*Thymus marshallianus, Th. serpyllum, Th. pulegioides, Th. vulgaris*),

– *Lavandula spp.,*

– *Melissa officinalis,*

– *Rosmarinus officinalis,*

– *Salvia officinalis,*

– *Marrubium vulgare.*

The family *Brassicaceae (Cruciferae)* includes many annual and biennial species of medicinal plants that are also used in food industry.

– Wild cabbage (*Brassica campestris*),

– Garden cabbage (*Brassica oleracea*),

– White mustard (*Sinapis alba*)

– Brown mustard (*Brassica juncea*),

– Black mustard (*Brassica nigra*),

– Turnip (*Brassica rapa*),

– Horseradish (*Armoracia rusticana*).

The official medicine of Ukraine uses a number of medicinal plant species of the Brassicaceae family (Tabl. 2).

Table 2

The major medicinal plants of the Brassicaceae family

The plant species	The main active substances	*Availability of resources
Capsella bursa-pastoris	vitamins, flavonoids, organic acids,	+
Erysimum diffusum	cardiac glycosides	+, c
Brassica juncea	thioglycosides, fatty oil	–

Note*: c – the plant is cultivated for the raw material; + – the natural resources are sufficient to collect; – the natural resources are limited.

The Apiaceae (Umbelliferae) family includes many aromatic, edible and medicinal plants (Table 3), which contain essential oils, chromones and furanocoumarins.

– *Ammi majus,*
– *Pimpinella anisum,*
– *Apium graveolens,*
– *Petroselinium crispum,*
– *Daucus sativus, D. carota),*
– *Pastinaca sativa,*
– *Foeniculum vulgare.*

Table 3

The major medicinal plants of the Apiaceae family

The plant species	**The main active substances**	***Availability of resources**
Conium maculatum	pyridine alkaloids	+
Angelica officinalis (Archangelica officinalis)	essential oils, bitters, tannins, resins, carbohydrates, organic acids	–
Daucus carota	organic acids, furanochromones, tannins	+

Note*: – the natural resources are limited; + – the natural resources are sufficient for harvesting

The species of the Lamiaceae family are traditionally used as the primary sources of essential oils. Most of them are cultivated in Ukraine for the raw material (Table 4).

Table 4

The major medicinal plants of the Lamiaceae family

The plant species	**The main active substances**	***Availability of resources**
Betonica officinalis	terpenoids, phenolics, phenolic acids and their derivatives, flavonoids	+
Hyssopus officinalis	essential oil, oleanolic and ursolic acids, tannins	c

Lavandula angustifolia	essential oil, coumarins, fatty and organic acids, tannins	c
Origanum vulgare	essential oil, flavonoids, tannins	+,c
Melissa officinalis	essential oil, organic acids, tannins, resins	c
Mentha aquatica, M. longifolia, M. piperita	essential oil, flavonoids, tannins, organic acids, vitamin C	c
Leonurus cardiaca, L. quinquelobatus	essential oil, flavonoids, tannins, vitamins	+,c
Thymus serpyllum	essential oil, tannins, flavonoids	+
Salvia officinalis	flavonoids, tannins, terpenoids	c

Note*: c – the plant is cultivated for the raw material; + – the natural resources are sufficient for harvesting

The family Fabaceae comprises many cultivated and wild food and fodder plants (Table 5), the raw materials of which are the sources of flavonoids, proteins and carbohydrates:

– *Pisum sativum,*
– *Phaseolus vulgaris,*
– *Trifolium repens, T. pratense,*
– *Medicago sativa,*
– *Trigonella foenum-graecum.*

Table 5

The major medicinal plants of the Fabaceae family

The plant species	The main active substances	Availability of resources*
Astragalus dasyanthus	cycloartane saponins, flavonoids (kaempferol, quercetin, isorhamnetin)	-, p
Melilotus albus, M. officinalis	coumarin, phenolic acids, essential oil, flavonoids	+
Ononis arvensis	isoflavones, phenolic acids, coumarins	+,c
Galega officinalis	alkaloids, flavonoids, saponins, tannins,	+,c
Robinia pseudoacacia	flavonoids, essential oil, hydroxycinnamic acid derivatives, coumarins	+
Sophora japonica	Flavonoids rutin, kaempferol-3-sophoroside, genistein and genistein-3-soforoside	+,c
Glycyrrhiza glabra	triterpene glycosides, flavonoids, pectins	-, p

Note*: c – the plant is cultivated for the raw material; + – the natural resources are sufficient for collection; – the natural resources are limited; p – under protection

The medicinal plants of the Rosaceae family are characterized by the greatest diversity of life forms (trees, shrubs, herbaceous plants) and of the range of biologically active compounds. There are many species of them, which have a high nutritional value; they are also a source of vitamins, carbohydrates, especially pectins:

– *Armeniaca vulgaris,*
– *Cerasus fruticosa,*
– *Aronia melanocarpa,*

– *Sorbus aucuparia,*
– *Pyrus communis,*
– *Rubus idaeus,*
– *Rubus caesius,*
– *Prunus divaricata,*
– *Prunus spinosa,*
– *Malus sylvestris.*

Also the Rosaceae family includes many medicinal plants (Table 6).

Table 6

The major medicinal plants of the Rosaceae family

The plant species	The main active substances	*Availability of resources
Crataegus spp.	flavonoids, phenolic acid, coumarins, triterpene acids	+
Rosa spp.	vitamins, carbohydrates, flavonoids, catechins, tannins	+
Filipendula ulmaria	salicylic aldehyde, phenolic glycosides, tannins, vitamin C	+
Agrimonia eupatoria	flavonoids, catechins, tannins	+
Potentilla anserina	tannins, flavonoids	+, c
Potentilla erecta	tannins, ellagic acid, triterpenoids	+
Sanguisorba officinalis	tannins, proanthocyanidines, phenolic acids and their derivatives, triterpenoids	+
Fragaria vesca	vitamins, hydroxycinnamic acids, flavonoids, gallic and ellagic acids, aromatic compounds	+

Note*: c – the plant is cultivated for the raw material; + – the natural resources are sufficient for uses

Many medicinal plants are among the families of Poaceae, Scrophulariaceae, Polygonaceae and Ranunculaceae. The ability of plants of a certain taxonomic rank to accumulate certain biologically active compounds is widely used to search for the new sources of the valuable medicinal raw materials among the closely related species. However, this consistent pattern is not followed in all families or even genera of plants. On the other hand, these bioactive compounds may be present in plants of different taxonomic groups, which may be quite distinct in terms of taxonomical classification. Therefore, the availability of the specific groups of active substances does not necessarily indicate the fact that the plant species belong to a particular family or genera.

2.4. Ways of search of new sources of the plant raw materials

The main directions of the development of the herbal pharmaceutical market are the following:

– Search for bioactive substances of plants, fungi and lichens to cure diseases; that is the reason why the flora and mycota of different regions are being screened, and the ethnomedicine is being studied;

– Expanding the raw material base of valuable species of the medicinal plants by incorporation of closely related species (within certain taxonomic groups, mostly genera), which are the prospective substitutes of the herbal sources of the biological substances with the limited natural stocks of the medicinal raw materials.

The mandatory condition for the successful search for new medications made from plants and fungi is the

presence of preliminary studies of the prospective taxa (species, genera, families). The basic data for analysis can be found in the most complete contemporary reports on the chemical composition of plants, meanwhile involving the published data on the chemical composition and biological activity of the species in other regions, located closely to the flora of the investigated region. This allows to include the new prospective species and genera of the medicinal plants into the scope of the purposeful search and to expand the natural resources base of the valuable plant species.

Each species of plants has its own specific complex of morphological and anatomical features, chemical, physiological, and pharmacological properties that distinguish them from one another. On the other hand, there is a certain relation between the systematic position of the plant (or fungi) species, its chemical composition and biological activity. Thus, a number of taxa at the level of genera and even family possess the characteristics of accumulation of similar bioactive compounds (Table 4-6). In pharmacognosy, these species are usually called closely related, even though the term often includes a number of other characteristics (genetic, geographic, *etc.*). For example, such alkaloids as atropine and hyoscyamine can be found in many species of 8 genera of the Solanaceae family; the lactone santonin is currently detected only in wormwoods, closely related to santonica (*Artemisia cina*) and is absent in most of other species of the polymorphic genera.

Obviously, there is no rule without an exception. There were cases, in which the same substances were present in different species of distant families. For example, the ephedrine alkaloid was found in the plant families of *Ephedraceae, Taxacae, Papaveraceae, Malvaceae, Chenopodiaceae* and others. Meanwhile, certain species sometimes did not contain the active substances typical for

the rest of the species of their genera. Evidently, the presence of similar exceptions does not disprove the general rule. In closely related species, it is more likely to find the same or, at least, similar chemical compounds than in systematically distant species, and thereby to increase the resource base of the medicinal plants. The cases of distribution of some biologically active compounds (for instance, alkaloids nicotine, caffeine, some flavonoids) among species belonging to different families are mostly considered to be an exception and often indicate some common stages of biogenesis in distinct taxa.

The accumulation of certain compounds by plants can be modified by different environmental factors although this process is usually genetically determined. The medicinal plants of certain species and populations in various organs accumulate their clearly defined biologically active substances, so their quantitative composition may vary. Fluctuations of the qualitative and quantitative composition of active compounds in each plant can be observed throughout the year in different phases of ontogenesis and depend on weather conditions, although the range of the quantitative values of the content of a compound remains constant for each species (varieties) of plants, and in some cases genera. Due to it the raw material of the most widespread species of the hawthorn genera (*Crataegus curvisepala, C. monogyna, C. oxycantha, C. pentagyna, C. sanguinea*) and wild rose species (*Rosa canina, R. corymbifera, R. majalis, R. pendulina, R. rubiginosa, R. rugosa, R. spinosissima*) are used in Ukraine for pharmaceutical purposes.

Species of the mint genera (*Mentha* spp.) are often used as sources of essential oils, but the quantitative content and the ratio of its individual active principles in different species have their own features. It is the ratio of the constituents of the essential oil (menthol, menton, pulegone, carvacrol and

linalool) that makes the flavor of various species and varieties of mint different. For selection of current mint sorts with the high menthol content are often used rich in essential oils plant species, e.g. *Mentha aquatica* and *M. longifolia*, which are widespread naturally in Ukraine and have considerable resource base.

About 14 species of thyme (*Thymus*) grows in wild in Ukraine [40], the most widespread ones comprise: *Th. serpyllum*, widely found in Polissia; *Th. Marschallianus*, mostly distributed in the Forest-Steppe zone; *Th. pulegioides*, common grown in Polissia, the North of the Forest-Steppe zone, and in the Carpathians; *Th. pallasianus*, massively distributed in the sandy Steppes. In the Right-Bank Steppe and the southern parts of the Forest-Steppe *Th. dimorphus* is common. In the Crimea, *Th. tauricus* and *Th. callieri* occur; *Th. alpestris* and *Th. alternans* are found in the Carpathians. All these thyme species are valuable to Ukraine in terms of the available raw material, although the only plants that are officially recognized in traditional medicine are the creeping thyme (*Th. serpyllum*) and cultivated *Th. vulgaris* [7]. Most species of thyme are not clearly distinguished while harvesting, therefore, the most represented type of thymes in a particular region constitutes the raw material of it.

In Zaporizhia and Kherson regions on the river sands, *Th. borysthenicus*, which is also listed on the Red List of IUCN, can be often found, sometimes forming brushwood [37]. Generally, the issue of individuality of many thyme species remains controversial and is still unresolved: the last edition of the «A Key Determinant of the Higher Plants of Ukraine» includes only 15 species, and the nomenclature edition of S. Mosyakin and M. Fedoronchuk [39] lists 36 species.

The main group of biologically active compounds of thymes is essential oil, consisting of phenolic compounds

thymol, carvacrol; aromatic hydrocarbon *p*-cymene; acids; flavonoids, tannins; bitters *etc.* The ratio of different active compounds determines the odour of essential oils. For example, the thymol odour is caused by the content of thymol, the citrus one – by the limonene and citral; the cineoleic one by cineole (eucalyptol). The chemical composition of the main active substances of the thyme raw materials from its various species is similar to one another; thus, the studies of closely related species of the genera are of great importance for expanding the natural resource base.

The closely related species of medicinal plants totally constitute about 20 % of the vascular flora of the medicinal plants of Ukraine [15], revealing the great potential of the pharmacognostic study. The list of plants approved for the medicinal application could be extended via the use of closely related species that have considerable natural resources of the raw materials.

CHAPTER 3

DIVERSITY OF HERBS, FUNGI AND LICHENS AND THEIR USE

3.1. The diversity of medicinal plants in the world

Every culture from ancient times to the present day used plants as sources of medicine. Nowadays, most plant species are not studied as the medicinal ones, so the study of their biologically active compounds opens great opportunities for expansion of the resource base for the phytopharmaceutical production. According to the World Health Organization (WHO), at least 80 % of people in the world use herbs or their biologically active compounds for therapeutic purposes nowadays. According to the WHO classification system, the medicinal plants (hereinafter referred as MP) are divided into three groups:

1) MP used for direct treatment;

2) MP used for the production of the herbal medicines (including the ones produced domestically);

3) MP that also constitute the raw material for industrial processing or for the production of biologically active substances, which are used in drug manufacturing.

More than 25 % of the pharmaceutical drugs that used in the world today derive from the plant natural products. There are about 120 main herbal substances applied for manufacturing of medicines worldwide, although regulation for the use of these compounds has specific characteristics in different countries.

There are over 400,000 species of plants on Earth; about 20 thousand of them are used in medicine, although it is believed that the number of potentially existing number of medicinal plants is nearly 50–70 thousand species [31], including about 15 000 species of endangered medicinal plants (IUCN). The raw material of most of the species is still extracted from the wild plants. Thus, in Europe are used about 2000 species of medicinal plants; the raw material of 1200–1300 plant species is obtained from the environment.

The greatest diversity of medicinal plants is found in China, India and the United States (Table 7). The flora of these countries is characterized by the great diversity due to the availability of various climatic conditions and landscapes. The data on the number of medicinal plant species in different countries indicates the degree on investigation of the flora of certain regions concerning the availability of bioactive compounds in plants.

Table 7

The diversity of medicinal and aromatic plants in different countries

Country	Number of plant species	Number of MP
China	32200	4 941
India	18664	8000

Indonesia	22 500	1 000
Iran	8100	2300
Morocco	5211	800
Malaysia	15 500	1 200
Nepal	6 973	700
Pakistan	4 950	300
Philippines	8 931	850
Sri Lanka	3 314	550
Thailand	11 625	1 800
USA	21 641	2 564
Vietnam	10 500	1 800
Ukraine	6086	2 219
Poland	2468	500
Bulgaria	3567	770
Croatia	4288	180
Romania	3297	800
Hungary	2214	270
Turkey	8650	2000
The world as a whole	422 000	52 885
Sources: Lange (2002), FAO (2002), UNEP-WCMC (2004)		

India and China present the most thoroughly studied flora. The most known ancient traditions for application of natural products, especially from plants and minerals, originate from these countries. The medicinal plants of the region are widely used in all indigenous medical systems, namely, Ayurveda, Unani, Siddha and Tibetan medicine. More than 95 percent of the medicinal flora of these countries constitute from the wild species. China is ranked as the first one among the world countries providing exports of medicinal plants, with India being the second [35].

3.2. The use of medicinal plants in the some countries

At least 2,000 known species are used for medicinal purposes in Europe, including 1200–1300 species of local flora, with all the rest being imported, about 90 % of which are the wild plants (about 20 000–30 000 tons a year). Europe imports about a quarter of the annual global import market of the medicinal plants (440,000 tons worth about $ 1.3 billion in 1996); Germany, France, Italy, Spain and the UK are amongst 12 major importers [28, 33, 51]. Germany, Bulgaria and Poland are among the 12 leading exporters of the medicinal plants. Harvesting of wild plants plays an important role in the economy of Albania, Turkey, Hungary and Spain. According to the volume of the raw material of the medicinal and aromatic plants in the Hungarian trade, the wild raw material comprises 30–50 % there, in Germany 50–70 %, Bulgaria – 75-80 %; Albania and Turkey have almost 100 % [43].

Applications of plant diversity in particular countries are determined by a complex interaction of social, economic and environmental factors, including the level of economic development, traditions, medication supplies etc. The demand for a certain kind of the raw material often varies from one country to another. The traditions within the country also play an important role. For example, Germany uses at least 1500 species of plants as sources of medicinal and aromatic raw materials, 600 species of which have European origin; and all the rest being imported from South-East Asia. 70–90 % of the plant raw material imported into Germany is harvested from the wild plants. Germany imports a great number of wild and cultivated raw plants from Europe, among which are *Adonis vernalis, Althaea officinalis, Centauriun erythraea, Gentiana lutea, Cetraria*

islandica. Matricaria recutita, Silybum marianum, Digitalis lanata are also cultivated in Germany in large quantities.

Out of the 6086 species of the vascular plants in Ukraine, 2219 species contain biologically active substances that are already used or could be applied for medical purposes. Only about 200 species of the flora of Ukraine are used in the traditional medicine; almost twice as many species are used as raw materials for the homeopathic medicines; the raw material of 30–35 species is used as a source of biologically active food supplements (plants that are sources of antioxidants, tocopherols, carotenoids, flavonoids and other substances).

The annually harvested raw material of 20–30 wild medicinal plants that are cultivated in large quantities comprise *Vaccinium myrtillus* (fruits, more than 5000 tons), *Rubus idaeus* (fruits, more than 1500 tons), *Rubus fruticosus* (fruits, 1000–2000 tons), *Oxycoccus palustris* (fruits), *Crataegus spp.* (flowers and fruits), *Rosa spp.* (fruits), *Tilia cordata* (flowers), *Chamomilla recutita* (flowers), Frangula alnus (bark), *Petasites hybridus* (roots), *Artemisia absinthium* (herb), *Achillea millefolium* (flowers, herb), *Sambucus nigra* (flowers, fruits), *Urtica dioica* (leaves), *Hypericum perforatum* (herb), *Plantago major* (leaves).

The evaluated diversity of the wild medicinal and aromatic plants in Poland is estimated as 500 species, 80–100 species of which are used for commercial purposes. The average annual harvest of the raw materials from the wild comprises about 8 000–10 000 tons, about 50 % of the annual volume is exported. The most important plants used from the natural environment in Poland are represented by *Urtica dioica, Tilia spp., Frangula alnus, Equisetum arvense, Betula* spp., *Quercus* spp., *Aesculus hippocastanum, Taraxacum officinale, Crataegus spp., Sambucus nigra, Equisetum*

arvense, Achillea milefolium, Tusillago farfara, Viola spp. and Salix purpurea. Distribution of the wild medicinal plants in Poland is differed. The raw material of most of them is harvested in ecologically pure areas of the eastern part of Poland [34].

In France, the number of medicinal and aromatic plants has about 900 taxa with about a half of them (475) being common in Europe. The following raw materials are harvested in large quantities (more than 1 ton per year): *Arnica montana, Betula pendula, Betula pubescens, Calluna vulgaris, Conyza canadensis, Fraxinus excelsior, Hippophae rhamnoides, Prunus spinosa, Frangula alnus, Ruscus aculeatus, Sorbus aucuparia, Filipendula ulmaria. Hypericum perforatum* and *Rosmarinus officinalis* are harvested 50–100 tons per year [31, 43].

About 700 different plants are used in Great Britain to produce herbal medicines with around 200 of them being widespread in Europe, 350 – in Asia; 89 – North America, 31 – South America, 23 – Africa, 6 – Australia.

About 800 species of the medicinal and aromatic plants are used in Spain. Moreover, the volume of domestically cultivated plant material in the industrial production of medications comprises 10–20 % with the rest 80–90 % being imported. Nearly 600 native species of medicinal plants among them are often used in traditional medicine, and about 450 plant species are the sources of the raw materials for the drug manufacturing, homeopathic remedies, herbal remedies, essential oils *etc* [32].

In Spain, the most commonly used raw materials, derived from the following plant sources: *Malva spp., Thymus spp., Ruta spp., Sideritis spp., Salvia spp., Sambucus nigra, Rosmarinus officinalis, Tilia platyphyllos,*

and Matricaria recutita. The most frequently used plant species for the purposes of traditional medicine include *Helichrysum arenarium, Urtica dioica, Plantago major, Centaurium erythraea, Hypericum perforatum, Rosa canina, Parietaria officinalis, Senecio jacobaea, Marrubium vulgare, and Chelidonium majus*. In the northwest of Spain, the raw materials of the following plants are harvested in large volumes: *Gentiana lutea, Origanum vulgare, Arnica montana and Sideritis hyssopifolia*. Among 20 medicinal and aromatic plants listed in the trade catalogues of Spain, the most common ones include *Crataegus laevigata and/or C. monogyna, Mentha* x *piperita, Equisetum arvense, Melissa officinalis, Pimpinella anisum, Thymus vulgaris, Rosmarinus officinalis, Salvia officinalis, Foeniculum vulgare*. The species of the genera *Thymus and Sideritis* as the sources of essential oils for health and food products, cosmetics have an especially high commercial value.

The Romanian flora includes 3450 species of plants, representing 30 % of the vascular flora of Europe. 800 taxons possess phytotherapeutic properties, and 384 of them are used in medicine, since their pharmacotherapeutic effects are already studied [25]. Currently, the largest amounts of the harvested raw material are collected from *Vaccinium myrtillus* (fruits, more than 2500 tons annually), *Rubus idaeus* (fruits, more than 1500 tons), *Tilia cordata* and *Tilia argentea* (flowers), *Betula pendula* (leaves), *Crataegus monogyna* (flowers, fruits and leaves), *Arnica montana* (flowers), *Petasites hybridus* (roots), *Artemisia absinthium* (herb), *Achillea millefolium* (flowers), *Arctium lappa* (roots), *Allium ursinum* (leaves) and *Sambucus spp*. (flowers and fruits).

In Bulgaria, there are about 770 species of medicinal plants of the native flora, 200–250 species of which are officially used. 50 % of all the Bulgarian medicinal plants

refer to the perennial herbaceous plants, 20 % – to annual, 25 % – shrubs and trees, 5 % – biennial herbaceous plants. The Bulgarian herbs are popular around the world, especially in Europe, and therefore, the export of different types of plant raw materials comprises an important part of the country's economy. In Bulgaria are harvested 15 000–17 000 tons of raw medicinal plants annually, 80 % of which are exported to 50 countries, including Germany (65 %), Spain (10 %), Italy (5 %), France (5 %) and other countries (15 %) [29]. Large volumes of raw materials are collected from *Tilia spp., Urtica dioica, Hypericum perforatum, Crataegus monogyna, Mentha piperita, Melissa officinalis, Lavandula vera, Chamomilla recutita, Valeriana officinalis, Rosa spp., Prunus spinosa, Rubus idaeus* and *R. caesius, Juniperus sibirica, Vaccinium uliginosum*. The cultivated plants form a half of the total harvesting volume.

The number of flowering plant species listed in the Turkey is estimated near 10,000. Nearly 2000 species from this number are used for medicinal and aromatic purposes, and near 500–1000 species are used in the traditional medicine. Nearly 350 medicinal plants and pteridophytes are sold at the shops of Attar's, the traditional herbal drug dealers. Raw material of 290 wild species is use for medicinal purposes in this country. The families with the highest number of medicinal plants are Lamiaceae (18), Asteraceae (18), Apiaceae (11), Liliaceae (9), Rosaceae (8), Ranunculaceae (7) and Fabaceae (6). The genera with maximum number of species used are Sideritis (10), Helichrysum (8), Rumex (6), Astragalus (5), Euphorbia (5), Gypsophila (5), Juniperus (5), Anthemis (5), Artemissia (5), Orchis (4), and Colchicum (4). Out of these 73 are used externally and 168 internally for the treatment purposes [41].

Camellia sinensis, Glycyrrhiza glabra and some other species grows in Turkey are routinely used as beverage.

Tea is now most commonly consumed plant and cultivated as a crop in the black sea region of Turkey. Herbal based teas like Mentha, Salvia, Melon, Tilia are derived from many parts of plants with medicinal values and are now very popular in the country. Large number species of genera *Thymus, Olea, Allium, Piper, Rosmarinus, Coriander, Laurus, Chrysanthemum, Hibiscus, as well as very popular are Hypericum perforatum, Anetum vulgare, Anisum sativum, Foeniculum vulgare, Crócus sátivus, Cynara scolymus, Ocimum basilicum*, at the shops of herb dealers and some local markets. Many medicinal plants used as spice, for flavor and taste but contain many medicinal compounds. The most frequently these plants used for such treatments as; anthelmintic, anti-anemic, anti-diabetic, anti-depressant, anti-diarrheal, antiemetic, anti-tussive, cardiotonic, carminative, diaphoretic, diuretic, expectorant, halitosis, hordeolum, headache, indigestion, orexigenic, purgative, sedative, toothache and tonic [41].

More than 80 % of people of Arab countries depend directly on plants for their medicines. The majority of the population in Arab countries still relies on herbal medicines to meet their health needs. Most of these herbal remedies have stood the test of time, particularly for the treatment of allergic, metabolic and cardiovascular diseases [41]. Arab physicians introduced many new aspects and upgraded the knowledge about herbs and their potential medical efficacy and safety. This resulted in a huge development in pharmaceutical science; causing pharmacologists and ethnopharmacologists to start searching for different ingredients and extracts to be used as remedies, and they even started to study the chemical properties of the materials used in the treatment of various diseases and ailments. Despite all the marvellous advancements in modern medicine, traditional herbal medicine has always been and is still practiced for the treatment of various illnesses in many Arab countries.

Research into the medicinal herbs still in use has also been conducted in other Arab countries like Iran, Syria, Egypt, Morocco and other countries. According to recent studies, the Middle Eastern region is home to more than 2600 plant species of which more than 700 are noted for their use as medicinal herbs. At this time, less than 200–250 plant species are still in use in Arab medicine for the treatment of different ailments

Herbal medicines of Iran are traditionally different from those in the west. Iranian Herbal Medicine has the Greek and Iranian roots, as well as use the best practices of other Arabian countries.

From the 8100 species of wild and cultivated plants in Iran, approximately 2300 species have aromatic and medicinal properties and about 450 species are sold by herbal apothecaries without any controls as to their purity. It has been affirmed that the consumers of these herbal medications have no knowledge of their toxicity, side effects or their interactions with other herbal or pharmaceutical medications nor are they instructed as to their dosage and specificity of their actions. Development of herbal medicines and herb shops in recent years and the lack of proper monitoring, as well as the misuse of some profiteers through the extensive and exaggerated propaganda of medicinal plant compounds such as weight loss and obesity, etc. which is often non-scientific and commercial in nature, make it more necessary to monitor these kinds of activities [53].

The most common herbal medicines sold in Iran, according to a survey carried out by Tehran University of Medical Sciences are as follows: *Borago officinalis* (golgavezaban), *Valeriana officinalis* (sonboletip), *Eruca vesicaria* (khakeshir), some species of *Viola* (banafsheh), *Chicorium* (kasni), *Thymus* (avishan), *Althaea* (khatmi), *Digitalis* (gole angoshtooneh), *Glycyrrhiza* (shirin bian),

Datura (taatooreh), *Cordia* (sepestan) as well as a host of other plants [48].

Morocco has a great geographical diversity (plains, low, medium and high mountains, valleys, cliffs etc.) accompanied by climate variability that led to the installation and development of rich and varied flora which aromatic and medicinal plants represents more than 15 %. Among 5211 species and subspecies of vascular plants inventoried in Morocco, 800 vascular plants have medicinal and aromatic value. The main aromatic and medicinal plants are: species of genera *Pistacia, Artemisia, Capparis, Cistus, Juniperus, Ephedra, Erica, Quercus, Lavandula, Mentha, Origanum, Salvia, Thymus* and other [50]. Currently, Morocco is ranked the 12th exporter of aromatic and medicinal plants in the world and has great potential in the field of medicinal and aromatic plants.

The recent trend of large-scale commercial extraction of MPs, to meet the growing demand of herbal industries, has increased the probability of over-exploitation of many valuable species. The pace, depth, and magnitude of human pressures in the different regions of the world are known to have exerted ecological stresses not only on the individuals and the populations of MPs but also on the life support ecosystems. This has lead to the degradation of diversity, quality and availability of many valuable species on the one hand and their habitats and ecosystems on the other. Knowledge of the sustainability of the use of such plant resources is thus urgently needed.

Sustainability of medicinal plant harvesting is challenged by many factors from both the social and ecological perspectives. It is now recognized that many interlinked dimensions – biological, ecological, socio-cultural, economic and political – must all be considered in order to achieve sustainable use of MP. Thus an sustainability of harvest is

the amount of plants resources (such as MP) that can be harvested indefinitely from a limited area of natural habitat without imposing deleterious effect on the structure and dynamics of populations of harvested species, and insuring that the population size and the availability of the extracted product do not decline as a result of harvesting. Thus, sustainable management systems of MP species should guarantee the long-term persistence of their populations, maintaining positive rate of their population growth.

3.3. The diversity and application of medicinal fungi and lichens

People always try to find a universal remedy that helps to cope with many diseases; therefore, one of these tools can be a drug derived from fungi. In the last decade, almost all edible and poisonous mushrooms were subjected to scientific experiments searching for the new bactericidal medications. The estimated number of fungi on Earth is equal to 140 thousand, but only 10 % of which (about 14 000 identified species) are studied. The fungi represent an unlimited source of polysaccharides which exhibit antibiotic, anticancer and immunostimulant properties. The higher basidiomycetes are believed to be an extremely valuable source for drugs. Many of them (*Lycoperdon spp., Agaricus spp., Piptoporus betulinus, Agrocybe dura, Lepista nuda, Inonotus obliquus, Lentinus edodes, Ganoderma spp.* and others) contain biologically active substances of antibiotic effects. These fungi are used traditionally in the folk medicine to treat inflammations of the mucous membranes, to stop bleeding wounds and to cure some kidney diseases. The puffball fungi even serve as the basis for such antitumor drugs as calvacine, which inhibits the development of many types of cancer and has an antibiotic effect.

There are several major achievements in the area of uses of fungi, such as penicillium, yeasts and basidiomycetes, in medicine over the past 50 years. Penicillin is widely used for treatment of the infectious diseases. Cyclosporine is applied for successful organ transplantation, since it reduces the risk of tissue rejection. Most of the compounds found in fungi are classified as potential immune protecting agents. They help the body to regulate the development of the lymphoid stem cells and ensure the development of other important protective responses.

The history of medicinal fungi application is deeply rooted in the history in the following South-East Asian counties: Japan, China, Taiwan and Korea. The fruit bodies of the lingzhi mushroom (*Ganoderma lucidum*) and other *Ganoderma* spp. are well-known in the traditional medicines of China, Korea and Japan. The Chinese name of these tree fungi are lingzhi, and the Japanese – reishi. Some species of *Ganoderma* have already been used in the traditional oriental medicine for thousands of years [54]. Under the name reishi it is also widely recognized in Europe. The effect of medicinal reishi is due to presence of polysaccharides and triterpenes, possessing oncostatic properties. In Ukraine is also paid special attention to the study of anti-inflammatory and oncostatic properties of *Ganoderma lucidum*.

In Japan, Russia, China and the United States several different antitumor products were developed on the basis of fruit bodies, mycelium and culture medium of various medicinal fungi, including *Lentinus edodes, Ganoderma lucidum, Schizophyllum commune, Trametes versicolor, Inonotus obliquus, Flammulina velutipes*. The group of antitumor drugs made of the medicinal fungi is often called as the biological response modifiers that are used in cancer treatment, along with surgical techniques and chemotherapy. Particularly, the Crestin drug is made from

Coriolus versicolor, the Lentinan from *Lentinus edodes, schisophillan from Schizophyllum commune*, Befunginum from *Inonotus obliquus* [36].

Basidiomycetes are used in South-East Asia in order to produce medications that contain the antibiotic mucidine (*Oudemansiella mucida*). In China and Japan the species of the Hericium genera are highly valued for their medicinal properties; *Hericium erinarius* has a long history of use in the Traditional Chinese Medicine. Its cytotoxic effect of compounds on cancer cells was revealed, as well as the stimulating effect on the synthesis of the factor of nerve growth, antimicrobial, nematicidic and antitumor effect. The Alzheimer's disease is usually treated with the preparations from this fungus [54].

The medicinal fungi have been widely used as dietary or nutritional supplements (as «nutraceutical» mushrooms) in different countries. The regular use of such supplements improves the immune condition of the organism, increasing its resistance to disease. There is no single approach to such use of fungi in medicine worldwide. Most European countries are governed according to the rules of the World Health Organization and use only those fungi as food additives that do not need to be studied clinically. China and several neighboring countries classified products from medicinal fungi as drugs that must undergo clinical studies.

The widespread incorporation of bioactive compounds from the fungi into the pharmaceutical practice is extremely prospective. All the countries nowadays conduct active research on these compounds for their use in medicine. The study of the effect of the neurotropic species of the genera *Amanita* and *Psilocybe*, as well as the antioxidant properties of active substances of the stress-protecting fungi, are of particular interest for the scientific community.

Most fungi are grown in artificial conditions for the purposes of their application in the pharmaceutical industry. It enables the process of extracting the raw material to be ecologically pure, having clearly identified biologically active compounds. In many cases, it also allows for the genetic uniformity and predictability of the chemical composition, as well as minimizes the risk of deviation among different batches. The fungi are easily reproduced vegetatively, and the mycelium can be stored for a long time; many fungi that cannot produce fruiting bodies artificially are able to be developed as mycelium.

There are no standard protocols for quality assurance of pharmaceutical fungi products. There is a need of the critical analysis on improving the quality and legal control of the use of fungi in pharmacy, as well as of establishing the regulatory authorities of the current and future standards.

Lichens are unique groups the fungi organisms. Their number approximates to 6000 species. For a long time lichens have been used as medications in the traditional systems of the Indian and Chinese medicine, as well as in medicine and homeopathy in many European countries. The use of lichens for medical purposes has a long history, and nowadays they are popular especially in the traditional medicine of the European countries, as well as in India, China, Korea, Japan and Indonesia. Most of the raw materials (thalli) used for therapeutic purposes include the species of the following genera: *Cetraria, Cladonia, Evernia, Lobaria, Parmelia, Peltigera, Pertusaria, Physica, Rocella, Usnea and Xanthoria*.

The widespread use of lichens as medications is conditioned by the presence of the secondary compounds with antibiotic properties. Thalli of the lichens contain 80 % of carbohydrates and 5 % of lichen acids. The lichens acids

(having the usnic acid as their most famous representative) determine the antimicrobial properties of many of lichens. Usnic acid, derived from various species of the genera *Usnea*, is used as an antifungal agent in the US, and to treat wounds, skin rashes and fungal infections in Finland. In Russia, the drug Binan, which yields the sodium salts of the usnic acid as one of its components, is used to treat venous varicose and trophic ulcers, burns of the second and third degree and during the plastic surgery.

The traditional Chinese medicine, homeopathy and conventional medicine in the Pacific Islands and New Zealand use the species of the *Usnea* genera as a sedative to treat inflammation of the mucous membranes in the mouth and throat. In Russia, usnea is used to treat cuts and wounds. Because of its antiseptic properties, usnea is used for various cosmetic ointments and creams. In Europe, usnea helps to treat inflammation of the oral cavity. In China decoctions from various *Usnea* spp. are employed to treat bronchitis with large amounts of mucus, as well as during the cancer phytotherapy, especially in the thyroid cancer. However, the internal use of usnea can cause serious side effects due to the hepatotoxic effects of the usnic acid; therefore, its usage is limited.

The Iceland moss (*Cetraria islandica*) is widely used all over Europe as a part of treatment of the lung, kidney and bladder diseases, of the inflammation of the mouth and throat mucous membranes, as well as for healing wounds externally. In the European folk medicine, it is also used to cure cancer. For the medical purposes, the whole thallus of the lichen is used since it contains 70 % of carbohydrates, with the dominant constituent the lichen starch (lichenin); other substances are exemplified by crystalline bitter substance centrarin, fumaric and other acids, gum, sugar, high quantities of iodine and boron, the antibiotics –

protolichesterinic and usnic acids. The Iceland moss has a emollient effect on the mucous membranes, and, thus, it is prescribed in cases of intestine disorders, gastric atony, chronic constipation, lung diseases and lack of appetite.

The Spanish folk medicine uses lichens to cure various diseases, such as decoctions of *Pseudoevernia* in cases of respiratory diseases, *Ramalina bourgeana* as a diuretic medication, *Xanthoparmelia scabrosa* is one of the aphrodisiac ingredient. *Flavocetraria* is used as a sedative in Poland [28].

In India, the species of the *Parmelia* genera are applied as aphrodisiac, diuretic and vulnerary agents. Lichens are included into the official pharmacopoeia of the Russian Federation. The German scientists have obtained from lichens an antibiotic drug Evozin-2, or parmicine, used to treat the open form of the pulmonary tuberculosis. The Spanish scientists developed a combination drug containing mixture of usnic acid and streptomycin to cure the skin diseases.

An antibiotic drug from lichens called Usnean which can be used to treat skin diseases was developed in Japan. In Finland, dermatologists have used the usnic acid in the form of ointments to cure lupus. In Germany are produced the medications, that have the Iceland moss as their component, Broncholind and Isla Moss / Isla Mint, which are recommended for sore throat and hoarseness. Cetraria is extremely popular in the traditional medicine of the Carpathian region as an anti-inflammatory agent in cases of broncho-pulmonary and gastrointestinal diseases. Ukraine imports such medicines, produced from the lichen species.

The research of medicinal properties of lichens and fungi constitutes the top priority of the herbal medicine

development of many countries. The herbal medicine of different countries prefers further research and use of various species of lichens.

3.4. Medicinal plants of Ukraine

Ukraine has more than 25 thousand species of flora and fungi, including 14 thousand fungi and slime molds, 1322 lichens, 4720 algae, 763 bryophytes, 6086 vascular plants (both cultivated and introduced). The currently available information states that the diversity of the vascular plants of Ukraine constitutes 2219 species containing the biologically active substances that are applied or could be used in medicine [15].

The traditional medicine of Ukraine uses about 200 species of the vascular plants. The State Pharmacopoeia of Ukraine (SPU) presents available information about the raw materials or products of their processing for 124 species of medicinal plants [6-8]. There are 25 species of wild plants, 22 of wild and cultivated plant species (both occurring in natural communities and cultivated to produce the raw materials, or the materials are imported from other countries), 20 species, available in Ukraine only as cultivated ones. The SPU lists 57 species of medicinal plants, the raw materials of which are imported to Ukraine from other countries.

About 10 % (244) of the 2219 species of medicinal plants of Ukraine comprise the cultivated and introduced species, with all the rest being considered as wild. The total number of the wild species of medicinal plants (1975) resource value has only 486 species (Fig. 2). Therefore, they either form the resource science arrays over the large areas (more than 1 ha) or are significantly spread in Ukraine without forming the arrays. This includes such environment-

forming species as *Pinus, Quercus, Vaccinium* etc.; as well as the valuable species in terms of their raw materials that act as dominant species in a particular layer or members of the plant communities (e.g. *Frangula alnus, Sambusus nigra, Rosa* spp., *Hypericum perforatum, Tussilago farfara*, etc.). They are widespread on the territory of Ukraine and have sufficient stocks. They include the medicinal plant resources, which are sufficient to meet the existing need of the raw materials, but nowadays their number is being decreased; consequently, the volume of their use in the environment is subjected to strict regulations. These species include *Convallaria majalis, Ledum palustre, Vaccinium vitis-idaea* etc.

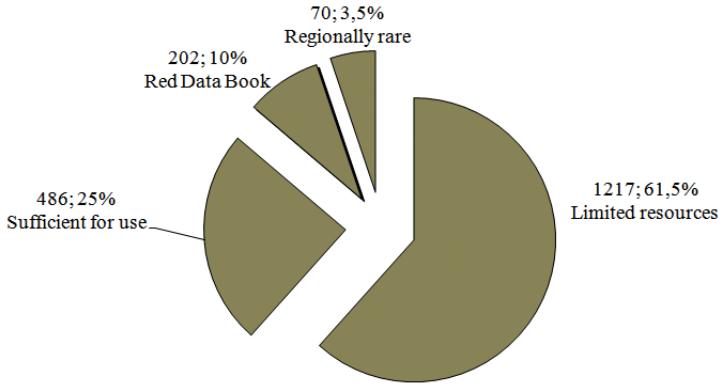


Figure 2. The quantitative distribution of wild medicinal vascular plant species of Ukraine in accordance with their resource significance

About 10 % of species of medicinal plants constitute a part of the cultivated and introduced ones, with about 32 species belonging to the crops, 29 to consumed as fruits and berries, over 150 species of plants are grown in specialized farms (Appendix, Table. 4), and the rest being introduced in botanical gardens and parks. Such introduced species as *Platycladus orientalis, Platanus orientalis, Juglans mandshurica, Securinega suffruticosa, Gleditsia triacanthos,*

and Sophora japonica are used in landscaping and protective plantations, with a significant portion of medicinal plants being available in the collections of specialized farms or grown in private households.

Resources of 1489 species of medicinal plants are low or absent. 202 species of them are listed in the Red Data Book of Ukraine (2009) [17], whereas the previous edition of the Red Book listed 170 medicinal plant species with 70 of them being regionally rare. Some of the rarest remain under the regional protection in all the areas, for instance, *Anemona sylvestris, Hypericum humifusum, and Polemonium caeruleum*; in several regions *Convallaria majalis, Ledum palustre, Alnus incana* are listed as the regionally rare, and some belong to the valuable ones in terms of their raw materials.

1217 species of the wild medicinal plants have limited resources (Fig. 2), and 50 % of them are widespread, although they growing singly or sporadically and their populations have no significant resources even without the impact of destructive factors in their habitats. They include the following species: *Agrostemma githago, Althaea officinalis, Consolida ajacis, Nigella arvensis, Ranunculus auricomus, R. flammula, Thalictrum aquilegifolium, Berberis vulgaris, Glaucium corniculatum, Fumaria officinalis, Gypsophila acutifolia, Melandrium album, Silene chlorantha, Pyrola media, Bryonia alba, Thymus marshallianus* and many others.

3.5. Specificity of the ecologo-cenotic distribution of medicinal plants

The analysis of the wild medicinal plants (1975 species) in terms of their environmental and coenotic characteristics shows that 744 of them are related to the forest and forest-

related communities (forests, meadows, logged land, bushes) (Fig. 3) with the latter ones constituting more than a half of this amount of species (Fig. 4). Overall, most of the resource significant plants of the forest and forest-related communities are characterized by the broad ecological and coenotic amplitude. They are directly involved into the formation of both forest communities and different types of post-forest formations, particularly, of the post-forest meadows.

The coastal water, wetland and aquatic habitats are the home for 411 species of medicinal plants. These are mainly hygromesophytes (or at least hydrophytes) that grow in conditions of permanent or temporary flooding, e.g., *Acorus calamus, Nymphaea alba, Nuphar lutea*.

368 species are typical representatives of synanthropic flora; therefore, they are mostly involved into the formation process of ruderal plant communities or appear to be the obligate ingredients of the communities at the stage of their recovery. For example, the species of the genera *Arctium, Artemisia, Chenopodium*, as well as *Capsella bursa-pastoris, Centaurea cyanus, Chelidonium majus, Conium maculatum, Urtica dioica* and others. In most cases they come from the purely meadow, meadow-steppe and steppe habitats and concern the communities of about 252 species of the wild medicinal plants (Fig. 3). The most famous ones include Astragalus dasyanthus, *Adonis vernalis, Paeonia tenuifolia, Glaucium flavum, Fragaria viridis, and Thymus marchallianus*.

200 species are characterized by a narrow ecological and coenotic amplitude, and, therefore, belong to the groups that are formed on the rock, limestone or rarely on chalk outcrops or on the rocks. The resource significance of the latter ones is usually small (Fig. 3).

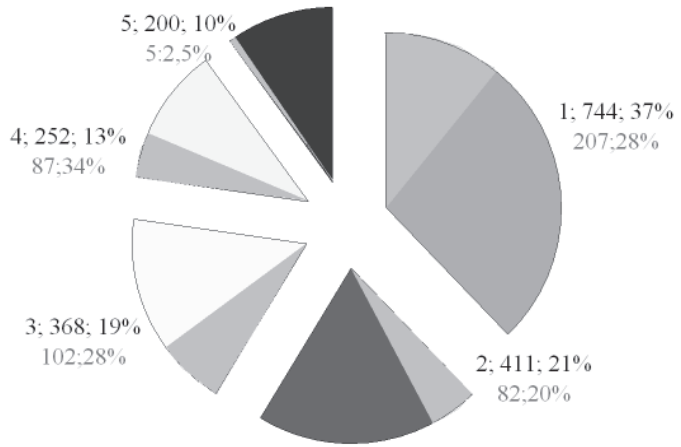


Figure 3. The quantitative distribution of the wild medicinal plant species in terms of their ecological and coenotic characteristics: 1 – species of medicinal plants, the main habitat of which are the forest, forest-meadow and shrub communities; 2 – the meadow, meadow-steppe and steppe, respectively; 3 – ruderal and segetal vegetation; 4 – located on the riversides and aquatic (mostly in low flow waters); 5 – in rocky formations and limestone outcrops. The sections highlighted with the light grey show the proportion of resource significant species in each section

The largest group in the total number of medicinal plants of the forest and forest-related plant communities comprises species that grow on the edges, lawns, cut-down forest areas, grasslands, and scrublands (Fig. 4).

Such communities yield the greatest number of medicinal plant species that are of high value for the resource science. These are the following the species – *Crataegus spp., Rosa spp., Rubus spp, Ajuga reptans, Betonica officinalis, Chamerion angustifolium, Hypericum maculatum, Melampyrum nemorosum, Ononis arvensis, Potentilla erecta, Prunus spinosa, Salvia glutinosa, Solidago canadensis, Telekia speciosa, Veronica officinalis* and others.

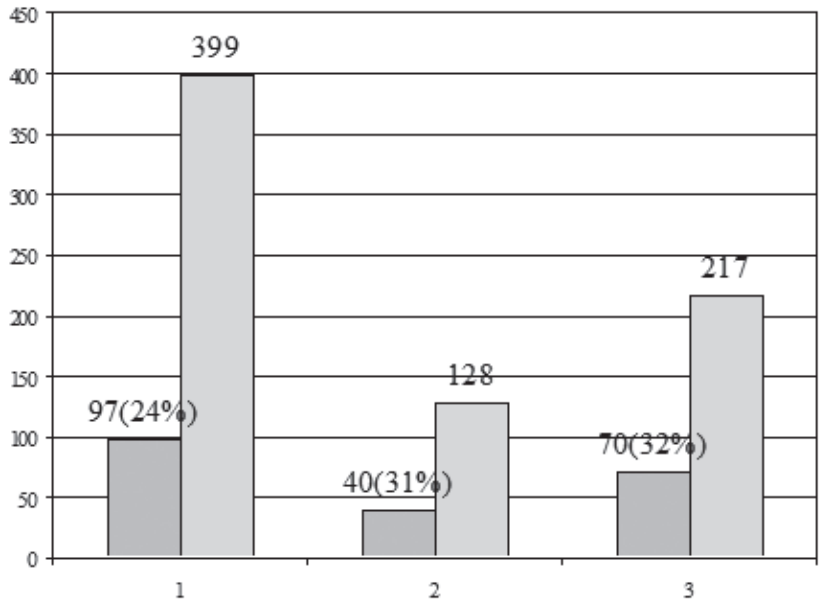


Figure 4. The quantitative distribution of the medicinal species according to their belonging to forest, bush and meadow communities and the importance for the resource science: 1 – plants that grow on the edges, lawns, cut-down forest areas, grasslands, and scrublands; 2 – in coniferous and mixed forests; 3 – deciduous forests, respectively

About 128 species of medicinal plants with almost a third of them being of resource value are associated with coniferous and mixed forests as their primary habitat. It is to be noted that coniferous forests comprise about 42 % of the area of forests in Ukraine and 43 % of broadleaf (including 33 % of beech and oak). The main resources are concentrated in the coniferous and mixed forests, for instance, *Vaccinium myrtillus, V. uliginosum, V. vitis-idaea, Ledum palustre, Pteridium aquilinum, Juniperus communis, J. sibirica, Chelidonium majus, Calluna vulgaris, Fragaria vesca, Frangula alnus, Sambucus nigra, S. rasemosa, Symphytum cordatum* and others. Moreover, the main

species of resources of the Vaccinium genera are localized in Polissia region and the Carpathians [37].

In addition to tree species of medicinal plants listed above (the species of genera *Acer, Betula, Carpinus, Fagus, Quercus, Tilia), the deciduous forests comprise resources of Asarum europaeum, Aegopodium podagraria, Chaerophyllum aromaticum, Convallaria majalis, Corulus avellana, Lathyrus niger, Polygonatum multiflorum, Pulmonaria obscura, Rhamnus cathartica, Stachys sylvatica.* The key resources of *Alnus glutinosa, A. incana, Filipendula ulmaria, Geum rivale, Humulus lupulus, Impatiens noli-tangere, Padus avium, Urtica dioica* are mostly associated with the floodplain forests.

3.6. Resource significance of the medicinal plant in Ukraine and their distribution

The results of the chorological analysis of the wild medicinal plants demonstrate that amongst the analyzed species on the whole or almost entire territory of Ukraine only 169 of them is widespread. These are mainly the Eurasian and multizonal types, most of which are representatives of the synanthropic flora and include the following genera: *Arctium, Artemisia, Atriplex, Carduus, Cirsium, Chenopodium*, as well as the species: *Capsella bursa-pastoris, Centaurea cyanus, Chelidonium majus, Conium maculatum, Cichorium intybus, Cynoglossum officinale, Daucus carota, Equisetum arvense, Melilotus albus, Tussilago farfara etc.*

In Ukraine, they are distributed unevenly and are mostly absent or occur occasionally in the highlands in the mountainous regions of the Carpathians and Crimea and wormwood steppe areas. The territories, where these species are valuable in terms of their raw material, occupy from

10 to 50 % of the distribution area of a particular species. Some species as *Cynoglossum officinale, Draba nemorosa, Fumaria officinalis, Reseda lutea, etc.* are of little raw value throughout the area regardless of their places of distribution.

The raw area with the most widespread species covers the forest and forest steppe zones of localization of the main resources in the Dnipro right-bank areas of Ukraine. These species comprise: *Alnus glutinosa, Artemisia vulgaris, Betula pendula, Capsella bursa-pastoris, Chelidonium majus, Cichorium intybus, Daucus carota, Dryopteris filix-mas, Equisetum arvense, Hypericum perforatum, Frangula alnus, Leonurus villosus, Lythrum salicaria, Melilotus officinalis, Oenothera biennis, Origanum vulgare, Persicaria maculosa, Populus alba, P. tremula, Quercus robur, Rubus caesius, Sambucus nigra, Tanacetum vulgare, Verbascum phlomoides* and others.

Synanthropic species, especially annual and biennial ones, often form dense high-population formation in a small area (5–10 m^2) with partially or completely disrupted vegetation. The existence of such highly productive raw populations is characterized by short life duration, although they quickly colonize other disrupted areas and provide the raw material of great significance in different regions due to their high level of reactivity [39]. Perennial species are able to form synanthropic raw arrays on the land of several acres, and in case of absence of the external destructive impact on their populations; they can preserve their raw material resource value for 5–10 years. Averagely, the resource significant types of the synanthropic flora (in sense of their raw materials) constitute about 15–20 % of the land they grow on; for some species, e.g. *Conyza canadensis, Centaurea cyanus, Conium maculatum, Daucus carota, Urtica dioica, Matricaria recutita* this value can reach up to 50 %.

Besides of the synanthropic species, to the widespread group of the medicinal plants belong also the species, the habitats of which are associated with natural or slightly disturbed plant communities: *Agrimonia eupatoria, Asparagus officinalis, Centaurium erythraea, Clinopodium vulgare, Crataegus sanguinea, Gratiola officinalis, Inula germanica, Lythrum salicaria, Ononis arvensis, Veronica officinalis etc.* They grow in a scattered or fragmented manner on a large territory and generally are valuable in terms of their raw material. However, the spatial structure of their populations is aggregated or multiple in nature as a small area of these types tends to be of low value in terms of their raw material. The total area of the populations with resourceful significance comprises less than 10 % of the area of the plant species distribution; however, for such species as *Althaea officinalis, Lavatera thuringiaca, Malva sylvestris, Marrubium vulgare, and Verbena officinalis* it is less than 1 %.

The highest number of species diversity of the medicinal plants is found in the forest-steppe zone (1337 species out of 2219). Among them, the percentage of species that grow only within this zone is less than 1 %. These are mainly such strictly local or sparse plants as *Dianthus eugeniae, Dodartia orientalis, Draba sibirica etc.* Besides the forest steppe area, other species are cultivated in various natural areas or spread throughout Ukraine. It is noted that in the Left-bank forest-steppe area has nearly 100 species less than the Right-bank forest-steppe area. The diversity of most species in the Right-bank forest-steppe area arises due to the incorporation of the Carpathians and Polissia plant species, particularly in its western part.

The proportion of the introduced and cultivated medicinal plant species in the flora of the Forest steppe zone comprises 13 %, with a number of introduced and cultivated plants

being distributed within the Left-bank and Right-bank forest steppe almost indistinguishably (168 and 174 species, respectively).

The medicinal plants of the traditional medicine of Ukraine those are significant in terms of their raw materials value, growing in the Right-bank forest-steppe area, list 76 species, while the Left-bank area has only 55 species. The predominantly plain Left-bank forest-steppe landscape is favorable for their agricultural use and the land proportion, where the medicinal plants can form the raw arrays, is negligible. Meanwhile, the degree of economic pressure on natural communities in the Right-bank forest-steppe areas is smaller due to a large area of dissection and difficulties of the economic application, especially in Precarpathian part.

Amongst the total number of the valuable medicinal plants in the Forest-steppe area or its particular districts, in terms of the resource science, the significant amounts of the raw materials are derived from the following species: *Achillea setacea, Artemisia annua, Asclepias syriaca, Fragaria viridis, Rhamnus cathartica, and Thymus marchallianus.* Most of the source species are resource significant in other areas, for instance *Filipendula ulmaria, Helichrysum arenarium, Hypericum perforatum, Leonurus villosus, Melilotus officinalis, Oenothera biennis, Origanum vulgare, Rosa canina, Sambucus nigra, Thymus pulegioides, Veronica officinalis etc.*

The second largest diversity of medicinal plants occurs in Polissia; in its Right-bank areas grow 965 species. 852 species were found in the Left bank Polissia regions, including 106 cultivated and introduced medicinal plant species. Overall, the main resource potential of the medicinal plants in Polissia is found in the Right-bank areas primarily due to the natural conditions and total areas of

lands, favorable for formation of the resource potential of the raw plant species. It comprises the largest number of plant species (92), the raw materials of which are harvested for medical purposes; in the Left-bank regions grow 73 medicinal plant species. Amongst the total number 10 wild plant species grow in Ukraine only in Polissia, mostly in the Right bank part. These are mainly species that are here on the edge of their distribution area (*Arctostaphylos uva-ursi, Chamaedaphne calyculata, Salix myrsinifolia*) or occur as disjunctions or separated localities (*Rhododendron luteum, Saxifraga granulata, Moehringia lateriflora*). They are rare, therefore, harvesting of their raw materials from the natural habitats is not allowed in Ukraine.

Many of the species with limited locality, which grow in Polissia, occur occasionally in the Forest steppe and the Carpathians. Thus, the main habitat of *Andromeda polifolia, Tofieldia calyculata, Ledum palustre*, and Oxycoccus palustris occupy the Right bank Polissia areas; these species occur sporadically in the Carpathians, Precarpathian and Roztochchia regions. On the other hand, the main resources of *Alnus incana* are concentrated in the Carpathians and its adjacent areas, and in Polissia the plant species occurs sporadically, in some administrative regions it is under regional protection; *Melittis sarmatica* is common in Roztochchia and Opilya, as well as in the Right bank Polissia and Forest-steppe areas; the limited resources of its raw material occur only in Roztochchia. *Comarum palustre, Menyanthes trifoliata, Padus avium, Thymus serpyllum* are widespread and have sufficient resources in Polissia, but occur sporadically in the Forest-steppe zone.

The species distribution of many plants covers the southern areas of Polissia, adjacent to the Forest-steppe (*Aristolochia clematitis, Berberis vulgaris, Echinops sphaerocephalus, Urtica cannabina, etc.*). Recently is

observed in the area an invasion of the south quarantine weeds, which have significant medicinal properties, such as *Ambrosia artemisiifolia, Grindelia squarrosa*; the increasing distribution of *Heracleum mantegazzianum* becomes especially threatening.

Among the most widely distributed species in Polissia region, the main resource focus lies on the following medicinal plant species: *Acorus calamus, Betula pendula, Bidens tripartita, Calluna vulgaris, Convallaria majalis, Dryopteris filix-mas, Frangula alnus, Helichrysum arenarium, Gnaphalium uliginosum, Juniperus communis, Lycopodium clavatum, Malus sylvestris, Nuphar lutea, Nymphaea alba, Potentilla erecta* [36].

One of the most valuable regions of Ukraine rich with raw materials, besides of the Polissia region, is the Carpathians. The region contains the least transformed vegetation. In the mountainous areas of the Carpathians about 741 species of medicinal plants are grown with only 36 species being cultivated and introduced. The raw material of about 40 wild species is harvested in significant quantities for medical purposes. A higher degree of diversity of medicinal plants is found in the Precarpattia and Transcarpattia (847 and 812 species, respectively), although these regions include generally smaller areas of plant communities, where the species of useful plants have a resource value. These regions are characterized by a large diversity of cultivated and introduced plants (114 and 115 species), the raw material of which is used for medicinal purposes.

Among other species, the main raw materials which are concentrated in the Carpathians and its adjacent areas, are the following: *Arnica montana, Astrantia major, Abies alba, Aconitum moldavicum, Adenostyles alliariae, Alchemilla flabellata, Aruncus dioicus, Carlina acaulis, Centaurea phrygia, Colchicum autumnale, Crataegus*

laevigata, Doronicum austriacum, D. carpaticum, Hypericum maculatum, Juniperus sibirica, Laserpitium alpinum, Pinus mugo, Polygonatum verticillatum, Pulmonaria rubra, Rumex alpinum, Symphytum cordatum, Thymus alpestris, Th. alternans, Veratrum album.

There is a considerable diversity of the plant species in the steppe regions of Ukraine, but the resource potential of most of them is limited due to the high economic development of the territories. Generally, in the Right bank of the steppe regions occur 896 species of medicinal plants with only 12 species having the significant raw material basis. The latter ones are dominantly represented by species of synanthropic flora and the widespread species, such as *Thymus dimorphus, Sambucus nigra, Matricaria recutita, Hypericum perforatum, Helichrysum arenarium, Crinitaria villosa, Crataegus* spp. and Rosa spp. The Left bank areas include a slightly smaller number of medicinal plants (839), and the steppe regions of Crimea are characterized by less diversity in terms of medicinal plants (615 species) due to a significant transformation of the natural ecosystems in the region. Most of the species that occur here are quite widespread with 28 of them growing only in the steppe areas.

In the southern steppe regions of Ukraine occurs the main resource potential of *Matricaria recutita* and localities of *Glycyrrhiza glabra*. The latter species is rare and under protection. The valuable medicinal plants in the Steppe area include *Adonis vernalis, Astragalus dasyanthus, Paeonia tenuifolia*, which are listed in the Red Data Book of Ukraine; their basic habitats are associated with the steppe plant communities of the Left bank steppe and the foothills of the Crimean mountains.

The high diversity of the medicinal plants is the main feature of the foothill and mountain regions of the Crimea. There are

938 species growing there, with only 47 of them being cultivated and introduced. 243 plant species occur in Crimea that does not grow in other regions of Ukraine with 191 of them found only in the mountain areas. Despite such a great variety of medicinal plant species, most of these resources are limited or absent due to the large quantity of transformed vegetation on the peninsula, as well as the limited area of habitat suitable for the implementation of the resource potential of the medicinal plants. Only 10 species of the medicinal plants have considerable stocks of the raw material, which include the genera of *Crataegus* and *Rosa*, synanthropic species and *Thymus callieri, Origanum vulgare, Mentha longifolia.*

Thus, among the species of the wild vascular plants of medicinal importance in Ukraine, only about 25 % of them are valuable in terms of the resource importance. Other species have limited resources and are incorporated into the group of the raw materials, which are either of little resource value or are currently under protection.

3.7. Threats to the medicinal plants and resources

The main threats to the medicinal plants and their resources include:

– Disturbance of their habitat;

– Excessive operational load;

– Contamination by herbicides, pesticides, heavy metals, radionuclides, and others.

Exploration of the type and degree of threat to the medicinal plants is essential in order to determine the acceptable use of their resources at the local and national levels or development of measures for environmental protection and conservation of their habitat areas.

Disturbance of the plant habitat (it's drying, timber stand cutting) causes a threat to the medicinal plant communities, which are related to the habitats of marshes and forests. Thus, *Acorus calamus* is sensitive to the decrease of the groundwater level. It quickly loses the resource value in a year or two in the areas subjected to drying. Meanwhile, such vitality parameters as the plant height, thickness of roots and their density per area unit become lower. The entire arrays become split into fragments located in dissensions. The consistent lowering of water levels below 10 cm is extremely dangerous for the resource value of the species.

These unfavorable environmental conditions for *Acorus calamus* get even more complicated with the use of partially dried floodplain areas with their populations for grazing. Unregulated harvesting on the partially dried lands leads to the catastrophic decline of natural resources of the species and a decrease in the volumes of its collection. Calamus belongs to the group of species, the natural raw stocks of which is on the verge of extinction in Ukraine. Over the past 20 years its resources in Ukraine have decreased in more than 10 times. The lost natural resources of this species cannot be restored. Therefore, it is extremely important nowadays to control the use of its raw materials in the natural habitats.

The key habitats and resources of *Ledum palustre, Acorus calamus, Menyanthes trifoliata, and Polygonum bistorta* occur in the wet meadows, marshes and coastal water communities. The resources of these species decreased not only due to the operational load, but also the dislocation of ecotypes, where these plants grow. First of all, it is drying. Succession of the plant communities in such areas is irreversible even in case of discontinuation of their economic development. The resource value of the raw material of these species may be lost in 2–3 years in the dried areas [17].

Deforestation leads to a complete or almost total destruction of the habitat for populations of *Convallaria majalis, Vacccinium myrtillus, V. vitis-idaea*, the resource significance of which may recover only within the period of 20 years, when will be formed the basic layers of forest communities.

The operating load of the plant populations includes mowing, grazing and the raw material harvesting. Moderate numbers of these activities are not detrimental to the plant resources. Moreover, different plant species have a specific reaction to such measures. Thus, plants of the genera *Hypericum, Achillea* and *Rosa* are weakly sensitive to the operational exposure, while *Adonis vernalis, Arnica montana* and *Astragalus dasyanthus* rather quickly lose their resource significance in conditions of the grazing and exploitative load.

Nowadays under the threat of natural resources depletion due to violation of environmental conditions for the growth and exploitation exposure are the following medicinal plant species: *Acorus calamus, Centaurium erythraea, Ledum palustre, Convallaria majalis, Menyanthes trifoliata, Thymus serpyllum, Vinca minor, Veratrum lobelianum, Polemonium coeruleum, Polygonum bistorta, Lycopodium clavatum* [36] (Appendix, Table 3).

The popularity of the phytotherapy, especially of the folk medicine, reinforced the negative human impact on the natural arrays of many medicinal plants. This is particularly true for the species, the wild resources of which are limited, and, thus, even the small quantities of the raw material harvesting could lead to the extinction of the species in a particular region (Appendix, Table 3).

Harvesting the raw materials with the possibility of its population and resources recovery does not harm the

plant population. Threat to the population status and their resources lies in non-compliance with rules and scope of the allowable harvesting of the raw materials, especially to species of plants those have limited distribution. With the objective of their preservation, the species are listed as the ones that are protected at the local or national levels. For the plant species, the raw materials of which are collected from the environment in large quantities, certain limits for their resource use are set.

The radioactive contamination of the large area of Ukraine caused irreversible harm to the resources of wild medicinal plants, where were more than 25 %, with some species reaching up to 80 % of the harvesting volumes of the raw medicinal plant materials.

At the contaminated territory of Ukraine are concentrated about 80 % of the resource potential of *Thymus serpyllum*, 60 % *Vaccinium myrtillus*, 40 % *Vaccinium vitis-idaea*, 70 % *Frangula alnus*, 90 % *Oxycoccus palustris*, 80 % *Ledum palustre*, 70 % *Menyanthes trifoliata*, 70 % *Lycopodium clavatum*, 20 % *Convallaria majalis*, 70 % *Calluna vulgaris*, 100 % *Arctostaphyllos uva-ursi*, 30 % *Dryopteris filix-mas*, 40 % *Pteridium aquilinum*, 20 % *Potentilla alba* and 40 % of *Potentilla erecta*.

Accumulation of the contaminants in the plant tissues is an undesirable process. The herbal substances containing heavy metals or other contaminants cause a real threat to the life processes in the human body. Additionally to the climatic factors, the environmental ones of the human nature also affect the chemical composition of the plants. These include various kinds of environmental contaminants present in the atmosphere, hydrosphere and lithosphere that enter plants directly. The response of plants to the environmental pollution is complex and ambiguous. Besides

of the type of pollution, its concentration in the environment and the time of impact there also matters the ability of plants to absorb the pollutants.

3.8. Sources of medicinal plants contamination

Ecosystems of Ukraine are characterized by the high levels of contamination that inevitably affect the medicinal plants. The contaminated medicinal raw material and herbal preparations derived from the raw materials are the sources of xenobiotics in the human body. These foreign substances can lead to malfunction of various organs and systems and modification of pharmacological activity of the active substances.

The main sources of contamination of the wild medicinal plants are:

– Industrial enterprises;
– Road and rail transport;
– Agriculture and forestry, which use fertilizers, herbicides and pesticides;
– Man-made disasters (accidents at nuclear power plants, explosions of pipelines, *etc.*).

Currently, there are about 15 thousand pollutants, the most dangerous of which include polycyclic aromatic hydrocarbons, metals, nitrates, pesticides, herbicides, and radionuclides.

Polycyclic aromatic hydrocarbons are contained in the exhaust gases of vehicles, industrial emissions (ferrous and nonferrous metallurgy, coal and coating industries, the coal-fired boilers) and characterized by a strong carcinogenic effect on the human body (e.g., benzo-a-pyrene causes skin cancer). These substances can easily penetrate through the

epidermis into the internal tissues of plants and accumulate in them.

Metals (nickel (Ni), chromium (Cr), selenium (Se), aluminum (Al), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), *etc.*) are the natural components involved in the processes of respiration, plant photosynthesis *etc.*, but their excessive concentration can be a source of mutations in plants and serve as toxins for humans. The use of metals in the contaminated plant raw material can change the physiological responses and biochemical parameters of the human body, and generally result in the disease of chemical nature.

The process of metals entering the human body largely depends on the dosage form obtained from medicinal plants. However, the following factors have a significant influence on the mineral transition in the preparations:

– The nature of the dissolution medium;

– The form of substance occurrence in the plant tissue;

– The texture and chemical composition of the raw materials.

It is established that a high quantity of the minerals diffuses into the aqueous or water-alcohol extracts having a 40 % concentration of alcohol (e.g., infusions, tinctures, teas, fresh juices, liquid extracts). The main sources of environmental pollution by metals are transport and industry.

The toxic substances accumulate in plants in much higher quantities in case of the joint impact, e.g., the content of lead in the roadside plants increases 50 times under the influence of ionizing radiation. In many areas that have undergone radiation are highly elevated levels of nitrates.

The highest accumulation of pollutants occurs in herbaceous plants with large dense leaves that have rosettes and form dense communities. Such plants as strawberries, nettle, coltsfoot, tansy, plantain, wormwood, motherwort and yarrow tend to accumulate toxic substances.

Fertilizers and pesticides penetrate inside the medicinal plants that grow in fields or nearby. These substances have a negative effect on the process of metabolism in the human body; they cause poisoning, allergic reactions, and have immunosuppressive and carcinogenic effects.

The accumulation of nitrates is plant species-specific character of the plants, e.g. dill, common plantain, celandine, nettle appear to be the nitrophilous. Consumption of 8–15 g of nitrates per day can be fatal to humans (the daily intake of nitrates in the amount of less than 1 mg / kg body weight is acceptable). The degree of conversion of nitrates into water in the raw plant material infusions and decoctions corresponds to 63–72 %.

The contamination of a medicinal plant with radionuclides causes a serious danger to human health. Once they enter the body, the radionuclides accumulate in the muscle and bone tissues and become the center of permanent radiation, which can lead to the acute radiation syndrome.

The radionuclides with long half-life time (e.g., cesium – 137, the half-life of which comprises 30 years) that occur in the environment as a result of man-made disasters or accidents pose the greatest threat to a human. The radionuclides can penetrate into plants both through the air and soil. The greatest concentration of ^{137}Cs amongst of all the medicinal plants may be found in the families of Ericaceae and Fabaceae, with the lesser degree of it being in Boraginaceae and Caryophyllaceae, even less in the

Lamiaceae (*Origanum vulgare, Salvia officinalis, Thymus* spp.), and the minimal level of it in occurs the families of Asteraceae (*Achillea millefolium, Calendula officinalis*) and Hypericaceae (*Hypericum perforatum*) [12].

The medicinal plants are both the dominants in the herb-under shrub layers of forests and the accumulators of ^{137}Cs in the typical phytocoenoses of pine forests of the boreal type (A2, A3, B2, and B3). Meanwhile, according to the values of the TC (transfer coefficient) of radionuclides ^{137}Cs from soil to the plant raw material, the species of this order are ranked in the following way: *Ledum palustre* (TC = 125.5) > *Calluna vulgaris* (110.4) > *Vaccinium vitis-idaea* (97.6) > *Vaccinium myrtillus* (96.6) > *Arctostaphylos uva-ursi* (12.1). This can be explained by the fact that the radionuclides are accumulated mostly in the lignified plant organs.

It is established that the plant accumulation of the radioactive cesium and strontium are not the same. Thus, in accordance with the intensity of accumulation of ^{137}Cs in the raw materials of the investigated medicinal plant species were divided into five groups based on the results of the disperse analysis considering the average value of the transfer coefficient (TC) from soil into plants [12]. The first group with the lowest rates of accumulation (TC = 0, 3-1,0) includes the fruits of *Rosa canina*, the herb of Fragaria vesca and flowers of Sambucus nigra. The second group (TC = 1,1-1,5) includes the aerial parts of *Tussilago farfara, Artemisia absinthium, Convallaria majalis, Bidens tripartita, Origanum vulgare, Achillea millefolium, Urtica dioica*; berries of *Crataegus monogyna* and of *Tilia cordata*. The third group (TC = 1,7-2,4) comprises the herbs of *Matricaria recutita, Hypericum perforatum, Polygonum aviculare, Leonurus quinquelobatus inflorescences, Agrimonia eupatoria, Viola tricolor, Mentha arvensis inflorescences and Tanacetum vulgare*. The fourth group (TC = 3.0-5.0) is represented by

the herbs of *Plantago major, Polygonum hydropiper, Thymus marschallianus* and the bark of *Quercus robur*. The fifth group with the highest degree of accumulation of cesium (TC = 9.0) includes only *Chelidonium majus*.

According to the intensity of ^{90}Sr accumulation, the medicinal plant materials are divided into three groups. The first group (CI = 15-40) includes the herbs of *Agrimonia eupatoria, Achillea millefolium, Betonica officinalis, Hypericum perforatum, Plantago major, Artemisia absinthium, Polygonum aviculare, Matricaria recutita*, the fruits of *Crataegus monogyna* and *Rosa canina*, the inflorescences of *Tilia cordata, Sambucus nigra* and *Tanacetum vulgare*, the bark of *Quercus robur*. The second group (CI = 50-60) includes the herbs of *Origanum vulgare, Thymus marschallianus, Fragaria vesca, Viola tricolor, Tussilago farfara, Chelidonium majus, Leonurus quinquelobatus*. The above-ground portions of *Urtica dioica, Convallaria majalis, Polygonum hydropiper, Mentha arvensis, Bidens tripartita* that grow on the lower slopes, where ^{90}Sr comes from above, have the maximum intensity of ^{90}Sr accumulation from the soil (CI = 75-90) [19].

These data should be considered while taking records of the resources and harvesting the medicinal plants in an area, where the use of plant resources is subjected to radiological control.

CHAPTER 4

HARMONIZATION OF THE RESOURCE POTENTIAL BY MEANS OF CULTIVATION OF THE VALUABLE PLANT SPECIES

4.1. Cultivation of medicinal plants in Ukraine and the developed European countries

The demand for the raw materials of many wild plant species becomes higher as the human needs increase. In the time of global transformation of environment, the numbers of natural stocks of many medicinal plants species decline rapidly; therefore, search for the cultivation opportunities of these plants received much attention worldwide in the last decades. However, at this stage of social development the idea of meeting the demand for medicinal raw materials by means of their cultivation is not always reasonable (Table 8).

The healing properties of plants arise mainly due to the presence of secondary metabolites that accumulate in the environment and that may not occur in a certain monoculture, or there will be much less of them than in

the wild raw material. The natural populations accumulate biologically active substances for a long time, which is difficult to achieve in the cultivated ones. In terms of cultivation it is possible to control the accumulation of the active substances to avoid impurities and to plan collection of raw materials. Most pharmaceutical companies in the international market prefer working with the cultivated certified raw materials, which improves the quality control after harvesting and guarantees stable supplies.

Table 8

Advantages and disadvantages of medicinal plants cultivation [48]

Advantages	Disadvantages
– Cultivation of the medicinal plants contributes to the conservation of the natural resources and allows for obtaining the ecologically pure raw materials that meet certain standards; – The cultivation of the plant species proves to be a stable source of the raw materials; – The quality of the cultivated medicinal plants is usually higher than the quality of the wild ones; – The methods of selection contribute to the development of the productive plant varieties containing a great number of active substances; – The culture conditions allow to modify the accumulation of the bioactive compounds using agrotechnical methods; – Plantations can provide the mechanized harvesting of the plant raw material – The raw material of the cultivated medicinal plants does not require additional measures for impurities removal	– The cultivation of several medicinal plants species is not economically efficient due to the plant specificities of cultivation in terms of their environmental conditions (*Ledum palustre, Acorus calamus, Arnica montana*); – Healing properties of some medicinal plant species may be reduced during the process of cultivation (*Panax, Eleutherococcus*); – The cultivation of medicinal plants requires specific herbicides and pesticides to be used that can affect the quality of the raw materials; – The cost of crops supervision significantly increases the cost of the raw materials; – The cultivated species can become invasive and have a negative impact on ecosystems

While the medicinal and aromatic plants usage, Europe sees an existing trend of the gradual increase in the proportion of the cultivated plant material of the European Union (EU) origin, although now it constitutes 10–20 % of the total amount of the raw materials. Generally, the prices for the raw materials extracted from the wild plants are much lower than from the cultivated ones. This is primarily due to the cost of cultivation. Different countries have their own specific traditions formed in the process of harvesting the raw materials from the wild plants, as well as their cultivation.

In the EU as a whole 130–140 species of medicinal and aromatic plants occupy the area of 70 000 hectares. In some countries the number of the cultivated species varies from 30 to 50. The largest areas of the medicinal plants cultivation are located in France, Hungary and Spain. Among them, the greatest demand in these countries has the *Lavandula spp., Papaver somniferum, Carum carvi* and *Foeniculum vulgare*. The raw material of some species is harvested and grown naturally (e.g., *Gentiana lutea, Arnica montana*, and some species can be only cultivated (*Mentha x piperita, Melissa officinalis, Anethum vulgare, Foeniculum vulgare, Origanum majorana, Ocimum basilicum, Silybum marianum*) [32].

More than a half of all medications in Germany are made from herbs or their substances. With approximately 440 local medicinal plants, about 75 species of them are grown in Germany on a total area of almost 10 000 ha, and the harvesting volume of 24 species of the raw materials comprises 92 % of the total quantity. The priority in the process of cultivation is given to the following species: *Chamomilla recutita, Mentha x piperita, Melissa officinalis, Anetum vulgare, Foeniculum vulgare, Petroselinum spp., Origanum majorana, Ocimum basilicum, Thymus vulgaris, Hypericum perforatum, Echinacea spp., Valeriana officinalis,*

Plantago lanceolata, Salvia officinalis, Foeniculum vulgare, Silybum marianum, and Hippophae rhamnoides [26].

The main regions of the medicinal plants cultivation in Germany are Thuringia, Bavaria, Saxony, Saxony-Anhalt and East Friesland. The total amount of the use of the cultivated raw materials in Germany comprises about 30%, with many raw materials from medicinal plant species, being imported from the South-East Europe and Asia.

Poland is an important producer of the medicinal and aromatic plants raw materials. There are about 70 species being cultivated, and the amount of average annual harvesting of cultivated plants comprises 10 000–20 000 tones. The following species are cultivated in large quantities: *Aronia melanocarpa, Hypericum perforatum, Thymus vulgaris, Oenothera spp., Borago officinalis, Silybum marianum, Mentha x piperita, Chamomilla recutita* (syn. *Matricaria recutita*), *Valeriana officinalis, Melissa officinalis, Cynara scolymus* and *Salvia officinalis* [55].

France is the leading European country in terms of production of essential oils from lavender, providing almost 33 % of the world production of this preparation. It is also the leader in the production of various aromatic spices. The priority species of medicinal and aromatic plants, the raw materials of which are cultivated, include *Lavandula angustifolia, Salvia sclarea, Valeriana officinalis, Mentha x piperita, Gentiana lutea, Papaver somniferum, Ginkgo biloba, Rosmarinus officinalis, Thymus spp.*; they are grown to meet the needs of the food, pharmaceutical and cosmetic industries.

The herb cultivation is traditional for Bulgaria. About 30–40 species of medicinal and aromatic plants are grown there, including the significant amounts of *Mentha x piperita,*

Coriandrum sativum, Silybum marianum, Tilia spp., Aesculus hippocastanum, Hypericum perforatum, Valeriana officinalis, Althaea officinalis, Foeniculum vulgare, Glaucium flavum, Chamomilla recutita and Melissa officinalis.

Romania uses almost 350 species of medicinal and aromatic plants; about 50 species of them are cultivated on its territory. The main cultivated medicinal and aromatic plants in Romania include *Artemisia dracunculus, Cynara scolymus, Cichorium intybus, Calendula officinalis, Coriandrum sativum, Thymus vulgaris, Foeniculum vulgare, Hyssopus officinalis, Lavandula angustifolia, Majorana hortensis, Mentha x piperita, Melissa officinalis, Origanum vulgare, Plantago lanceolata, Rosmarinus officinalis, Salvia officinalis, Satureja hortensis, Silybum marianum, Sinapis alba, Tagetes patula, Trigonella foenum-graecum, Valeriana officinalis* [22]. The new cultivated species were introduced into culture in order to obtain the new raw materials (*Aconitum napellus, Artemisia abrotanum, Gentiana lutea, Leonurus cardiaca and Lychnis coronaria*. A large number of the medicinal plant species, herbs and fruits are widely harvested there.

Spain is a country with a great variety of natural herbs, which uses and exports a lot of wild medicinal materials. Cultivation of the medicinal plants for raw materials is carried out mainly in small farms. The main regions of cultivation of medicinal plants here are Catalonia and Andalusia, where the plantations of the medicinal plants cover about 9000 hectares. The dominant cultures of plants in Spain include *Lavandula spp.; such plants as Anetum vulgare, Anthemis nobilis, Equisetum arvense, Humulus lupulus, Mentha x piperita, Melissa officinalis, Origanum vulgare, Plantago lanceolata, Rosmarinus officinalis, Salvia officinalis, Silybum marianum, Thymus spp.* and others are cultivated in significant quantities.

Diversity of the cultivated medicinal plants is not significantly different in Europe. Most of the raw materials are extracted from 50 species of medicinal and aromatic plants, the 20 species out of which are being cultivated in large quantities. Cultivation of many valuable species of medicinal plants is economically disadvantageous because of their specificities in terms of the environmental conditions for growth (*Acorus calamus, Drosera rotundifolia, Ledum palustre, Panax ginseng*). The raw materials of these species tend to be imported or harvested from the environment in a controlled manner.

In Ukraine are cultivated about 115 species of medicinal and aromatic plants (Appendix, Table 4). Some of them constitute a part of agricultural crops (*Vicia faba, Fagopyrum esculentum, Papaver somniferum, Rumex acetosa*), or are used as spices and condiments (*Anetum vulgare, Armoracia rusticana, Carum carvi, Coriandrum sativum, Foeniculum vulgare, Pastinaca sativa, Petroselinum crispum, Sinapis* spp.). More than 25 species of medicinal plants are available only in culture, or occasionally became naturalized by themselves (*Calendula officinalis, Carthamus lanatus, Digitalis lanata, Echinacea purpurea, Hyssopus officinalis, Mentha x piperita, Silybum marianum, Stevia rebaudiana, Dracocephalum moldavicum, Salvia officinalis, Lophanthus anisatus, Lavandula angustifolia, Scutellaria baicalensis*). The State Pharmacopoeia of Ukraine monographs list the available of 20 species of medicinal plants, the raw materials of which are harvested only from cultivated plants (Appendix, Table 5) [6-8].

Several species of medicinal plants naturally grow in Ukraine and constitute the basis of raw materials, which makes it possible to provide a stable source of the raw materials (*Achillea millefolium, Agrimonia eupatoria, Althaea officinalis, Bidens tripartita, Chamomilla recutita*

(syn. Matricaria recutita), *Cichorium intybus, Hypericum perforatum, Helichrysum arenarium, Oenothera biennis, Plantago major, P. lanceolata, P. psyllium, Rosa canina, Valeriana officinalis*. Many highly productive varieties of these species have been created over the past decade. In terms of medicinal plant selection in the territory of Ukraine, the region of Berezotochia in Poltava, where the medicinal plants are grown from the early 20th century, has traditionally been a leader in cultivation of the medicinal plants.

4.2. The impact of environment on accumulation of bioactive substances by medicinal plants

The main indicator of the quality of medicinal plants is the content of their biologically active substances. The chemical composition of plants, the quality and quantity of the active substances depend on complex of environmental and climatic factors. The most significant effect on the quality of the biologically active compounds of wild plants (other than genetically determined properties) have the chemical composition of the soil, temperature during the growing season, rainfall and illumination. In terms of cultivation, these factors of influence can be reduced to some extent through the use of the farming practices.

Natural and climatic factors have a decisive impact on the chemical composition of plants. Thus, temperature is one of the most important factors influencing the life of the plant since the duration of vegetation; accumulation of active substances and the mass of the plant depend on the warm and light energy. Rainfalls and humidity of the environment also affect the quantity and composition of the active compounds of plants. It is established that xerophytes (plants of arid habitats) can be harmed with the excess of

moistures; on the contrary, hygrophytes cannot tolerate the drought conditions; mesophytes have wide amplitude of adaptations to moisture.

The accumulation of the chemical compounds depends primarily on the type of physiologically active compounds. The increasing content of alkaloids in plants is encouraged by the high intensity and duration of sunlight, high temperatures at relatively low level of humidity, and occurrence of soils rich in nitrogen and calcium.

It is believed that the accumulation of alkaloids in plants, as well as the alkaloid related diversity of plants, increases from the north to the south. In other words, climate of the southern latitudes contributes to the synthesis and accumulation of alkaloids. Apparently, higher temperatures and intense solar radiation play a positive role in this case. The temperature lowering has a negative impact on the accumulation of alkaloids in plants.

Altitude also affects the dynamics of alkaloid accumulation. Such alkaloid related plant species in Ukraine include *Atropa belladonna, Scopolia carniolica*, which grow up to 800 m ASL.

The same pattern was found in plants that are rich in essential oils. The variety of aromatic plants and the content of the essential oils increases from the north to the south. Most of these species are aromatic plants of subtropical zone, where occurs the combination of high temperature and lighting, and sufficient humidity conditions. The main aromatic plants of the temperate zone include the species of *Mentha x piperita, Melissa officinalis* and *Origanum* spp. However, the quantitative value of essential oils in these plant species in the southern areas is higher than the value of the north ones. Meanwhile, the prolonged period of high

temperatures and lack of moisture content in the process of cultivation leads to the reduction of quality of mint essential oils; the same phenomenon is found in cases of the lack of warm temperatures and light or excessive humidity.

Several species of the medicinal aromatic plants demand specific lighting and temperature conditions during the growing season (lavender, sage, and rosemary) and are less sensitive to the soil moisture. Therefore, the moderate climate contributes to their unreasonable cultivation.

Various aromatic plants respond differently to the increasing altitude; for example, lavender shows the decreased content of essential oils on the plantations located in the high mountains, and the rose, on the contrary, has an increased amount of them.

An important condition for the formation and accumulation of glycosides in plants is the high level of insolation and solar activity in the climate zone. The great amount of nitrogen in the soil reduces the amount of glycosides inside the plant organs, which is taken into consideration for glycoside containing plants. The high level of rainfalls and humidity of the environment also negatively affects the amount of glycosides in plants.

The naturally growing and rarely cultivated plant of licorice usually grows in Ukraine; however, the licorice cortex is being imported from the Central and Southeast Asia, as its raw material contains a significant amount of glycyrrhizic acid than the raw materials cultivated in Ukraine and other European countries.

The moderate climate (average temperatures are mild and there is a sufficient amount of moisture) promotes the synthesis and accumulation of nitrogen-free compounds.

The key factors for the synthesis of phenolic compounds are balanced and optimal for a certain type of plant combination of the amount of warm, light and rainfalls. In the extreme environmental and weather conditions (the lack of water), the phenolic compounds are wasted for the protective functions, and, therefore, the reduction in their amount occurs. In cases of favorable moisture conditions and average daily temperatures during the blossoming, the plant synthesis of phenolic compounds exceeds their losses and therefore their concentration remains high [2]. The low levels of iron also stimulate the increased level of biosynthesis of phenolic compounds.

A variety of flavonoids is caused by their different properties and functions in the plants. These compounds, like most other chemical compounds of plants, are synthesized to protect plants from adverse conditions or in response to stress. Flavonoids inside the plants perform a protective function against the ultraviolet radiation to protect plants from pathogens and herbivore organisms.

In the process of medicinal plants cultivation, much attention is paid to studying the impact of the mineral nutrients on the content of the bioactive compounds in the plants. The reason for it lies in the fact that the use of fertilizers as means to influence the formation and accumulation of biologically active substances is optimally realized in a certain culture.

Since alkaloids are the compounds containing nitrogen, the nitrogen fertilizers undoubtedly play an important role in the biosynthesis and accumulation of these substances. There is some correlation between the quantity of alkaloids and the nitrogen intake; therefore, the amount of alkaloids increases dramatically during the process of the maximum absorption of the nitrogen into the soil, for instance, in cases

of the flowering of some species. On the other hand, when the flow of nitrogen from the soil to the plant is reduced, which usually happens after the flowering period, the amount of alkaloids decreases? In case of nitrogen starvation, when the items related to life or death of the plant arises, the alkaloids are being dissimilated.

Fertilizers containing potassium, calcium and phosphorus have a positive effect on the accumulation and concentration of glycosides and essential oils in the tissues of the plant. The high doses of nitrogen fertilizers have a negative effect on the accumulation of these compounds.

4.3. Relationship of trace elements in plants and the accumulation of the biologically active substances

Medicinal plants require the same essential elements as other plants: C, H, O, N, S, P, Ca, and K, Mg as macronutrients and Fe, Mn, Zn, Cu, B, Mo, Cl, Ni as micronutrients.

Among the macronutrients, the carbon/nitrogen balance (CNB) is of special relevance for both biomass production and N-containing secondary metabolites like alkaloids. In contrast, N-deficiency can favor the production of essential oils, while the synthesis of alkaloids is strongly inhibited. The specific roles for essential micronutrients in the production of active principles are due to their function as components or activators of enzymes of the secondary metabolism. Moreover, metals can quilted certain phytochemicals in plant tissues. Micronutrients with redox functions like Fe, Cu, Mn, and Mo are key factors for many enzymes involved in biosynthetic steps of secondary compounds.

Copper, for example, is essential for the function of many oxidases and oxygenases with a key role in secondary metabolism. Copper deficiency strongly inhibits the activities of diamine oxidase, which is essential for the metabolism of the diamines putrescine and cadaverine.

Iron is a component of heme and non-heme oxygenases with key function in isoprenoid synthesis. Cytochrome P 450 enzymes are also acting in several steps of biochemical pathways to different types of phenolics and flavonoids. Synthesis of dihydroflavonols, a major branch point in flavonoid biosynthesis, requires Fe for the activity of the dioxygenase. Manganese is essential for Mn-SOD activity. Molybdenum is essential for nitrogenase and nitrate reductase and therefore plays a key role for the production of N-containing active principles like alkaloids. However, Mo deficiency seems to limit biomass production rather than alkaloid synthesis [42].

Micronutrients without redox functions are also directly or indirectly involved in plant secondary metabolism. Boron has a central function in the phenol metabolism in plants, and its deficiency strongly stimulates polyphenoloxidase. Zinc is required for the activity of thousands of plant proteins [16].

A close relationship between the amount of some trace elements in soils and the plant's production of individual groups of biologically active substances has been set recently:

> Plants that produce cardiac glycosides absorb manganese, molybdenum, chromium selectively;
> Plants that produce alkaloids: copper, manganese, cobalt;
> Plants that produce saponins: molybdenum, vanadium;

> Plants that produce terpenoids: manganese;
> Plants that produce anthracene-derivatives: copper;
> Plants that produce vitamins: manganese, copper;
> Plants that produce polysaccharides: manganese, chromium.

The study of the impact of geochemical factors on the production of the active substances by plants lead for the development of recommendations for the collection of the raw materials of the wild medicinal plants in those areas of habitats where they had different levels of BAS (biologically active substances); it sets prerequisites for the directional impact on the biogenesis of the active substances in the process of cultivation of the medicinal plants through the use of appropriate micronutrients.

It is known that the species of the foxglove (*Digitalis*) genera accumulate manganese, molybdenum and chromium selectively. The injections of mangan and molybdenum stimulate the activity of the enzymes responsible for the synthesis of coenzyme A, which leads to an increase of the amount of cardiac glycosides [3].

The most suitable doses of boron for the peppermint are 0.1–0.3 mg/kg of soil, which will result in the increase of the leaves harvest by 11 % and of the amount of essential oils by 0,24 %. Further addition of boron to the mixture reduces the yield of leaves, while the amount of essential oils remains the same. The optimal dose of zinc constitutes 2.2 and 8.8 mg/kg. If these proportions are taken, the mint crop increases by 19 %, and the further addition of zinc doses reduces the weight of the leaves and increases the amount of the essential oils by 0.5 %.

The presence of trace elements – iron, manganese, cobalt, and copper – in soil are of a particular value for belladonna.

Similar to other alkaloid-yielding plants characterized by the considerable accumulation of copper. The most effective micronutrients for it are boron, which causes a significant increase in the amount of alkaloids, followed by molybdenum and manganese. Qualitative composition of alkaloids inside the plants does not change.

All the trace constituents (manganese, boron, molybdenum, zinc) increase the productivity of the hops. Manganese facilitates a greater accumulation of glutathione and the reductive form of ascorbic acid, as well as to a greater accumulation of bitters in hops mainly due to the most valuable components of this complex. The increasing of the bitter constituents yield in the hop strobiles is also caused by boron and molybdenum (it increases on 3,3–3,4 %).

The stage of plant development is also essential for the process of accumulation of biologically active compounds. For example, the percentage of flavonoids in the plant phenolic complex of maidenhair tree (*Ginkgo biloba*) increases with the growth of its leaves from 17 % (young leaf) to 25 % (adult leaf) [19]. Similar phenomena may be found in the leaves of tea. The number of flavonoids in maidenhair tree also increases from the north to the south, indicating the important role of the sunlight and warm in the process of formation of this group of biologically active compounds. These data are important to determine the duration for the optimal period of raw material harvesting.

4.4. Rules and terms of collection, processing and storage of plant raw material

In the process of the plant material harvesting, the collectors are required to follow the rules of raw materials

collection, which provide not only the highest quality raw materials, but also the ability of populations of species to recover themselves. The general conditions of the raw material procurements are its collection during the period of the highest level of biologically active substances accumulation (Appendix, Table 1).

All above-ground parts of the plants are harvested only in dry weather period. In case of the morning dew or after the rain, the materials should be collected only after full plant drying. However, the raw materials absorb moisture and quickly darken and lose quality when dried. The freshly packed materials can lose their quality even in an hour (*Sambucus flos*), so it is recommended that after harvesting a primary processing (drying, canning *etc*) of the plant material is ensured as soon as possible.

Do not carry out continuous and annual collection of medicinal plants, especially the roots, rhizomes, bulbs and tubers, in all areas, as it leads to the plants extinction. Harvesting of plant material in the woods, where the measures were introduced to combat pests and diseases with the use of chemicals, and afforestation, which are in the roads and areas of chemical and industrial plants are not recommended. The dusty plants that grow along the field roads and are damaged by pests and diseases should not be collected.

4.5. The common techniques of collection and initial processing of the raw material

Harvesting of flowers and inflorescences is carried out in the period of mass flowering until fruiting. A part of raw materials should be remained in an array for the next seed

renovation of the population (10–20 %). It is prohibited to damage plants (to break the branches, uprooting of plants *etc*). Flowers from the majority of plants are harvested at the beginning of their flowering and for some species – at the time of budding. The name «flowers» refers not only to a single flower (lily) or some of its elements (marginal funnel-shaped flowers of inflorescence in *Centaurea cyanus*, spikes of *Verbascum spp.*), but also to the inflorescence (linden, chamomile, elderberry, everlasting sand).

Collection and primary processing of flowers requires a special care. Firstly, they should immediately be collected in a shallow box with a grade (mesh) bottom; they are laid in a thin layer to avoid unnecessary transshipments, during which they can be damaged. Secondly, they must be quickly dried in special closed driers with active air circulation at a temperature of 50–60 °C air or on racks under cover, since sunlight and spontaneous heating in the collected flowers can quickly cause undesirable biochemical reactions.

Fruits and seeds are harvested mainly during maturation, leaving a portion for seed recovery (10–20 %). Juicy fruits (blueberries, cranberries, raspberries, elder, and buckthorn) and seeds are encouraged to collect during dry weather. Alder fruits and juniper cones are harvested in autumn and winter, by shaking them down on the cloth. It is not recommended to wash juicy fruits (strawberries, blueberries, and raspberries), however it is desirable to leave them under the sunlight for a few hours, and then dry in the dryer or oven at a temperature of 60–70 °C.

Collection of plants underground parts is done in autumn after the leaves fall off or aerial organs of herbaceous plants die off, rarely – in the early spring, considering the annual allowable use for raw materials of a particular species. To comply with this condition, an array area should be

divided into equal parts (stripes, unit squares), and then the material is collected in the relevant field, selecting the most developed species. Roots, rhizomes, tubers, bulbs are dug up, cleaned from soil, washed in running water (if needed) and dried immediately.

The leaves of living plants are collected during a massive bloom with the account of not more than 25 % of the shoot, however only mature leaves are collected. In some cases, stems are cut, which are subsequently dried and threshed. Exceptions include *Tussilago farfara, Menyanthes trifoliata, Vaccinium vitis-idaea* and some other plant species, which blossom at the period of occurrence of their immature leaves. This work can only be conducted in dry and sunny weather, by selecting only fully formed leaves, free from damages or diseases. The collected raw material is separated from impurities and spread out thinly to dry. It is dried depending on the availability of biologically active substances.

Annual and perennial herbaceous plant species (St. John's wort, marjoram) are collected during the flowering (before fruiting) without rough parts of the stem. It is forbidden to uproot the plants. Within the areas of the harvesting at least 20 % of the plants should be remained for seed regeneration. In Pharmacognosy and Phytotherapy the term «herb» refers to aerial parts of medicinal plants without coarse stems, therefore, consisting of stems, growing up to 30 cm, with leaves and flowers. Damaged and defective parts are immediately discarded.

Buds are collected in winter or early spring when they just begin to swell, but the covering scales have not yet begun to unfold. Pine and poplar buds are cut with a sharp knife from the lower lateral branches of trees. Birch buds are smaller, so they are collected during cutting of trees by hand or by threshing from already cut and dried branches. Collected

buds are spread by a thin layer on a piece of parchment and dried in a well ventilated area at temperatures above 25 °C, so as not to provoke them to unfold and prevent from excessive evaporation of essential oils.

The best term for collection of bark is the beginning of spring juice flow when it is easily separated from the wood. The bark is collected out of young branches at a rate not exceeding 5 % of biological stock. Circular cuts are curved on cut branches at a distance of 25–50 cm from each other, connecting them with one or two longitudinal cuts, and then removed in the form of tubes. It is advisable to harvest bark for medical purpose in spring, out of trees and shrubs in areas assigned for cutting-out during the current year.

Roots, rhizomes, tubers, bulbs are harvested in autumn, during of dormancy of perennials or in spring, while they have not yet developed vegetative organs. Dug up underground organs of most plant species should be carefully shaken from the ground, thoroughly washed under running cold water and spread out on a thick layer of sackcloth or other material that absorbs moisture well. Dried rhizomes with roots, cleaned from residual stems, basal leaves and other impurities, are cut into small pieces and dried on racks under eaves or in special dryers, depending on the content of biologically active substances.

Each type of medicinal raw materials should be dried under certain conditions. First of all, compliance with the required temperature that ensures the preservation of volatile compounds. For example, raw plants such as *Valeriana officinalis, Lavandula spp., Origanum vulgare, Melissa officinalis, Mentha x piperita, Arthemisia absinthium, Thymus spp., Carum carvi, Anethum graveolens, Salvia officinalis*, which contain essential oils, are dried slowly at temperatures above 30–35 °C.

Raw materials, containing vitamin C (*Fructus Ribis nirgi, Fructus Rosae cinnamomeae*) require rapid drying at a temperature of 80–90 °C to avoid the destruction of ascorbic acid.

Herbs containing alkaloids are typically dried at 40–50 °C.

In order to keep flavonoids, rapid drying at higher temperatures may be applied (50–60 °C, occasionally up to 90 °C).

In some cases, raw material is processed into fresh juice and then frozen; it is used for the manufacture of alcohol or oil extracts, according to the developed technologies.

4.6. Good Agricultural and Collection Practice for medicinal plant materials

In 2012, the Ministry of Public Health of Ukraine adopted the regulation (guideline) on «Good Agricultural and Collection Practice (GACP) for Starting Materials of Herbal Origin», in accordance with the basic principles of the «Guideline on Good Agricultural and Collection Practice (GACP) for Starting Materials of Herbal Origin» (London, 20 February 2006) of the European Medicines Agency [56].

This guideline establishes the rules (requirements and recommendations) concerning cultivation practices and harvesting of starting raw materials, extracted from plants (herbs / plant material) and serves as the basis for the establishment of an adequate system of quality assurance in this area. It is applied to the specific issue of growing, harvesting and primary processing of medicinal plants / plant material intended for use in medicine. This guideline sets out specific rules relating to agricultural production of medicinal plants / plant material and collecting them in the wild, which is necessary to ensure good quality.

The main goal is to ensure the safety of consumers by establishing appropriate quality standards for medicinal plants / plant material. This guideline provides recommendations for manufacturers on minimizing the possible harmful effects of pollutants upon human health.

Regulations and recommendations presented in this guideline are intended for all producers, collectors of raw materials, wholesalers and processing enterprises and relevant enterprises whose products are imported into Ukraine. In addition, persons engaged in cultivation and collection of medicinal plants / plant material should guarantee that they do not harm the existing natural populations.

The guideline discusses the basic requirements for personnel, premises for storing and processing the plant materials, equipment, accompanying documentation, seed and planting material; conditions of cultivation, harvesting, primary processing and storage of raw materials plants. Briefly, these requirements are highlighted below based on traditional rules of collection of raw herbs.

The guidelines of World Health Organization (WHO) on good agricultural and collection practices (GACP) for medicinal plants are above all intended to provide general methodical guidance on obtaining medicinal plant materials of good quality for the sustainable production of herbal products classified as medicines. In Ukraine, they are approved as a regulatory document for cultivation and collection of medicinal plants, including certain post-harvest operations.

Raw medicinal plant materials should meet all applicable national and/or regional quality standards. The guidelines therefore it is necessary to adjust in accordance with situation in the country.

These guidelines are intended to be used for cultivation, harvesting and medicinal raw material processing:

– contribute to the quality assurance of medicinal plants raw material used as the source for herbal medicines, which aims to improve the quality, safety and efficacy of finished herbal products;

– guide the development of national and/or regional GACP guidelines and GACP monographs for medicinal plants and related standard operating procedures;

– encourage and support the sustainable cultivation, collection and processing of medicinal plants and material by good quality in ways that support the conservation of medicinal plants and the environment in general.

Growers and collectors should have adequate knowledge about the medicinal plant. This should include botanical identification, cultivation characteristics and environmental requirements (soil type, soil pH, fertility, plant spacing and light requirements), as well as the means of harvest and storage.

All specialists (including field workers) involved in the propagation, cultivation, harvest and post-harvest processing stages of medicinal plant production should look after one's hygiene and should have received training regarding their hygiene responsibilities. Only properly trained specialist, wearing appropriate protective clothing (such as overalls, gloves, helmet, goggles, face mask), should apply agrochemicals.

Producers and collectors should receive instruction on all issues relevant to the protection of the environment, conservation of medicinal plant species, and proper agricultural stewardship.

The guidelines included five sections: section 1 provides a general introduction, sections 2 and 3 discuss some good agricultural practices for medicinal plants and good

collection practices for medicinal plants, respectively. Section 4 outlines common methodical aspects of good agricultural practices for medicinal plants and good collection practices for medicinal plants, while section 5 considers other relevant issues of cultivation, harvesting and medicinal raw material processing [56].

The guidelines included five annexes, which set out a sample record for cultivated medicinal plants (Annex 5) and a model structure for monographs on good agricultural practices for specific medicinal plants (Annex 4), as well as national and regional documents on good agricultural practices for medicinal plants from the People's Republic of China, the European Agency for Evaluation of Medicinal Products, and Japan (Annexes 1, 2 and 3, respectively).

Medicinal plants should be harvested during the optimal season, when plants accumulated maximum biologically active substances to ensure the production of medicinal plant materials and herbal remedies of the best possible quality. The time of collection depends on the plant part to be used. Detailed information concerning the appropriate timing of harvest is available in national pharmacopoeias (as well as in Ukrainian State Pharmacopoeia), published standards, official monographs and major reference books.

It is well known that the concentration of biologically active constituents varies with the stage of plant growth and development. This also applies to non-targeted toxic or poisonous indigenous plant ingredients. The best time for harvest (quality peak season/time of day) should be determined according to the quality and quantity of biologically active constituents rather than the total vegetative mass of the targeted medicinal plant parts. During harvest, care should be taken to ensure that no related substances, weeds or toxic plants are mixed with the harvested medicinal raw materials.

Medicinal plants material should be harvested under the best possible conditions, avoiding dew, rain or exceptionally high humidity. If harvesting occurs in wet conditions, the harvested material should be transported immediately to an indoor drying facility to expedite drying so as to prevent any possible deleterious effects due to increased moisture levels, which promote microbial fermentation and mould.

Equipment and collecting accessories, harvesters, and other machines should be kept clean and adjusted to reduce damage and contamination from soil and other materials. They should be stored in an uncontaminated, dry place or facility free from insects, rodents, birds and other pests, and inaccessible to livestock and domestic animals.

In section «Good collection practices for medicinal plants» described the general principles and basic methods for small- and large-scale collection of fresh medicinal plant materials. Collection practices should ensure the optimal populations recruitment long-term survival of wild populations and their associated habitats. Management plans for plants harvesting should provide a framework for setting sustainable harvest levels and describe appropriate collection practices that are suitable for each medicinal plant species and plant part used (roots, leaves, fruits, etc.). Collection of medicinal plants raises a number of complex environmental and social issues that must be addressed locally on a basis of state normative. It is acknowledged that these guidelines vary widely from region to region and cannot be fully covered by these issues.

In section «Good collection practices for medicinal plants» described the general rules and basic methods for small- and large-scale collection of fresh medicinal plant materials. Collection practices should ensure the long-term survival of wild populations and their associated habitats. Management plans for medicinal plants harvesting should provide a framework for setting sustainable harvest levels and describe appropriate collection practices that are suitable for each

medicinal plant species and plant part used (roots, leaves, fruits, etc.). Collection of medicinal plants raises a number of complex environmental and social issues that must be addressed locally on a case-bycase basis. It is acknowledged that these issues vary widely from region to region and cannot be fully covered by these guidelines.

Requirements to collectors

It is necessary to carry out all pre-cultivation procedures in full compliance with the requirements of personal hygiene (including staff working in the fields) and receive adequate training regarding responsibilities pertaining to hygiene requirements [56].

Employees must be protected from contact with toxic or potentially allergenic medicinal plants / plant raw material with the help of suitable protective clothing. Individuals with open wounds, inflammation and skin infections should be withdrawn from work in the areas of plant cultivation or must wear suitable protective clothing / gloves until their full recovery.

Staff (collectors) has to undergo appropriate training on botany before performing work that requires such knowledge. Collectors must have sufficient knowledge of plant raw materials which they collect. Collectors must be able to distinguish between species that are harvested from similar types to prevent any risk to human health. They must have sufficient knowledge of the optimal time and technology of gathering, as well as the importance of initial treatment to ensure the best quality.

Collectors of medicinal plants / plant material should receive instructions on all aspects of environmental protection and on preserving the diversity of plant species. These

instructions should include information on the regulatory requirements concerning the species under protection.

The medicinal plant species or botanical variety selected for collection must be consistent with the requirements of national pharmacopoeia or recommended by other authoritative national documents of the end-user's country, as the source for the herbal medicines concerned. In the absence of such national documents, the selection of medicinal species or botanical varieties specified in the pharmacopoeia or other authoritative documents of other countries should be considered. In the case of newly introduced medicinal plants, the species or botanical variety selected for collection should be true identified and documented as the source material used or described in traditional medicine in original countries.

Collectors of medicinal plants and producers of medicinal plant materials and herbal medicines should prepare botanical herbarium for submission to regional or national herbaria for identification. The specimens of herbaria should be retained for a sufficient period of time, and should be preserved under proper conditions. The name of the botanist or other experts who provided the botanical identification or authentication should be recorded. If the medicinal plant is not well known to the community, then documentation of the botanical identity should be recorded and maintained.

Requirements for premises

Buildings used for processing the collected medicinal plants/ plant material should be clean and sufficiently ventilated; should provide adequate protection of collected medicinal plants / plant material from birds, insects, rodents and pets.

Requirements for growing

During cultivation it is necessary to follow a good practice of agriculture, including an appropriate system of crop rotation. Medicinal plants cannot be grown in soil that is contaminated with sewage, heavy metals, waste products, weed and pest killers or other chemicals.

The use of any chemical substances to promote growth or crop protection should be minimized. Utilized manure should be properly composted; it must not contain human faces. Avoid the use of pesticides and herbicides as much as possible. If necessary, it is allowed to apply crop protection products in minimum effective quantities according to the manufacturer's recommendations and the competent authorities.

Requirements for the collection

Collecting the plants should be carried out in accordance with the current regional and/ or national legislation for the conservation of plant species diversity. It is essential that collection methods were not detrimental to the environment, provided optimal conditions for the resumption of medicinal plants / plant material in the field of collection.

The species of medicinal plants / plant material that are endangered (listed in the *Convention on International Trade in Endangered Species* of Wild Fauna and Flora – CITES, the Red Book of Ukraine) cannot be collected unless the competent authority has not given its consent. Endangered medicinal plant species must be sourced only in accordance with national and/or regional legislation. When medicinal plant materials from threatened, endangered or protected medicinal plant species are harvested through cultivation, they should be accompanied by appropriate documentation in accordance with national and/or regional regulations, to

certify that no such medicinal plant materials collected from the wild are included [56].

Medicinal plants / herbal substances should be harvested when they are at the best possible quality for the proposed use. Damaged plants or plant parts need to be excluded or limited in accordance with a specific pharmacopoeias monograph, where relevant.

Collection practices should ensure the long-term survival and regeneration of wild populations and their associated habitats. The population state of the target species at the collection site(s) should be determined and species that are rare or scarce should not be collected. To encourage the regeneration of medicinal plants population a sound demographic structure of the population has to be ensured. Management plans should refer to the species and the plant parts (roots, leaves, fruits, etc.) to be harvested and should specify collection levels and collection practices. It is incumbent on the government or environmental authority to ensure control of medicinal plant harvesting that collectors of plant material do not place the collected species at risk.

Medicinal plant materials should be collected during the most suitable season or time period to ensure the best possible quality of both source materials and finished products.

Only ecologically non-destructive and non-contaminated plant communities for medicinal plant collection should be employed. These will vary widely at different species and plant organs. For example, when collecting roots of trees and bushes, the main roots should not be cut or dug up, and severing the taproot of trees and bushes should be avoided. Only some of the lateral roots should be collected.

When collecting species whose bark is the primary material to be used, the tree should not be girdled or completely stripped of its bark; longitudinal strips of bark along one side of the tree should be cut and collected.

Medicinal plants should not be collected in or near areas where high levels of pesticides, heavy metals or other possible toxic contaminants are used or found, such as roadsides, drainage ditches, mine tailings, garbage dumps and industrial facilities which may produce toxic emissions. In addition, the collection of medicinal plants in and around active pastures, including riverbanks downstream from pastures, should be avoided in order that avoid microbial contamination from animal waste.

In the course of harvesting, efforts should be made to remove parts of the plant that are not required and foreign matter, in particular toxic inclusions. The inconsistent with requirements medicinal plant materials should be discarded.

The collected raw medicinal plant materials should not come into direct contact with the soil. If underground parts (such as the roots) are used, any soil rom the plants as high as possible should be removed fatter collection. Harvested material should be placed in clean baskets, mesh bags, other well aerated containers or drop cloths that are free from foreign matter, including plant remnants from previous collecting activities. After collection, the raw medicinal plant materials may be subjected to appropriate preliminary processing as soon as possible, including elimination of undesirable materials and contaminants, washing (to remove excess soil), sorting and cutting. The collected medicinal plant materials should be protected from insects, rodents and other pests, and from toxic agents.

To the extent that the collection site is located some distance from processing facilities, it may be necessary to air or sun-dry the raw medicinal plant materials prior to transport. If more than one medicinal plant part is to be collected, the different plant species or plant materials should be gathered separately and transported in separate

packing containers. Cross-contamination should be avoided at all times.

Collecting instruments, such as sickles, shears, saws and mechanical tools, should be kept clean and maintained in proper condition. Those parts that come into direct contact with the collected medicinal plant materials should be free from excess oil and other contamination.

Requirements for primary processing

Primary processing includes washing, cutting before drying, fumigation, freezing, distillation, drying *etc.* All these processes should be carried out in accordance with regional and / or national regulations (if applicable) and implemented as soon as possible after collection.

On arrival to the places of primary processing, medicinal plants / plant raw material should be quickly unloaded and unpacked. It is essential that prior to processing, the material was not exposed to direct sunlight, except when this is necessary on purpose; it must be protected from rain, insect infestation etc.

When drying outdoors, medicinal plants / plant raw material should be spread in a thin layer. To ensure adequate air circulation, drying frames should be placed at a sufficient distance from the floor. Avoid drying directly on the floor or in direct sunlight, except when it is necessary.

Except in the case of open air drying, other drying conditions, such as temperature, duration, air circulation etc., should be selected taking into account the characteristics of used parts of medicinal plants such as roots, leaves or flowers, and the nature of their active ingredients such as essential oils. The conditions for each case should be documented in detail.

Requirements for packaging

After the treatment, which must be accompanied with control over the production process, the products must be packed in clean, dry and preferably new bags, sacks or boxes. Labels must be clear, firmly attached and made of non-toxic material. The information indicated on them has to match the regional and / or national regulatory requirements for labeling.

Reusable packaging material requires a good cleaning and should be thoroughly dried before use. It should be stored in a clean and dry place, protected from pests and inaccessible to livestock and pets. It should be ensured that while using packaging materials, especially fiber bags, there is absolutely no pollution (contamination) of products.

Requirements for storage and transportation

Packaged dried herbs / plant raw material should be stored in dry, well ventilated area where daily temperature fluctuations are limited and proper ventilation is ensured. Organically grown medicinal plant materials should be stored and transported separately or in a manner that ensures their quality. Appropriate security measures should be applied to the storage and transport of medicinal plant materials that are potentially toxic or poisonous [56].

Fresh products should be stored at a temperature of 1 °C to 5 °C and frozen products – at temperatures below –18 °C (or below –20 °C for prolonged storage).

Fumigation against pest can be performed only when needed; it is performed exclusively by personnel who have the appropriate license or permit to conduct such activity. Use only registered chemicals. Any fumigation against pest must be recorded in the documents. When freezing or using saturated steam as agents against pests after treatment, is necessary to control the moisture content of the material.

CHAPTER 5

HERBS AND HERBAL REMEDIES WITHIN THE UKRAINIAN PHARMACEUTICAL MARKET

5.1. Regulation of the processing of herbal substances and preparations of herbal remedies in the world

According to the data of WHO, preparations based on medicinal herbs are used by 80 % of the world population. Use of medicinal plants to the medicinal purposes has a long tradition in Europe, while in some parts of the world (e.g., China and India), herbal remedies still represent a central link in the chain of health services [35].

Biologically active components of herbal medicines and herbal preparations are extremely complex multi-component mixtures, as opposed to synthetic drugs that are most commonly a single pure compound. In the production of herbal remedies or drugs, certain actions and procedures are needed to be undertaken (collecting medicinal plants from

wild flora and plantation cultivation, obtaining extractive isolates, and their characterization), which do not precede the production of synthetic drugs.

At the present time, the procedures of making herbal medicines are largely modernized and defined in all segments. There are a number of guidelines that prescribe standards in all aspects of making herbal medicines: The European Medicines Agency standards for the quality of herbal medicines, the WHO guidelines provide standards and guidelines for good agricultural practices, good laboratory practices, and so on. The development of new, sophisticated analytical and technological methods and procedures within the development and characterization of biologically-active agents has greatly improved the quality of the final plant products. The process of standardization of the quality system for the production and herbal drugs control is present in many countries. But globally, more effort is yet to be made in order to revive the prescribed guidelines and regulations in practice [30].

The main goal of the Committee for herbal products (Herbal Medicinal Product Committee–HPMC) is to prepare a detailed list of monographs and processed herbal substances and preparations, which are in medical use for long enough time that their use is safe under any conditions. The monograph contains the professional opinion of the Committee on a particular plant products based on the scientific data or detail information on traditional use within the European Union (EU). For each plant, the substances are stated indications, speed, usage, and other relevant characteristics concerning its safe use or composition that contains it. List and some versions of monographs are available for public discussion [24].

In European companies can apply for three different types of market authorization of herbal medicinal products (HMPs):

– Full implementation. Manufacturer of a herbal drug must provide documentation proving its efficiency and safety, and studies are identical to those submitted for the registration of a synthetic drug.

– Well-established use. Manufacturer of a herbal drug may be permitted to register, on the basis of the submitted detailed scientific information, stating that the herbal medicinal preparation is in use for medical purposes not less than 10 years in Europe and has recognized efficiency and an acceptable level of safety.

– Traditional use. Efficiency and safety of an herbal drug can be accepted on the basis of full characteristic and long experience of use. Herbal remedies can be registered, if the documents prove their use in mitigating certain diseases, not less than 30 years, with at least 15 years in Europe.

The registration procedure for herbal medicines and drugs, at all levels of the European Union (EU), is done according to European Directive 2004/24/EC, which introduces simplified, but strictly defined procedures and affects the harmonization of existing national legislative regulations and standards. Regarding the registration in the non-EU countries, despite the efforts made within the framework of national legislation and harmonization in larger systems, a limited number of herbal medicines have been registered. Therefore, the identification of problems and discrepancies and the systematic plan for overcoming them represent a major challenge for the presence of these herbal medicines and drugs on the market of EU countries [45].

For example, in Republic of Serbia, legislation on plant products is harmonized with recommendations of The European Directive 2004/24/EC. Law on medicines and medical devices (Official Gazette of the Republic of Serbia No. 30/2010), Regulation on health safety of dietary products (Official Gazette of RS No. 45/2010), Guidelines

of Good Manufacturing Practice, Annex 7 – Manufacture of herbal medicines, are effectively used for regulation of produce of herbal remedies and drugs. According to the Law on medicines and medical devices, Herbal medicine, is each drug whose active ingredients are exclusively one or more substances of vegetable origin or one or more herbal preparations, or one or more substances of vegetable origin in combination with one or more herbal active ingredients.

Traditional herbal medicine may be based on scientific principles and is the result of tradition or other traditional long -term therapeutic approaches. The active components of an herbal medicine/ traditional herbal medicine are herbal drugs, herbal remedies or their combinations, and this is widely accepted in all European and national documents. In the context of food supplements (dietary supplements), a new the Regulation defines the notion of herbal dietary supplements. These are supplements that contain active pharmaceutical ingredient from medicinal plants, their parts or preparations and their quantity in a daily dose of the product should not be less than 15 % and greater than 65 % compared to a known therapeutic dose of these plant materials or preparations [49].

5.2. Medicinal plants of Ukraine in domestic herbal remedies

The collected survey data of the pharmaceutical market of Ukraine in recent years shows its steady annual growth of about 15–20 %. Thus, the volume of the pharmaceutical market here in 2013 reached 36 billion UAH in selling prices, which is 14 % more than the previous year. Over 65 % of this amount occupies the lot size of Ukrainian products [20]. The reason of the high demand for domestically produced

pharmaceuticals is their relatively low cost. Ukrainian manufacturers develop analogues of imported remedies actively and can offer their customers a lower price. However, there has not been a possibility to cover market needs completely, since occur some market segments, where the developments of domestic operators do not allow offering a complete alternative to the consumer.

According to the State Register of Drugs of Ukraine [9], in the last 5 years, around a thousand of herbal remedies from plant materials of medicinal herbs or those comprising biologically active compounds from plants have been registered. Out of these, 735 items are preparations of domestic production, 487 – of foreign one (imported). The structure of these remedies includes plant materials or active ingredients from raw material of 351 species of medicinal plants for allopathic and homeopathic medicines. 116 species among this number are growing wild in Ukraine, although some of them are grown for raw materials or imported to ensure their increased demand (Appendix, Table 9).

Processing of medicinal plants and herbal medicines production is concentrated in Kyiv, Kharkiv and Zhytomyr regions (Table 9).

The company «Liktravy» is the undisputed leader of the Ukrainian market of phytopreparations. They collect medicinal plant raw materials in ecologically clean regions of Ukraine and foreign countries. The company «Liktravy» operates a system of multi-stage quality control of products, which includes verification of incoming plant material, control at intermediate stages and control of finished products. The modern laboratory of the enterprise allows carrying out tests on all indicators of quality and safety of medicinal plant raw materials in accordance with the requirements of the State Pharmacopoeia of Ukraine and other normative acts. Considerable attention is paid to the control of the medicinal plant raw material entering the production, the presence

of radionuclides, cesium-137 and strontium-90, as well as the content of heavy metals - lead, cadmium, mercury, and arsenic. Today in the company «LKTRAVY» there is a quality system that ensures the production of the highest quality products on the market that meets all the requirements of Good Manufacturing Practice (GMP) for medicinal products of plant origin.

The important centres of production of phytopharmaceuticals comprise also Public Joint Stock Company «Galychpharm» (Lviv); Private JSC Pharmaceutical factory «Viola» (Zaporizhzhya); Public JSC «Lubnyfarm», Private JSC «National Homoeopathic Union» (Lubny, Poltava region), «Sumyfitofarmacia» Ltd. (Sumy), Public JSC «Biolik» (Ladyzhyn, Vinnitsa region), «Fitolik» Ltd. (Ivano-Frankivsk), «Ternofarm» LLC (Ternopil), Public JSC «Liky Kirovohradshchyny» (Kropyvnytsky), «Avetra» Ltd. (Uzhgorod), Public JSC «Vitamins» (Uman, Cherkasy region) and others.

The oldest company «Lubnyfarm» was founded in 1932 – at that time it was a factory for the processing of medicinal plants. A modern company is a pharmaceutical enterprise, the main activity of which is the development and production of medicines for external and internal use.

Table 9

The main centres of medicinal plants' processing and production of herbal medicines in Ukraine

Location	Name of the company
Zhytomyr	Private JSC «Liktravy», «SCC Pharmaceutical Factory» Ltd.
Kharkiv	"Search plant "DNCLZ" Ltd, "Pharmaceutical company "Zdorovya" Ltd., "Scientific and production pharmaceutical company "Eym», JSC «Stoma», Public JSC «Chemico-pharmaceutical plant "Chervona Zirka", JSC "Lekhim-Kharkiv"

Kyiv	Public JSC "Kyivmedpreparat", Public JSC "Research and production center "Borshchahivskiy chemical and pharmaceutical Plant", Community company of Kyiv Regional Council "Pharmaceutical Factory", Public JSC "Kyiv Vitamin Plant", Public JSC "Farmak", «State Experimental Plant of Medicines of the Institute of Bioorganic Chemistry and Petrol Chemistry of the National Academy of Sciences of Ukraine», Scientific and production company "Ecomed»
Kyiv region	Private JSC "Biofarma" (Bila Tserkva), "Valartin farma" Ltd. (Chaika), "Astrafarm" Ltd. (Vyshneve), "Agropharm" Ltd. (Irpin)

The raw material of valerian (*Valeriana officinalis*) is the most tradable among Ukrainian wild herbs for the production of herbal remedies, a constituent of 67 medicinal remedies of domestic origin and 23 – foreign origin (Appendix, Table 9). Wild raw material of valerian is not commonly used in Ukraine, as *V. officinalis* have limited natural resources. A number of farms cultivated the valerian for raw materials in Ukraine.

Among medicinal plants which have large resources in Ukraine and their active ingredients are the components of many herbal remedies, are follows: *Leonurus cardiaca* (constituent of 76 remedies), *Mentha piperita* (72), *Valeriana officinalis* (67), Crataegus monogyna (numerous species) (58), *Calendula officinalis* (53), *Humulus lupulus* (55) (Table 10).

Many species and varieties are cultivated in specialized farms in Ukraine so as to ensure a stable resource base for several species of wild medicinal plants with limited natural resources are (*Chamomila recutita, Leonurus quinquelobatus*, and *Althaea officinalis*) and raw of some of these are imported

from other countries (Table 12). As sources of herbal remedies are widely used cultivated material of *Humulus lupulus* (55 remedies) and *Glycyrrhiza glabra* (34 ones) (Appendix, Table 9). Liquorice is listed as endangered species in Ukraine; its cultivation is limited because demand for its raw material is met mainly by imports from countries of Central Asia. For production of many homeopathic herbal remedies use cultivated domestically or imported raw material of rare species (as *Atropa belladonna, Rhodiola rosea*) (Appendix, Table 9).

Rhizomes of Acorus calamus harvested in Ukraine only from wild for the production of 23 herbal medicines (Rhizomata Calami; Phytodentum, Bronhophytum, Gastrophytum, Detoxiphytum, Immunophytum, Prostato-phytum, Ginekophytum, Balm Vigor, Vikalinum, Vikayirum, Fitomiks-12, Alloton, Dental-phyto etc.) because it is difficult to create conditions for its cultivation. Resources of *Acorus calamus* suffer from draining of floodplains in Polissia lowlands and steppe regions of Ukraine; therefore, in most administrative areas collection of calamus rhizomes is prohibited. There is a need to find alternative sources of raw materials.

Many herbal remedies are registered on the pharmaceutical market of Ukraine, with active ingredients of *Achillea millefolium* (25), *Equisetum arvense* (25), *Rosa canina* (21), *Betula pendula* (20), *Thymus serpyllum* (20), *Urtica dioica* (19), *Chelidonium majus* (19), *Origanum vulgare* (14), *Artemisia absinthium* (13) (Appendix, Table 9). These are the promising raw plant species that have large quantity of natural resources in Ukraine.

Some species of medicinal plants have large resource potential in Ukraine, but have not in great demand in

medicines, as: *Quercus robur* – 10 phytopharmaceuticals, *Tussilago farfara* – 10, *Plantago major* – 9, *Frangula alnus* – 8, *Daucus carota* – 8, *Calamagrostis epigeios* – 8, *Capsella bursa-pastoris* – 7, *Solidago virgaurea* – 7, *Taraxacum officinale* – 6 ones and others (Appendix, Table 9).

Currently at the pharmaceutical market of Ukraine new phytomedicines from medicinal plants, the raw materials of which have not been used until current time or had a limited application in official medicine are appeared. For example, Proteflazidum, Flavozidum, Immunoflazidum, Protfenolozidum with active compounds of *Deschampsia caespitosa* and *Calamagrostis epigeios*; Tribestan, containing as an active component the dry extract of *Tribulus terrestris* herb; Tazalok, which contain *Filipendula vulgaris, Galium verum, Linaria vulgaris* and some others.

For production of phytopharmaceuticals traditionally in Ukraine are applied materials from entirely cultivated medicinal plants, such as: *Mentha piperita* leaves (72 remedies), *Calendula officinalis* flowers (53), *Echinacea purpurea* roots (20), *Salvia officinalis* (17), *Melissa officinalis* leaves (15), *Levisticum officinale* leaves (11). Somewhat less in the medicines are presented *Ammi visnaga, Anetum graveolens, Coriandrum sativum, Silybum marianum, Zea mays* (under 9 remedies of each) and others.

Relatively small number of medicines contains biologically active compounds from *Alnus glutinosa, Hippophae rhamnoides, Sorbus aucuparia, Pinus sylvestris, Vaccinium myrtillus* (there or thereabout 4 remedies of each), the resources of which are large in wild.

Table 10

Medicinal plants of Ukraine with large wild resources in different herbal remedies

Engl. name of the species	**Latin name of the species**	**Medicinal plant material**	**Medicines**
1	2	3	4
Motherwort	*Leonurus quinquelobatus*	herb	Likson; Motherwort tincture; Sedafloks; Motherwort herb; Fitosed; Sedaflor; Detoxiphytum; Cratalum; Prostatophytum; Sedafiton; A-diston; Cratal for children; Motherwort thick extract; Florysed-Zdorovya; Pechajivski validol-natur; Sedative tea - dry extract; Cardiovascular tea; Sedative herbal species № 2; Trykardyn cardiac drops; Cardiophytum; Cardiopasyt
Hawthorn (different species)	*Crataegus spp.*	fruits, flowers, leaves	Sedafloks; Fitulvent phyto balm; Hawthorn tincture; Fitosedum; Sedoflor; Healing-prophylactic tea; Cratalum; Neokardyl; Sedafiton; Hawthorn leaves and flowers; Fitomiks-12; Hawthorn fruit; A-Diston; Sedavit liquid extract; Cratalum for children; Pechajivski validol-natur; Cardiovascular tea; Trykardyn cardiac drops; Cardiophytum; Sedavit thick extract; Cardiopasyt

1	2	3	4
Yarrow	*Achillea millefolium*	herb, flowers	Gastrofloks; Fitulvent phyto balm; Cholagogue tea; Rotocanum; Healing prophylactic tea; Detoxiphytum; Gynekophytum; Vigor balm; Yarrow herb; Vundehil; Gastric tea; Ugrynum; Fitokan
St. John's wort	*Hypericum perforatum*	herb	Prostalad; Beroz; Sedafloks; Gastrofloks; Immunotone; Fitulvent phyto balm; St. John's wort herb; Urofloks; Phytolytum; St. John's wort dry extract; Healing-prophylactic tea; Detoxiphytum; Gynekophytum; St. John's wort tincture; Gastric tea; Uroholum; St. John's wort liquid extract; Sedavit liquid extract; Sedavit thick extract
Stinging nettle	*Urtica dioica*	leaves, roots	Nettle leaves; Allocholum; Phytodentum; Bronhophytum; Hepatophytum; Healing-prophylactic tea; Gastrophytum; Prostatophytum; Antiallergic herbal species; Cardiophytum; Alloton; Nettle leaves grounded
Plantain	*Plantago major*	leaves	Bronhofloks; Tea pectorales № 2; Nephrophytum; Healing- prophylactic tea; Plantain juice; Plantain leaves; Expectorant tea; Broncholytic tea; Antiallergic tea

Horsetail	*Equisetum arvense*	herb	Horsetail herb; Urofloks; Fitourolit; Horsetail dry extract; Nephrophytum; Uronefron; Detoxiphytum; Fitolizyn plus; Arphasetinum; Uroholum; Diuretic herbal species; Liquid extract (1: 2,8) of medicinal plant materials
Rose (number of species)	*Rosa spp.*	fruits	Fitofloks; Phytodentum; Hepatophytum; Healing- prophylactic tea; Gastrophytum; Detoxiphytum; Immunophytum; Arphasetinum; Rose fruits; Fitomiks-12; Vitaminic herbal species № 2; Rosehip oil; Rosehip liquid extract; Cholosasum
Elderberry	*Sambucus nigra*	flowers	Bronhofloks; Sedafloks; Urofloks; Fitofloks; Bronkhofit; Anhinofit; Healing prophylactic species № 2; Gastrophytum;Elderberry flowers; Species pectorales; Broncholytic tea; Uroholum; Antiallergic tea; Diuretic tea; Cardiophytum; Cerebrum compositum
Source: State Register of Drugs of Ukraine [9]			

5.3. Import of medicinal plants and herbal remedies in Ukraine

The current pharmaceutical market of Ukraine presents remedies from medicinal plants (or containing them as ingredients) from more than 30 countries. About 83% of remedies come from Europe (Table 11). The main foreign suppliers whose products are represented on the Ukrainian market are Germany, Austria and India (Fig. 6).

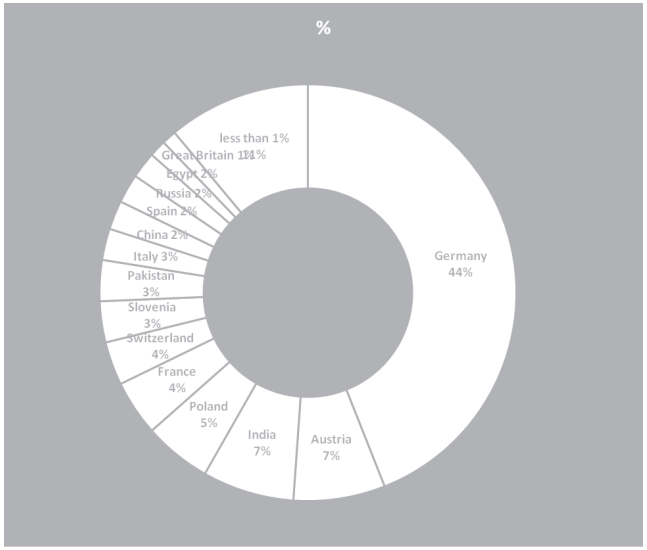


Figure 6. Distribution of imported into Ukraine of herbal remedies amongst major exporting countries

Among the main exporting companies that provide pharmaceutical products to Ukraine are: Dr. Willmar Schwabe GmbH & Co.KG, Bionorica CE, Dr. Theiss Naturwaren GmbH, Deutsche Homöopathie-Union DHU-Arzneimittel GmbH & Co. KG (Germany); Bittner Richard AG, Fresenius Kabi GmbH (Austria), Herbar Paweł Baryła,

Poznan Plant of Medicinal Herbs Herbapol S.A., «Herbapol Wrocław S.A., «Fruktus bis» (Poland); Orchid International, Himalaya Drug Co., Unic Pharmaceuticals Laboratories, Indo World Trading Corporation (India).

Table 11

Differentiation of imported into Ukraine herbal remedies from supplying countries *

Exporting Countries	Amount of remedies
Germany	235
Austria	38
India	38
Poland	28
France	23
Switzerland	18
Slovenia	17
Pakistan	17
Italy	13
China	12
Spain	12
Russian Federation	11
Egypt	7
Great Britain	6
Bulgaria	5
Australia	5
Czech Republic	5
Hungury	5
USA	4
Republic of Slovakia	
Georgia	4

Latvia	4
Netherlands	3
Belgien	3
Thailand	2
Canada	2
Vietnam	2
Lithuania	2
Romania	2
Republic of Kazakhstan	1
Republic of Uzbekistan	1
Turkey	1
Sweden	1
Corea	1
Estonia	1
Ireland	1

* Note: According to the State Register of drugs of Ukraine [9]

There is a territorial differentiation regarding the variety of raw materials and components of medicinal herbal remedies that are supplied to Ukraine. Thus, a number of European countries supplies substances for the production of non-sterile dosage forms of medicinal plants that are naturally grow and cultivated in Ukraine. For example, marshmallow roots and herb, St. John's wort herb, horse chestnut seeds, plantain leaf, chamomile flower, thistle seeds *etc.* In Ukraine there are also considerable resources of these species, but the quality of their raw materials often do not meet the requirements of modern pharmaceutical market. In addition, advanced technologies of cultivation of medicinal plants are actively introduced in Europe, thereby increasing the quality and reducing the cost of raw materials. Therefore, at this stage it is economically advantageous to import these

raw materials from other countries, than to cultivate them in Ukraine.

In order to provide the pharmaceutical industry by high quality raw materials, Ukraine imports medicinal plant raw materials from different countries, where there are optimal conditions for the accumulation of biologically active substances in these plant species (Table 12).

Table 12

Medicinal plants, raw material of which are imported into Ukraine in large volume

Herbal substance	Exporting countries
Eucalýptus viminális, leaves	Georgia, Indonesia
Aerva lanata, herb	Georgia, India
Laminaria spp., thallus	China
Cassia acutifolia, leaves	India
Eleutherocuccus senticosus, roots	China
Orthosiphon aristatus, leaves	Indonesia
Stevia rebaudiana, leaves	China
Ginkgo biloba, leaves	China
Glycyrrhiza glabra, roots	Uzbekistan
Inula helenium, roots and rhizomes	China
Arctostaphylos uva-ursi, leaves	Russia
Vaccinium vitis-idaea, leaves	Egypt
Hibiscus sabdariffa, calyces	Poland, Egypt
Matricaria recutita (syn. Chamomilla recutita), flowers	Egypt
Caléndula officinális, flowers	Egypt
Crataegus spp., leaves and flowers	Bulgaria

Ukraine imports from Europe a number of modern medicines (including homeopathic), which include less

known plant species such as *Consolida regalis, Filipendula ulmaria, Eupatorium cannabinum, Euphrasia spp., Phytolacca americana, Solanum nigrum, Solanum dulcamara etc.* It is, therefore, important to investigate stocks of these species to provide a resource base for development of domestic phytopharmaceuticals.

Most European herbal remedies that are present in the pharmaceutical market of Ukraine, include well-known medicinal plants. For example, Germany provides the state with drugs to treat respiratory diseases, which include biologically active compounds of *Althaea officinalis, Thymus* spp., *Atropa belladonna, Cetraria islandica, Hedera helix*; remedies of anti-inflammatory action – *Salvia officinalis, Chamomilla recutita, Calendula officinalis, Gentiana lutea, Primula veris, Verbena officinalis, Sambusus nigra* and others. The resources of most of these species available in Ukraine, therefore, domestic pharmacy has great developmental prospects.

Within the Ukrainian market are popular German injection solutions containing biologically active compounds from *Vincetoxicum hirundinaria, Veratrum album, Veronica officinalis, Pinus sylvestris, Gentiana lutea, Equisetum hyemale, Lycopodium clavatum, Pulsatilla pratensis, Melilotus officinalis, Solanum nigrum.* A number of companies (Biologische Heilmittel Heel GmbH, Dr. Theiss Naturwaren GmbH, Engelhard Arzneimittel GmbH & Co. KG) supply remedies, produced from *Galium aparine, Galium mollugo, Sedum acre, Sempervivum tectorum, Clematis recta, Caltha palustris, Saponaria officinalis* and others. These species of medicinal plants that grow in Ukraine have sufficient resources and are quite promising for pharmacognostic research to develop national medicines.

South-East Asia and Australia supply into Ukraine raw materials and drugs, made from medicinal plants, whose

resource potential is absent in the country: *Gingko biloba*, species of the Orchidaceae family, *Eucalyptus viminalis, Senna spp., Stevia rebaudiana, Orthosiphon aristatus, Eleutherococcus senticosus, Laminaria spp., Aerva lanata, Panax ginseng, Cinchona* spp., *Glycyrrhiza glabra, Zingiber officinalis, Capparis spinosa* and other species that are grown naturally in these regions or if there are favourable conditions for their growth. Balms from India, China, and Vietnam are also popular in the pharmaceutical market of Ukraine. They comprise essential oils of peppermint, camphor, basil, clove, cinnamon, eucalyptus etc. This region also actively uses biologically active compounds, extracted from mushrooms for pharmaceuticals; the most famous among them are shiitake and reishi mushrooms, which are being actively investigated in Ukraine. The main supplier of *Hibiscus sabdariffa* (karkade) calyces to Ukraine is Egypt, where there are favourable conditions for its cultivation.

The main trend of the phytopharmaceutical market development at the international level is aimed at finding sources of medicinal plants, working out of complex herbal remedies of direct effect and reduction of the cost of the final product. Most developed countries are actively engaged in re-exporting the cheaper medicinal plants, which contributes to the development of the industry.

5.4. The world market of medicinal and aromatic plants

Markets for herbal medicines in developed countries – especially in Europe, Canada and the United States are highly regulated and very difficult to penetrate, particularly for developing countries and countries whose materials have not undergone the stringent tests required by

developed country pharmaceutical manufacturers before mass production. Therefore, the developed countries tend to import unprocessed or slightly processed materials from countries with developing economy. As the case of India, around 80 percent is export of raw materials including dried plants, extracts and isolated ingredients. The export of finished medicinal products, mostly homoeopathic and Ayurveda medicines, accounts for the remaining about 20 percent.

A number of developing countries with a long tradition of use of medicinal plants are major exporting countries – China, the Republic of Korea, Chile, India, Brazil and Thailand, for example. Exports are predominantly in raw material form and only to a lesser extent finished products and herbal remedies. With their large populations, diversity of medicinal plants and ancient heritage of traditional herbal-based medicines, China and India are two of the world's largest markets for medicinal plants, though not necessarily the largest traders. Nearly 30 percent of the medicinal and aromatic plants global trade is made up by top two countries of the import and export. China and India from Asia; Egypt and Morocco from Africa; Poland, Bulgaria and Albania from Europe; Chile and Peru from South America are important supply sources. The U.S., Japan and Europe are the major consumers of the world [46]. Liquorice roots, Ginseng roots and Tragacanth are among the top of medicinal and aromatic plants traded items.

The demand for raw medicinal and aromatic plants in developed countries is gradually increasing, which serves as an incentive to trade on the local, regional, national and international levels. The world market for medicinal and aromatic plants currently provides about 83,000 million dollars. Depending on the segment, the growth is constant, ranging from 3 % to 12 %. Distribution of sales turnover

between different areas of using plant products is complex, since the use of raw materials and some of the species can be carried out simultaneously for different purposes (medical, food, cosmetic etc.).

In Europe, the market of herbs and spices has increased from 265 000 tones in 2003 to 321 000 tones in 2007, representing an average annual increase of 5 %. It is estimated that Europe imports about 400 tones of medicinal plants annually from Africa and Asia, with an average market value of 1 billion USD.

The main consumers of raw aromatic and medicinal plants are Germany, which uses 19 % from the total consumption of raw materials in the EU, Great Britain (16 %), Romania (14 %) and Hungary (12 %). Regarding the use of essential oils, the European imports have increased between 2004 and 2008 by 6.3 % in terms of value. The main importers of essential oils and oleoresins are France (26 % of total EU imports), United Kingdom (19 %), Germany (19 %), the Netherlands (9.2 %), Spain (6.8 %) and Italy (4,3 %).

Germany is currently the leading country of import and export of medicinal and aromatic plant materials in Europe. Their annual import averagely exceeds one third of the total volume and value of imported raw materials in Europe. Import from Germany, Eastern and South-Eastern Europe is six times higher than from France or Italy, and ten times higher than from Spain [31].

German export constitutes approximately one fifth of the total European export and one third in value numbers. Germany exports herbs to central, western and south-western European countries, so it is a key country in intra-European trade, which acts as a link between different regions in Europe.

Apart from Germany, the countries with dominant import of medicinal plants' raw materials (countries-consumers) include France, Italy, UK, Spain, Switzerland and Belgium / Luxemburg. Exporting countries (exports prevail over imports – producing countries) include Bulgaria, Hungary, Poland, Turkey, Czech Republic, Croatia and Romania. Within Europe the medical and aromatic plants' trading is very large; its volume constitutes about 40 % of the European import and 80 % of its export.

Iran is home to a great variety of medicinal plants, and is ranked third among 12 mega – diversity countries of the world. Medicinal plants as a group comprise approximately 8,000 species and account for around 50 % of all higher flowering plant species of Iran. Iran is designated as one of the global biodiversity hotspots, where ecological, phyto-geographical and evolutionary factors favor high species diversity. A bio-geographically unique region, it has the maximum degree of endemism in the Asian region – it supports about 18,440 species of plants, of which 25.3 % are endemic to the region, and has a large repository of medicinal plant species.

Medicinal and aromatic plants (MAPs) are traded both as raw materials and as processed final products. Demand for a wide variety of species is increasing as these markets expand and new end-uses are developed. The price trends of most of Iranian species of medicinal plants traded in market have been upwards in the last 3 years. However, about 90% of medicinal plants used by the industries are collected from the wild. While over 950 species are used in the industry, less than 20 species of plants are under commercial cultivation.

In international trade, it is usually impossible to select a plant material, which is intended solely for herbal medicine and pharmacy, as raw materials of many species of herbs are simultaneously used for different purposes. For example, chamomile (*Chamomilla recutita*) flowers, rosella (*Hibiscus*

sabdariffa) calyces can be used to produce food additives (teas), pharmaceutical products (tinctures, ointments, herbal collections) in cosmetics (shampoos, conditioners, creams) as detergents etc. A range of liquorice species – *Glycyrrhiza* spp. – is widely used as an expectorant and anti-inflammatory agent, as an ingredient in manufacturing candy, cigarette paper and even fire extinguishers. This variety of uses for various plant species is reflected in international trade, concerning differentiation of the purpose of raw materials stock. Most raw materials of medicinal plants within international trade are also represented in the food and perfume.

The global value of plant material in international trade is immense and increases every year. The majority of plant resources are still withdrawn from the environment. This is a threat to many other valuable species. From 1200–1300 species of medicinal plants exposed on the open market in Europe, 900–1200 species (70–90 %) were collected from their natural habitat. In terms of turnover, wild-grown medicinal herbs comprise here about 50–70 %.

There are several reasons why trade of wild plant material at the international level is a threat to their resources:

– Legislation that exists to control the collection and trade of medicinal plants is inadequate and ineffective in its current form; a new policy and simpler mechanisms are required to monitor the trade;

– Lack of awareness among the public concerning threats to the resources of plant species and their conservation needs; wild growing collected materials are used;

– International trade organizations are not interested in receiving information on the status of resources of plant species, which are under threat of extinction;

– Low price of wild plant material contributed to the reduction of demand for cultivated raw materials, whose cost is higher than that of wild-grown ones as a result of the financial costs of caring for crops.

Therefore, the whole world enhances control over the use (including trade) of natural resources of economically important plant species (medicinal, edible, aromatic etc). International organizations are created to coordinate activities in this area; regulations are agreed on an international level and steps are taken to preserve rare species.

5.5. Quality standards of herbal substances and drug preparations

Globalization and increased international trade of medicines and raw materials contribute to the growing need of developing global standards for high-quality medicines. Any drugs manufactured and sold in Ukraine and in most countries are subjected to strict control for compliance with national and international standards of quality, efficiency and safety. The Convention on the Elaboration of a European Pharmacopoeia was signed in 1964. On the basis of this Convention, Europe began to implement unified quality standards. Ukraine joined to the Convention in 2012, and in March 2013 it became the thirty-eighths member of the European Pharmacopoeia. By ratifying the Convention, Ukrainian authorities confirmed the desire to participate in the development of European standards of high-quality medicines and strengthen cooperation with European countries in the area of pharmaceuticals, including standards for application of medicinal plant materials.

European Pharmacopoeia, therefore, provides for the quality of medicines and facilitates their free movement within Europe and outside it. In the Council of Europe this work is carried out by the European Directorate for the Quality of Medicines and HealthCare (EDQM). Currently, the European

Pharmacopoeia Commission involves 38 members: Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, the Republic of Macedonia, Turkey, Ukraine, United Kingdom and the European Union. EP is the official pharmacopoeia in these countries and the European Union. There may be additional Pharmacopoeia (both in the UK and Germany).

The sessions of the Commission of the European Pharmacopoeia also involve observers from 28 EU Member States, countries that are not members of the Council of Europe and international organizations, in particular – Albania, Algeria, Argentina, Armenia, Australia, Azerbaijan, Belarus, Brazil, Canada, China, Georgia, Israel, Madagascar, Malaysia, Morocco, Moldova, Guinea, Kazakhstan, the Republic of South Africa, Russian Federation, Senegal, Singapore, Syria, Tunisia, the Taiwan Food and Drug Administration (TFDA), the United States and the World Health Organization (WHO).

The European Pharmacopoeia is a set of quality standards outlined in monographs, which may be applied to all drugs [27]. They contain a detailed description of the quantitative and qualitative composition of medicines, necessary studies and requirements for raw materials to manufacture medicines and drugs. These requirements have a binding effect; their compliance is a prerequisite to receive a permission from the National or European regulatory authorities to sell medicines. The Pharmacopoeia comprises monographs describing a wide range of active substances and additives, as well as general chapter on biological substances, preparations based on medicinal plants, antibiotics, vaccines, the dosage forms and packaging.

Since 2001, Ukraine adopted the State Pharmacopoeia of Ukraine (SPU), which prescribed quality standards for all medicines and raw materials [5-8]. The SPU publication is based on the current editions of the European Pharmacopoeia. Appendices of SPU unit contain monographs on herbal drugs of nearly 124 species of medicinal plants in Ukraine and worldwide. Out of them, 57 species (including 5 species of algae) do not grow in Ukraine. Their materials or substances are imported from around the world. For example: *Thymus zygis* often occurs in Southern Europe (Spain, Portugal); *Origanum onites* (Greece, Turkey, Sicily); *Syzygium aromaticum* (clove tree of the Myrtle family) grows in Malaysia and Indonesia; *Cymbopogon winterianus* (lemongrass, citronella grass) is cultivated in India, Bangladesh, Burma, Egypt; *Hibiscus sabdariffa* (rosella, karkade) originates from India, and now is common in many tropical countries. The first two species have botanically related ones with significant natural resources in Ukraine (*Thymus serpyllum, Origanum vulgare*) and are included in the SPU. *Origanum vulgare* is also grown for raw materials. Brown algae (*Ascophyllum nodosum, Fucus vesiculosus, F. serratus, Laminaria japonica, L. saccharina*) are common in the northern seas of the Atlantic and Pacific Oceans.

The SPU also presents a number of species of the *Crataegus* genera, which do not grow naturally in Ukraine (*Crataegus azarolus, C. nigra, C. korolkowii, C. chlorocarpa, C.dahurica, C. alemanniensis, C. orientobaltica etc*), though they may be introduced or cultivated as ornamental plants. It also contains monographs on three species, listed in the Red Data Book of Ukraine (*Glycyrrhiza glabra, Gentiana lutea and Atropa belladonna*). They naturally grow in Ukraine, but it is forbidden to collect them, so their raw materials are mainly imported (Table 12) or grown in specialized farms.

CHAPTER 6

INTERNATIONAL POLICY AND REGULATIONS THE USE OF THE MEDICINAL PLANT RESOURCES

International cooperation in the area of environmental protection is carried out on a global (worldwide), regional (e.g., European, Pan American, Pacific etc) and national (state) levels.

The content of international activities in the area of conservation and sustainable use of resources of flora, including resources of medicinal plants, is being developed in the following directions:

– international protection of rare plant species;

– establishment of efficient and environmentally sustainable mode of utilization of natural plant resources on the national and international levels;

– regulation of international trade by plants (including their raw materials).

Threats to the resources of medicinal and aromatic plants in the world include:

– Excessive exploitation of natural resources;

– Destructive methods of harvesting and land uses;
– Violation of the ecological balance and loss of habitat species (mainly as a result of excessive anthropogenic transformation of habitats over the past 100–200 years).

Growing diversity and volume of international trade in raw materials of wild medicinal plants also threatens their resources, especially in developing countries.

Considering the seriousness of this problem, the environmental legislation to regulate the use and trade by wild plants raw materials at international and national levels is now being actively developed. Legal instruments, regulations, assessment criteria and lists of rare species are elaborated and implemented.

6.1. International protection of rare plant species

In 1963 International Union for Conservation of Nature and Natural Recourses (IUCN) initiated the establishment of the International Red List of endangered species.

Currently, the International Red List of IUCN is a voluminous electronic database (due to the characteristics and volume of keeping the list, there is no modern paper counterpart), access to which is open to everyone online (http: //www.iucnredlist .org). It is possible to read information on the website concerning the status and condition of type (subtype), as well as review the definitions and categories of IUCN criteria.

Assessment (and reassessment) of taxon status is held on a regular basis, mostly at intervals of several years, the

last «full-scale» list review took place in 2013. The process of registration and evaluation is performed by groups of experts, who are responsible for a taxonomic group or a geographic region.

The Red Data Book of IUCN and the IUCN Red List are recommendatory documents, not being juridical ones. At the same time, many countries use them in designing national Red Books, including the system of categories for species that must be protected, and methods of evaluation of their status.

6.2. Sources of international legislation in the field of regulating the use of medicinal plant resources

Among the international agreements, regulating international cooperation in the area of regulation of the plant resources' application, primary attention is devoted to general political agreements, separate chapters or articles which are dedicated to sustainable use and conservation of plants and their resources.

Ukraine joined the following **international legal instruments** that directly deal with or are related to the protection and sustainable use of resources of flora:
– Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1973);
– Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention, 1979);
– Convention on Biological Diversity (1992).

International cooperation in the field of international trade in rare and endangered plant species is made primarily on the basis of the Convention on International Trade in

Endangered Species of Wild Fauna and Flora (1973). CITES is an international governmental agreement, which was signed as a result of resolutions elaborated by the International Union for Conservation of Nature (IUCN), also known as the Washington Convention. It entered into force on July 1, 1975, and today its members are 175 countries (Ukraine has become a party to the Convention in 1992 as a successor of the USSR, which joined this document in 1976). The Convention adopted three Appendices. Appendix I contains a list of species that are endangered and their trade has adverse effects on their existence. Appendix II lists species that may be endangered if their trade is not strictly controlled. Appendix III lists species, the trade of which is necessary to control. The Convention establishes general rules for state regulation of trade in rare species of fauna and flora. These Appendices do not include species of medicinal plants, whose raw materials are officially taken from natural habitat in Ukraine, although many existing species of medicinal plants around the world are available.

Bern Convention on the Conservation of European Wildlife and Natural Habitats (ratified by the Verkhovna Rada of Ukraine on October, 29, 1996) aims at the protection of wild flora and fauna and their natural habitats, especially those species and habitats that require protection by cooperative effort of several states, as well as facilitation of such cooperation. Special attention is paid to endangered and vulnerable species.

Flora of Ukraine from the list of species in Appendix I of the Bern Convention comprises 64 species, 43 of which are listed in the Red Book of Ukraine (1996), including medicinal plants: *Colchicum fominii, Cyclamen hederifolium, Paeonia tenuifolia, Pulsatilla patens, Salvinia natans, Narcissus angustifolius, Trapa natans*, species of the Orchidaceae family.

The objectives of the Convention on Biological Diversity (CBD, 1992) is the conservation of biological diversity, sustainable use of its components and common obtaining benefits associated with the use of genetic resources on a fair and equal basis. Countries determine the components of biological diversity, taking measures for their conservation and sustainable use, estimating the activity values and minimizing adverse consequences, regulating the application of biotechnology, *etc.*

In 1993, in the city of Geneva, considering the fundamental provisions of these conventions, aimed at ensuring the sustainable use and conservation of natural resources of medicinal plants, 9 international organizations decided to establish an international non-governmental organization, called International Council for Medicinal and Aromatic Plants (ICMAP) in order to promote mutual understanding and cooperation between national and international organizations in the field of medicinal and aromatic plants in science, medicine and industry, to improve the exchange of information between them. The council coordinates and promotes collaboration between partners by providing a forum for mobilizing the ideas, actions, discussions, development of long-term concepts and measures in the field of education and training in all areas related to medicinal plants.

With the increasing demand for herbal drugs in the international market and the threat of depletion of natural resources of medicinal plants, Medicinal Plant Specialist Group (MPSG) of the International Union for Conservation of Nature (World Conservation Union) (IUCN), IUCN Canada, the German Federal Agency for Nature Conservation, TRAFFIK (the world trade monitoring group), WWF (World Wide Fund for Nature – promotion of education and

regulation of production and consumption, Germany), SIPPO (Swiss Import Promotion Programme) in 2008 proposed to found a non-governmental international organization «The International Standard for Sustainable Wild Collection of Medicinal and Aromatic Plants» (ISSC-MAP).

The basic principle of sustainable use is that biological resources should be collected within the capabilities of self-renewal.

The main purposes of ISSC-MAP are:

• to stop excessive exploitation;

• to stop the illegal collection and illegal trade of wild herbs;

• to promote a non-exhaustive collection of raw materials in the wild due to working out of an effective system, especially in developing countries.

Funded by the German Federal Ministry for Economic Cooperation and Development, the founders of the fund started the implementation of ISSC-MAP projects around the world through joint initiatives. They are currently operating in Brazil, Cambodia, India, Lesotho, Nepal, China, Bosnia and Herzegovina, as well as alternative financing source in Ukraine.

The main objectives of these projects are: detection of the diversity of useful plants, evaluation of measures relating to their conservation, promotion of knowledge on sustainable use, the involvement of resource users to their management, as well as other social and economic research.

These initiatives are aimed at combining rational use and conservation of medicinal plants (and other non-timber products) with further industrial exploitation of those resources.

6.3. Categories of the protection status of plant and fungi organisms (IUCN)

Categories, elaborated for the Red List of the International Union for Conservation of Nature – IUCN [52], which are not identical to the categories of the Red Data Book of Ukraine, are regarded to be basic for granting the conservation status to the species [20].

Entry to the IUCN Red List is realized according to the following categories:

Extinct (E) – there is no reasonable doubt that the last individual of a taxon has died within the world. In Ukraine, species are considered extinct if there is no information about their presence within the state in nature or culture.

Extinct in the Wild (EW) – when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. The same category is applied in Ukraine.

Species under threat of extinction in Ukraine are considered as the category of «**endangered**», but in terms of IUCN they are divided into the following two groups:

Critically endangered (CR) – are considered taxons to be facing an extremely high risk of extinction in the wild; in the near future, which is defined by the following characteristics: distribution of populations is limited to 10–100 km^2 and observation for 10 years or the lifetime of three generations of individuals suggests that the intensity of reduction comprises 80 % of populations. In Ukraine, at present, this category is combined with the next one as «**endangered**» species. Currently, the species of vascular herbs are absent within such category in Ukraine.

Endangered (EN) – for these taxons exists a high risk of extinction in nature in the near future, and extent of occurrence estimated to be within 500–5000 km^2 and observations, showing that during 10 years or the lifetime of three generations, the population size reduction reaches up to 50 %. In the Ukrainian version of the list it was revealed that their area of inhabitancy has decreased and conservation is unlikely without eliminating negative factors.

Vulnerable (VU) – are defined as taxons with high risk of extinction in nature in the future, since the total extent of occurrence estimated to be within 2000–20000 km^2 and observations show a decrease during 10 years or the lifetime of three generations of individuals up to 20 % from the number of populations. According to Ukrainian legislation, the category of «vulnerable» contains species that in the near future can be categorized as endangered if the negative factors will have an impact on their populations. In most cases, the reason for becoming a «vulnerable» species of plants is critical violations or loss of their habitat and weak stress-adaptive characteristics of populations.

Among the herbs of Ukraine the group include: *Lycopodium annotinum, Juniperus excelsa, Pinus cembra, Taxus baccata, Leucojum aestivum, Narcissus angustifolius, Gladiolus imbricatus, Rhodiola rosea, Oxycoccus microcarpus, Astragalus dasyanthus, Gentiana lutea, Paeonia daurica, Paeonia tenuifolia, Glaucium flavum, Pulsatilla patens, Atropa belladonna* and a number of less-known species of medicinal plants.

The following four categories of IUCN are rare in Ukraine, therefore they were combined into the category of «**rare**» as species, known from a few locations; their populations are characterized by relative stability, in spite of the low or «**not evaluated**» the total number of individuals of the

taxon, which may belong to the category of endangered, vulnerable or rare, but have not been designated as any of these categories; including more or less widely distributed in various regions of Ukraine. These species are listed in the Red Data Book of Ukraine (2009) and the use of their raw materials from natural habitat is prohibited.

The category of rare taxons «not evaluated» comprises the following medicinal plants: *Allium ursinum, Huperzia selago, Salvinia natans, Galanthus nivalis, Leucojum vernum, Colchicum autumnale, Lilium martagon, Glycyrrhiza glabra, Adonis vernalis, Adonis wolgensis, Pulsatilla pratensis, Scopolia carniolica, Trapa natans*.

Species with lower risk of extinction do not belong to the first three categories, but include three subcategories:

– **Conservation Dependent** (CD) – protection of habitats and localities, where the species exist, or it is protected in order to determine the degree of extinction threat and enrollment in the aforementioned categories;

– **Near Threatened** (NT) – endangered with a decrease of the total number of individuals and further disappearance; the taxon does not belong to the category «Conservation Dependent«, but is close to «vulnerable»;

– **Least Concern** (LC) – taxon which requires minimum conservation and does not belong to previous subcategories, but there has been a detected tendency of reducing its population in many states. This specific category includes many species of medicinal plants threatened with depletion. The category is given to species that have gone through an assessment of their population, according to which in the conditions of the transformed environment there is a real threat to the number and area of their populations, but they were not enrolled in any other category. According to the categorization of the Red Data Book of Ukraine, they constitute species of the category «**not evaluated**», whose

populations are inherent to the reduction in the number and area of distribution as a result of anthropologically induced transformation of the environment.

Note that Arnica montana is listed in the IUCN Red List as a plant species with minimal risk, but it was withdrawn from the last edition of the Red Data Book of Ukraine and is currently not under state protection.

There are two more categories of rare species of IUCN, for which there is very little information (Data Deficient) or not evaluated (Not Evaluated). In Ukrainian interpretation there is a category «insufficiently known» that cannot be assigned to any of the above categories because of the lack of reliable information, however a violation of biotypes causes the threat of their extinction in the future. Taxons of the above-listed categories, enrolled in the Red Data Book of Ukraine, are protected at the state level and collection of them from their natural habitat is prohibited.

6.4. Protection of medicinal plant species of in various European countries

According to the International Union for Conservation of Nature and the World Wildlife Fund, there are between 50,000 and 80,000 flowering plant species used for medicinal purposes worldwide. Among these, about 15,000 species are threatened with extinction from overharvesting and habitat destruction and 20 % of their wild resources have already been nearly exhausted with the increasing human population and plant consumption. Although this threat has been known for decades, the accelerated loss of species and habitat destruction worldwide has increased the risk of extinction of medicinal plants [22, 24].

List of the taxons and the degree of rarity of medicinal plant species varies depending on the country. 150 species of medicinal plants in Europe are threatened with extinction due to their over-use. In most EU countries the following plant species are under threat of depletion of natural resources: *Adonis vernalis, Arctostaphylos uva-ursi, Arnica montana, Cetraria islandica, Drosera rotundifolia, Gentiana lutea, Glycyrrhiza glabra, Menyanthes trifoliata, Gypsophila spp., Paeonia spp., Primula spp., Sideritis spp., Thymus spp., Origanum spp.*, species of the family Orchidaceae. Many of these species are rare and they are protected in Ukraine. Here are a few examples:

Adonis vernalis is now extinct in Italy and the Netherlands, it is an endangered species in Germany, Slovakia, Sweden and Switzerland. The use of the natural resources of this herb is limited or not allowed in the EU, since it is included in the list of plants, the use of which is regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The plant is listed in the Red Data Book of Ukraine (2009) due to the development of a tendency of the natural resources' depletion as a result of ploughing, overgrazing, afforestation and terracing of slopes, operating load.

Arnica montana is included into the IUCN Red List of species, subjected to conservation, and also in national Red lists, although it is common in almost all European countries, from Norway to the Balkans and from Spain to Ukraine. This is an endemic species, whose populations react negatively to human pressure. In Germany, Lithuania, Slovenia, Bosnia and Herzegovina and Croatia, arnica is classified as a vulnerable species (according to the international classification). In France it is protected species in some regions (Aquitaine, Centre, Bourgogne) and in more

than five departments. In Hungary, it is classified as a species extinct in the wild.

In Ukraine, *Arnica montana* entered the Red Data Book of Ukraine (1996), but is was not included in the latest edition of this book in 2009 due to a decrease of anthropogenic impact on its habitat in the Ukrainian Carpathians.

Ledum palustre was enrolled in the European Red List as a species, whose population declined by more than 30 % within ten years. For these reasons, it is classified as the least vulnerable (Least Concern) [version 3.1]. The main reason for the reduction of its resources is irreversible ecological changes of its habitat. In Ukraine, *Ledum palustre* is distributed and has sufficienr resources on the Right - bank Polissia, while the use of its resources is strictly controlled at the local and state levels.

Centaurium erythraea and *Centaurium pulchellum* are also included in the Red List of the least vulnerable category (Least Concern, 2013.2). They are quite widespread in Europe, but intensive grazing load on meadow communities with the presence of these species is a threat to the depletion of their populations. In Ukraine, the use of their raw materials is strictly controlled, while their resources are limited.

Approach to the conservation of economically important plant species has specific characteristics in different countries, depending on the population status of the species and national policy. For example, in Poland the list of medicinal plants which are under strict protection, contains about 20 species of herbaceous plants, including *Adonis vernalis, Atropa belladonna, Archangelica officinalis, Arnica montana, Colchicum autumnale, Galanthus nivalis, Nymphaea alba, Nuphar luteum, Polemonium coeruleum, Leucoium vernum, Hierochloe odorata, Drosera spp., Gentiana spp., Lycopodium spp., Veratrum spp.* Species subjected to partial protection

comprise *Cetraria islandica, Ononis spinosa, Frangula alnus, Ledum palustre, Arctostaphylos uva-ursi, Viburnum opulus, Polypodium vulgare, Asarum europaeum, Primula officinalis, Asperula odorata, Gentiana asclepiadea, Helichrysum arenarium, Convallaria majalis etc.*

In Ukraine about 200 species of vascular medicinal plants mentioned above are under state protection (listed in the Red Data Book of Ukraine), the most famous of them include: *Atropa belladonna, Allium ursinum, Adonis vernalis, Adonis wolgensis, Astragalus dasyanthus, Galanthus nivalis, Gentiana lutea, Glaucium flavum, Glycyrrhiza glabra, Huperzia selago, Lycopodium annotinum, Paeonia tenuifolia, Rhodiola rosea, Scopolia carniolica, Taxus baccata.*

70 species of medicinal plants are regionally rare. Some of the last ones remain under regional protection in all areas, such as *Anemona sylvestris, Hypericum humifusum, Polemonium caeruleum; the following medicinal plant species Convallaria majalis, Ledum palustre, Alnus incana* in some places are registered as regionally rare, and in other administrative regions are regarded to be valuable raw materials. Collection of plant materials of rare species and those under regional protection is banned in Ukraine.

In Romania, it is prohibited by law to use raw materials of *Acorus calamus, Angelica archangelica, Arctostaphylos uva-ursi, Arnica montana, Centaurium erythrea, Leucojum vernum, Gentiana lutea* from their natural habitat.

In the EU, the collection and sale of raw materials of rare plant species is prohibited. In some countries (Albania, Romania) it is allowed to collect raw materials of some rare species in limited volumes within some regions, but the resources of many plant species are in danger due to the depletion of uncontrolled harvesting of plant populations.

6.5. Protection of plants and plant resources in Ukraine

The leading executive body of Ukraine in the field of environmental protection and management of non-timber natural plant resources, including resources of medicinal plants is the Ministry of Environment and Natural Resources of Ukraine. Its main objectives in the field of health and management of the plant world are:

– Implementation of environmental, scientific, technical and economic policies aimed at preservation and restoration of the safe existence of flora environment;

– State control over compliance with requirements of legislation on the use and protection of natural plant resources;

– Maintenance of public evaluation, inventory and monitoring of flora;

– Implementation of legal regulations concerning the uses of plants;

– Substantiation for the development of national and regional environmental programs according to the results of the study and research of the plant world or specific regional problems of natural plant resources;

– Fulfillment of international cooperation on protection of uses and reproduction of flora.

The implementation of these tasks is carried out in accordance with the laws of Ukraine and subordinate legislation (orders, regulations, instructions, *etc*). Environmental, forestry and land legislations of Ukraine outline the basic provisions of the rights and obligations of citizens and legal entities to ensure the sustainable use and conservation of natural resources, plants and fungi.

The main legislative acts that govern the preservation, use and reproduction of species of wild plants and mushrooms in Ukraine are:

– Law of Ukraine «On Environmental Protection» (1991);

– Law of Ukraine «On the Nature Reserve Fund» (1992);

– Forest Code of Ukraine (1994);

– The Land Code of Ukraine (2001);

– Law of Ukraine «On Accession to the 1979 Convention on the Protection of Wild Fauna and Flora and Natural Habitats in Europe» (1996);

– Law of Ukraine «On Accession of Ukraine to the Convention on International Trade in Endangered Species of Wild Fauna and Flora» (1999);

– Law of Ukraine «On Plant World» (1999);

– Law of Ukraine «On State Program on Formation of National Ecological Network in Ukraine for 2000–2015» (2000);

– Law of Ukraine «On the Red Data Book of Ukraine» (2002);

– Law of Ukraine «On Ratification of the Convention on Biological Diversity» № 257/94 VR dated November 29, 1994;

– On Extent of Compensation for Excavation (Collection) and Damage, Caused to the Species of Animals and Plants Listed in the Red Data Book of Ukraine (Order of the Cabinet of Ministers of Ukraine on June 1, 1993 p. № 399);

– Instruction on Setting of Limits Regarding the Use of Natural Resources within the Territories and Objects of the Wildlife Reserve Fund (Order of the Ministry of Environment and Natural Resources of Ukraine, dated March 12, 1993);

– On Approval of the Order for Harvesting of Secondary Forest Materials and the Implementation of Indirect Forest Uses in the Forests of Ukraine (Order of the Cabinet of Ministers of Ukraine on April 23, 1996 p. № 449);

– Instruction on Establishment of Norms concerning Specific Uses of Natural Plant Resources (Order of the Ministry of Environment and Natural Resources of Ukraine, February, 2002);

– On Approval of Rules for Issuing of Permissions and Certificates for Ukraine Border's Crossing by Species

Specimens of Wild Fauna and Flora that are Objects of Regulation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Order of the Ministry of Environment and Natural Resources of Ukraine and Ministry of Agrarian Policy and Food of Ukraine; on April 16, 2002 № 147/110)

– Program for the Nature Chronicles of Wildlife Resources and National Parks (Order of the Ministry of Environment and Natural Resources of Ukraine on November 25, 2002).

– On Approval of the Procedure of Carrying out of the State Evaluation and Cadastre of Flora (Order of the Cabinet of Ministers of Ukraine # 195, 2006).

The protection, use and reproduction of flora are regulated by the Constitution of Ukraine, Laws of Ukraine «On Environmental Protection» (1991, as amended and supplemented), «On Plant World « (1999); in areas of nature reserve fund – the Law of Ukraine «On the Nature Reserve Fund» (1992, as amended and supplemented); concerning rare plants and animals – Law of Ukraine «On the Red Data Book of Ukraine» (2002). A range of issues pertaining to regulation of the use and protection of plants are highlighted in the Forest (1994), Water (1995) and Land (2002) Codex of Ukraine. Various aspects of liability for environmental damage, including plant resources, are highlighted in the Civil and Criminal Codexes of Ukraine (2001).

Applicable regulations are implemented through proper mechanisms that are part of a general strategy of sustainable use and protection of plant resources of Ukraine.

State control over the abidance of legislation on the flora is carried out by executive bodies of the Ministry of Environment and Natural Resources of Ukraine, local state administrations, local authorities and institutions, which conform for the appropriate plant resources.

The following aspects are subjected to the state inspection:

– Compliance with rules and regulations of general and special use of natural plant resources;

– The methods and volumes of harvesting for raw materials of plants;

– The order of setting and limit volumes for collection of raw materials in particular administrative areas at scientifically substantiated basis;

– Procedure of the trade by the medicinal and technical raw materials from wild plants by legal entities and individuals;

– The requirements for the protection, use and reproduction of flora during design, arrangement, construction, reconstruction, commissioning, maintenance of buildings and facilities, the use of technologies that affect the state of the plant kingdom;

– Regulations of import into Ukraine and export abroad of vegetation, including raw materials from wild medicinal plants.

The objective of this monitoring is to ensure compliance with the legislation on plant world by all state authorities, enterprises, institutions and organizations regardless of their type of ownership and subordination, and by the citizens.

Public control in the area of protection, use and reproduction of the plant world is performed by public inspectors of environment and community organizations.

6.6. Legislation, conservation and evaluating of medicinal plant resources in Ukraine

Basic legal rules of evaluation, utilization and conservation of wild species of medicinal and food plants are determined in

the Law of Ukraine «On Plant World», the resolutions, issued by Cabinet of Ministers of Ukraine (CMU) «On Approval of the Order for Harvesting of Secondary Forest Materials and the Implementation of Indirect Forest Uses in the Forests of Ukraine» and «On Approval of the Procedure of Carrying out of the State Evaluation and Cadastre of Flora».

The resolution of the Cabinet of Ministers «On Approval of the Order for Harvesting of Secondary Forest Materials and the Implementation of Indirect Forest Uses in the Forests of Ukraine» notes that the harvesting of wild fruits and medicinal plants is carried out in ways which exclude resource depletion. Collection of plants (their parts) and fungi, listed in the Red Data Book of Ukraine, is strictly prohibited.

During the collection of medicinal plants, one must comply with the following requirements:

– harvest underground plant parts (roots, rhizomes, tubers, bulbs) after ripening and shedding of seeds; to remain some plants to restore thickets and young plants for further growth;

– cut the herb without rough ground parts; do not pull out the plants with roots, rhizomes, tubers, bulbs;

– collect the bark only from trees intended to be cut in the current year, and buds in early spring just before expansion;

– remain the best specimens of flowers and blossoms for pollination and subsequent recovery of plants, avoid cutting and clipping of branches from trees and shrubs.

The Law of Ukraine «On Plant World» [11] adopted in 1999 became a significant contribution to the conservation and sustainable use of plant resources as well as a number of regulations concerning applicaion and reproduction of natural plant resources and their important components – the resources of medicinal plants.

In line with the relevant regulations of the Law of Ukraine «On Plant World», natural plant resources, including resources of wild medicinal plants, accordingly to their value and other features are divided into nature **plant resources of national and local importance**. In its environmental, economic, scientific, medicinal and recreational value and other characteristics, plant resources are divided into natural plant resources of national and local importance.

The natural plant resources of **national importance** are:

a) objects of the plant world within:

– internal sea waters and territorial sea, continental shelf and exclusive (maritime) economic zone of Ukraine;

– surface water (lakes, reservoirs, rivers, canals) and all their tributaries which are located and used in the territory of more than one administration region

– natural and biosphere resources, national natural parks and resources, natural monuments, botanical gardens, dendroparks, zoological parks, natural monuments of park landscape art of national importance;

b) Forest resources of national importance;

c) Rare and other species that are under threat of extinction, vascular plants, mosses, sea weeds, lichens and fungi species which are listed in the Red Data Book of Ukraine;

d) Rare and other species under threat of extinction and typical natural plant communities listed in the Green Data Book of Ukraine.

The **natural plant resources of local importance** include wild and other non-agricultural vascular plant, moss, sea weed, lichen and fungi species, not assigned to natural plant resources of national importance. Therefore, most species of medicinal plants, raw materials of which are harvested, belong to resources of local significance and regulation of their use is carried out by local executive authorities.

According to the Law of Ukraine «On Plant World», **harvesting (collection) of materials from wild medicinal plants** is carried out in the order of ***general*** or ***special use*** of natural plant resources, i.e. general and special uses are the forms for application of natural plant resources.

The collection of plant material of wild plant species for personal use without profit belongs to the general use of plant resources. It is carried out in compliance with the relevant rules, without providing citizens with permissions.

Legislation of Ukraine guarantees the citizens a right for general use of natural plant resources to meet their vital needs without gaining profit. In the course of general use of natural plant resources, people can gather medicinal raw materials (flowers, berries, fruits, vegetables and others) to meet their own needs.

The general use of natural plant resources is conducted by citizens in compliance with the rules of gathering the raw materials from wild plants, that are approved by the central governmental authority in the area of environmental protection (Ministry of Ecology and Natural Resources of Ukraine), without appropriate permits for the collection of raw materials.

Citizens are not allowed to collect raw materials of plants and fungi listed in the Red Book of Ukraine and species under regional protection. The well-known medicinal plants of the Red Data Book of Ukraine [20] include: *Astragalus dasyanthus, Huperzia selago, Rhodiola rosea*, all species of the family *Orchidaceae, Atropa belladonna, Valeriana dioica, Adonis vernalis, Vaccinium microcarpum, Glaucium flavum, Paeonia tenuifolia, Lycopodium annotinum, Drosera anglica, D. intermedia, Scopolia carniolica, Glycyrrhiza glabra, Rosa donetzica, Juniperus excelsa.*

The Red Data Book of Ukraine (2009), in addition to the aforementioned species, lists a number of closely related medicinal plants such as birch (*Betula borysthenica, B. humilis, B. klokovii, B. obscura*); pine (*Pinus cembra, P. stankewiczii, P. cretacea*); sphagnum (*Sphagnum balticum, S. subnitens, S. wulfianum, S. molle, S. tenellum*); gentian (*Gentiana acaulis, G. laciniata, G. nivalis, G. punctata, G. utriculosa, G. verna*); thyme (*Th. kaljmijussicus, Th. littoralis*). Collectors should be aware of these plant species to prevent their destruction.

It is prohibited to collect wild plants classified as nartotic-containing plants and their fruits, seeds, stubble residues, waste materials, and also to sell medicinal and ornamental plant species and their parts (roots, stems, fruits) collected in order of a general use of natural plant resources.

The general use of natural plant resources in case of exhaustion, drastic reduction of population and coenotic variety etc., may be restricted by local executive bodies and bodies of local self-government, as well as the specially authorized central authority of the state executive power in the area of environment and natural resources.

Restriction for the general use of natural plant resources is made on the basis of peer review materials on plant resources and expert opinions of territorial administration of the Ministry of Ecology and Natural Resources of Ukraine or competent scientific institution.

Harvesting the natural resources of plants and fungi in a line of general and special uses, **citizens must adhere to the following basic requirements**:

– ensure the preservation of natural variety of plant world objects and fungi and their natural resources;

– facilitate the conservation of places, where wild plants, fungi and their natural communities grow;

– implement measures for the reproduction of natural resources of plant species, fungi and their communities, whose natural resources are being depleted;

– adhere to established rules, regulations and terms of use of natural plant resources.

Key ***provisions*** describing the ***general use*** of natural plant resources:

a) individuals as right holders to use plant resources;
b) legally defined purpose of use;
c) no special permission;
d) free of charge;
e) obligatory adherence to the rules.

Special use of natural plant resources includes the types of usage associated with the resource withdrawal from the environment, directed to meet the industrial, scientific and material needs of legal entities and individuals, and also aimed at gaining profit from trade of these resources or processed products.

Special use of natural plant resources (including medicinal plants) is paid; it is performed due to special permission. The utilization of the plant world for profit by individuals, institutions (i.e., legal entities and individuals) without proper permission is prohibited. The amount of fee for special use of plant resources is determined on the basis of natural resources, distribution, value, recovery capabilities and productivity of these resources.

The Law of Ukraine «On Plant World» provides certain exceptions to the general permit system for the use of natural plant resources. For example, the permission is not obligatory for the owners of land, which contains objects of flora other than those listed in the Red Data Book of Ukraine and the Green Book of Ukraine; as well as for users (including landholders) of land.

Issuance of permits (including forest tickets) for the special use of plant resources is carried out by the representative institutions (forestry, local councils of deputies and other entities whose lands contain available resources of particular species) within the limits of their permissible use on the defined territory.

Collection of raw materials from wild plants is prohibited through the purchase of plant material from organizations or individuals who do not have the permission to harvest raw materials. Private trade by raw material of wild plants is permitted only with the availability of a permit for the collected materials.

As far as territorial aspect is taken into consideration, it is not allowed to collect medicinal plant materials:

a) within the territories and objects of natural reserve fund of Ukraine, where it is limited by a prescribed regime of protection;
b) in the forest park parts of forests of green spaces;
c) in forests that are located within cities, towns and other populated areas;
d) on other areas, defined for protection by scientific institutions and established state executive branch.

Normatives and limits for the use of resources of medicinal plants

State regulation of natural resources of medicinal and other groups of useful plant species involves determination of ***Normatives*** and setting of ***limits on the use of these resources***.

The **Normatives** of using natural plant resources of raw materials of useful plants are determined by the Ministry of Ecology and Natural Resources of Ukraine on the basis of evaluation records of natural resources of plants, whose

raw materials are harvested for a period of 5–10 years within particular administrative regions. They present suggested amounts of allowable resource use of certain plant species, established as a result of their resource assessment in the administrative region (oblast).

Due to the fact that the resources of many herbaceous plant species may vary considerably within a few years, each year ***limits*** are set on the uses of natural flora resources of local importance. This is the actual volume of acceptable resource use of certain plant species, taking into consideration the changes in conditions of the resources during the previous year.

The limits for usage of natural resources of local flora are set by the Councils of the People's Deputies on the basis of scientifically based expert conclusions (approvals), issued by the local departments of the Ministry of Ecology and Natural Resources of Ukraine on the current status of natural plant resources, and for the resources of national importance by the Ministry of Ecology and Natural Resources of Ukraine, correspondingly.

At the beginning of the calendar year the above-mentioned authorities approve the ***limits*** for usage of resources of medicinal and food plants for the current year, which is basically a list of the plant species and amounts of possible use of their materials in a particular administrative region or Ukraine as a whole.

Normatives and limits for using of resources of medicinal and food plants are determined according to the results of natural resource evaluation, performed by competent institutions (research institutes, universities, where relevant experts are available), which has to be carried out at least once every five years, since in conditions of transformed environment this is the optimal period for saving of resource values for arrays of wild medicinal plants.

Resource evaluation involves the determination of biological, operational reserve of the raw material from particular plant species and extent of allowable annual use.

The main executive bodies (Ministry of Ecology and Natural Resources of Ukraine, the State Forestry Committee of Ukraine) and their regional offices control the process of usage and conservation of flora diversity in Ukraine.

In 2000 the Ministry of Ecology and Natural Resources of Ukraine initiated the establishment of the State Cadastre of Flora of Ukraine (hereinafter – Cadastre) which is a scientifically substantiated basis for managed and controlled use of resources for different groups of useful plants: food, medicinal, industrial etc. The development of the Cadastre is conducted in accordance with the Law of Ukraine «On Flora», according to the ratification of the international Convention on Biological Diversity.

State registration and cadastre of flora is aimed at evaluation the quantity, quality and other characteristics of natural plant resources, volumes, characteristics and mode of uses; also in monitoring of the qualitative and quantitative changes in the plant world to provide a current status information for executive and local authorities, owners and users (including tenants) of land areas, which contains objects of flora.

The State Cadastre of Flora of Ukraine contains a system of data and documents concerning the distribution of vegetation between the owners and users of land (tenants), quantitative and qualitative characteristics of the resources of economically important plant species in a particular area, an economic assessment of technical, forage, medicinal, food and other properties, and other related data of natural plant resources, necessary to ensure their sustainable use, conservation and effective protection.

In general, the Cadastre consists of three interrelated components: flora – vegetation – plant resources (Fig. 7), each of them has its own structure and objectives. The main objective of the Cadastre is to account and monitor the quantitative and qualitative changes in the plant world.

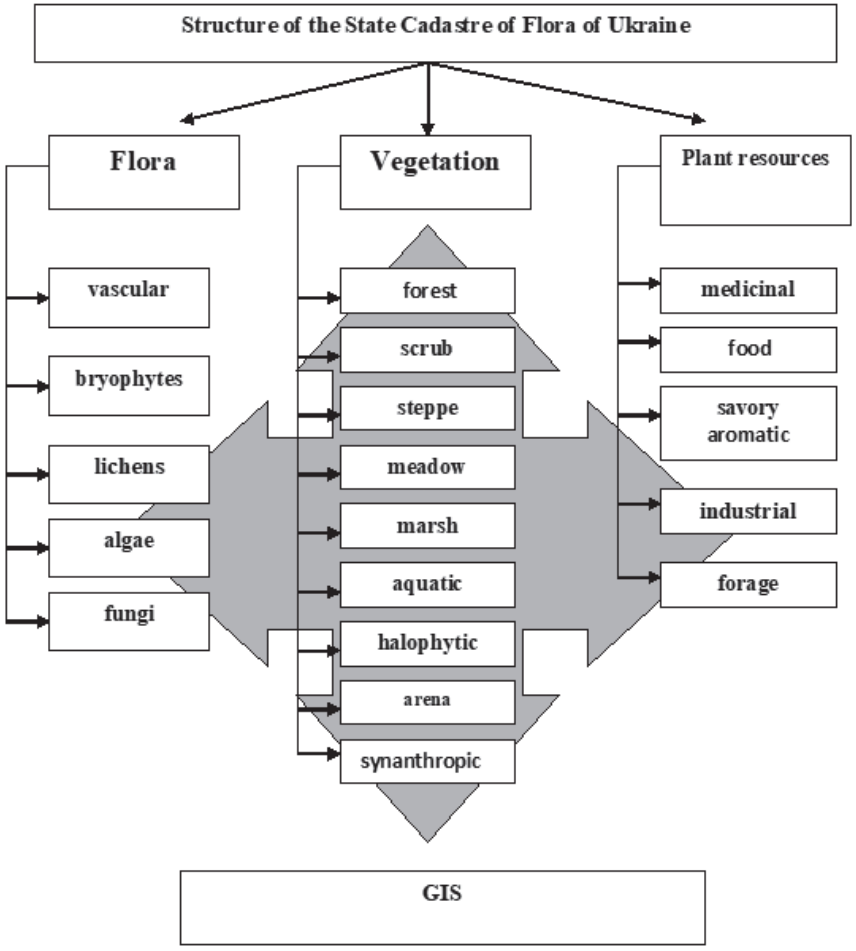


Figure 7. Structure of the State Cadastre of Flora of Ukraine

The state registration and cadastre of flora is conducted using a unified methodology, procedures and forms of reports on the cadastral documentation.

The state registration and cadastre of flora involves the following activities:

– determination of particular areas (aquatorium) where the research, processing of official and literary materials containing information about the flora, fungi, vegetation and plant resources on the assigned territory will be conducted;

– evaluation of vegetation diversity, determination of their main characteristics directly in the natural environment;

– processing of account data on flora, obtained during field expeditions, determination of their qualitative and quantitative characteristics, including the volumes of allowable uses of the raw plant species, features of their representation in the region, the establishment of the determining factors that threaten their existence in terms of the transformed environment, etc;

– filling in an electronic database of the flora cadastre, summarization of the information received and publication of data on the state registration and cadastre of flora.

Within the development of the Cadastre immediate and long-term objectives are distinguished. The primary ones include inventory description of flora, vegetation and plant resources, formation of an electronic version of the inventories, connected with geographic information system (GIS), with the possibility of generalization of information at the regional and national levels.

During the inventory of resources on a particular territory the priority is ascribed to species, whose raw materials are used for medicinal, food and other purposes. Their resources are further accounted and the volumes of acceptable uses are established to allow recovery of populations. Below is a

list of priority species of medicinal and food plants requiring primary attention concerning the collection and analysis of resource inventory information within Ukraine (Table 13).

Table 13

Priority species of medicinal and food plants requiring primary attention concerning the collection and analysis of resource inventory information

1. Acorus calamus	*32. Nymphaea alba*
2. Althaea officinalis	*33. Tilia cordata*
3. Arnica montana	*34. Rubus idaeus*
4. Astragalus dasyanthus	*35. Origanum vulgare*
5. Ledum palustre	*36. Tussilago farfara*
6. Vinca minor	*37. Arctostaphylos uva-ursi*
7. Betula pendula	*38. Inula helenium)*
8. Menyanthes trifoliata	*39. Potentilla erecta*
9. Vaccinium vitis-idaea	*40. Tanacetum vulgare*
10. Sambucus nigra	*41. Lycopodium clavatum)*
11. Melilotus officinalis	*42. Lycopodium annotinum)*
12. Valeriana officinalis	*43. Artemisia absinthium*
13. Alnus glutinosa	*44. Bistorta officinalis (syn Polygonum bistorta)*
14. Ononis arvensis	*48. Sanguisorba officinalis*
15. Persicaria hydropiper (syn Polygonum hydropiper)	*49. Rhododendron luteum*
16. Persicaria maculosa (syn Polygonum persicaria	*50. Matricaria recutita)*
17. Nuphar lutea	*51. Polemonium caeruleum*
18. Crataegus fallacina and other raw material sources of Crataegus spp	*52. Leonurus quinquelobatus*
19. Adonis vernalis	*53. Sedum maximum*
20. Sorbus aucuparia	*54. Sedum acre*

21. Capsella bursa-pastoris	*55. Fragaria vesca*
22. Achillea millefolium	*56. Gnaphalium uliginosum*
23. Agrimonia eupatoria	*57. Helichrysum arenarium*
24. Rhamnus cathartica	*58. Thymus serpyllum and other raw material sources of Thymus spp*
25. Oxycoccus palustris	*59. Veratrum lobelianum*
26. Hypericum perforatum	*60. Bidens tripartita*
27. Centaurium pulchellum	*61. Chelidonium majus*
28. Viburnum opulus)	*62. Vaccinium myrtillus*
29. Convallaria majalis	*Rosa majalis and other raw material sources of Rosa spp*
30. Urtica dioica	*63. Juniperus communis*
31. Frangula alnus	

CHAPTER 7

EVALUATION OF MEDICINAL PLANT RESOURCES IN UKRAINE

7.1. History of medicinal plant resources studies

The problem of sustainable use and conservation of wild resources of medicinal plants has become particularly urgent in Ukraine since the middle of last century. Ukraine has large natural resources of valuable plant species, including medicinal ones. However, the resource potential of many of them is limited, so now the actual task is to detect raw material resources of these species and develop a scientifical substantiation of basis for their rational management. A prerequisite condition for sustainable use of available resources of plant species is the information about their regional location, resource potential, the possibility of enriching of raw materials in natural conditions of growth etc.

There are many works devoted to the study of medicinal plants in Ukraine and their resources. A significant

contribution to the formation and development of medicinal plant resources studies was done by Dmytro S. Ivashyn (1912–1992), PhD (biology), who dedicated all his life to studying of medicinal plants: their distribution, medicinal properties, the state of resources and the need for protection. He dedicated more than 200 scientific papers to those issues. He spent a significant part of his life working at zonal station of All-Union Scientific Research Institute of Medicinal and Aromatic Plants (Berezotocha, Lubensky district, Poltava region), now it is the Medicinal plants research station of Ukrainian Academy of Agrarian Sciences. In these years different long-term resource studies expeditions were organized to various regions of Ukraine. Simultaneously the collection of raw plant materials was performed for further pharmacognostic research. A well-known work by D.S. Ivashyn «Wild medicinal plants of Ukraine» (1965) was reprinted five times (later it called «Handbook for harvesting of medicinal plants»). It contained general rules of resource studies, harvesting and primary processing of medicinal plants material, methods and ways for protection of medicinal plants.

Traditional medicine of Ukraine widely uses raw materials from wild plants to produce pharmaceuticals and phytotherapeutic collections. Harvesting of wild species of medicinal plants in large quantities is carried out mainly by private collection organizations through the purchase of raw materials from individuals and departments of forestry. One of the major producer of medicinal plant materials in Ukraine is PJSC «Liktravy» (Zhytomyr).

The main consumers of medicinal plants are pharmaceutical companies, pharmacies, legal entities who have licenses for activities related to the manufacturing and sale of medicines from plant materials, individuals (in order to use raw materials for their own purposes). Uses of natural

resources of medicinal plants is regulated by the state at the local (within the administrative regions) and national levels.

The main tendencies of medicinal plant resource studies in Ukraine are:

- creation of checklists medicinal plants of Ukraine and some administrative or natural areas (inventory) in order to identify new species of medicinal plants for the expansion of the resource base;
- an account of the resources of particular wild-grown medicinal plants to ensure their sustainable use and conservation;
- improvement of methods for evaluation of resources to reduce the cost of resource investigations;
- development and improvement of legal framework regulating of evaluation, utilization and conservation of natural resources of valuable plant species;
- monitoring of the populations and resources of priority species in order to protect and restore them;
- development of training programs and manuals for educational purposes.

7.2. Review of methodical approaches to the estimation of medicinal plant resources

Research of resource status of medicinal, food, industrial and other groups of economically important wild plant species is required to solve the totality of fundamental, applied and environmental objectives, in particular: determination of features for formation of resource potential of phytodiversity in terms of anthropogenic transformation of plant communities, sustainable use and conservation of phytoresources through administrative measures at local and national levels. In Ukraine, the evaluation of non-timber

plant resources, including resources of medicinal plants, is implemented to ensure the regulation of the use of these resources at the local and state levels.

For evaluation of the medicinal plant resources of and fungi in different countries, the most widely used traditional methods of model specimens, projecting cover and registration plots were developed in the late 60s. They were repeatedly tested and widely used in different regions of Ukraine, Russia, Belarus, the Baltic countries. These traditional methods allow obtaining the objective information on the resources of a particular plant species in certain area based on the analysis and summarization of its resource characteristics within that territory. Of course, the application of these methods gives the most representative results, however requires essential financial and time expenses and also a large number of professionals, i.e. economically unprofitable. In addition, while determining the resources of a single species within even one administrative district, it is impossible to survey all habitats where this species may have a resource value. It is therefore important to develop methods of evaluation, the application of which would reduce costs in carrying out resource studies and provide obtaining of objective approximate data on the resources of a particular species in the region.

In the last decade a number of methods have been developed that reduce the time spent in direct evaluation. Thus, I.L. Krylova with coauthors (1992) developed a table for rapid evaluation of certain species in field studies [13] (Appendix, tables 7–9).

Under conditions of uniform distribution of individuals in populations, these tables provide obtainment of approximately reliable data on the resources of a certain plant species with an accuracy of 50–70 % on certain raw

array. However, the heterogeneity of the environment leads to uneven placement of plant individuals within large outlines, especially it is appropriate for populations of species that are characterized by aggregation-diffusive nature of the distribution of individuals. It is difficult to explore all raw arrays in the field conditions. Therefore, to account the resources of economically valuable plant species on large areas, it is advisable to combine the methods of a particular evaluation and extrapolation of averaged data upon the area of land, where the populations of the species have resource value.

The method of extrapolation in resource studies is a mode of distribution of plant resource characteristics, patterns for implementation of resource value, relationships and dependencies that occur in a proper territorial dimension in terms of another one. This method is important and promising for establishment of raw resources of any plant or fungi species over large areas. Based on knowledge of the characteristics and patterns for formation of resources by populations of certain species in particular ecological and coenotic conditions, one can predict the state of resources of this species in another territory, where occur the habitats that are optimal for the formation of its resources. The disadvantage of this method lies in proximity and minimum values of resources, resulting from its use, since during extrapolation the average or minimum resource characteristics of populations are usually considered to be the basis for its conduction. However, the main purpose of the medicinal plant resource science is to detect raw resources of the species for their sustainable use and conservation, which is largely provided by the application of these methods.

For determination of the biological stocks of raw materials of a particular species in all methods for evaluation of plant

resources on any territory the basic are data concerning density of raw material stocks and the area of the territory where the species have a resource value. The area of resource significant array is determined in the field with a tape or a pedometer, in the desk stage – processing data of forest and land management. Quantitative characteristics of density of the stock for particular plant material are defined with a set of relevant resource values, including the size and weight of the raw material, density of its individuals or projective cover.

While determining the resources of plants by traditional methods, the statistical analysis of the collected field data is carried out; it serves as the basis for obtaining data on biological stock of a certain raw material within the investigated area. The estimation of resources for plant species over large areas is based on the average values of raw stock density of the species and extrapolation of indices to the area of lands where its populations have resource value. The proportion of such lands is determined experimentally. The area of potential raw commodities for each of the model species is estimated on the basis of analysis of its environmental and coenotic affinity, forest and land management cartographic materials, data of navigation devices and aerial photographs.

Available data from these materials only indirectly determine the potential area of plant communities where a particular species of investigated plants can occur; therefore, in order to determine areas of potential raw arrays for each of the studied species is determined the fraction of communities where its coenopopulations have resource significance among the total number of researched communities with the presence of the analyzed species. Mechanism for the further estimation of resources of a particular plant species for a certain area is not differed from traditional methods

for calculation of biological resources, which is determined by multiplication of the raw stock density on the area of surveyed arrays. Biological reserve is determined in freshly collected conditions (if the raw material comprises fresh fruits or other parts of the plants), or in terms of dry raw materials (when the materials are exemplified by leaves, corms, inflorescence).

Fundamentally, there are two basic approaches to resource evaluation of plants and areas. One approach comprises a single-case study of resource status of particular plant species within an appropriate area. This approach is implemented by applying of classical methods for evaluation of resources and methods of data extrapolation. It is carried out for scientifically-based regulation for the uses of resources of economically important plant species in the individual administrative regions.

Another approach is associated with long-term stationary observations and finally focuses on the monitoring of resources of the most valuable plant species. In this case, the basic are results of the primary evaluation of resources, followed by observation of changes in populations and resources of model species. Methodological aspects for monitoring of resources of valuable plant species have recently received considerable attention [14]. Both approaches involve the implementation of primary evaluation of resources and analysis of important resource characteristics of populations of valuable species. The main methodological approaches to resource evaluation, implemented in Ukraine, are listed below.

CHAPTER 8

METHODS OF EVALUATION OF THE MEDICINAL PLANT RESOURCES

Methodology and methods for evaluation of useful plants, including medicinal ones, are largely determined in terms of concept of «resource evaluation» and assigned tasks. Initial resource record of useful plants is performed for qualitative and quantitative assessment of the resource status to ensure their sustainable use, restoration and preservation.

Implementation of works concerning evaluation of wild medicinal plant resources is carried out in several stages, which are combined appropriately; the main task of each of them is a maximum collection and rapid analysis of information about the objects being studied.

Preparatory (reconnaissance) stage

The first (reconnaissance) stage for evaluation of plant resources is the analysis of primary data, the results of which include:

– preparation of the list of medicinal plants, raw materials of which are used;

– analysis of utilization of resources of the studied species within the region;

– analysis of the representation of each species in the region;

– determination of terms and scope of works on resource assessment;

– coordination of resource studying works with major land users.

The works begin by formation of a list of plant species, whose state of resources should be investigated. This primarily concerns the species, for which collection of derived raw materials is subjected to limitation. For an objective analysis of the status and dynamics of natural plant resources it is appropriate to include to this list the species, whose natural resources are being depleted due to changes in environmental conditions.

For urgent and most detailed survey deserve the species with restricted habitat and species of medicinal plants, applied as sources of scarce raw materials (Appendix, Tables 1, 3). In some cases these are critical species in need of study of the current state and dynamics of resources without the exclusion of their raw materials for the development and implementation of protective measures. In single administrative regions quantity of wild medicinal plants, whose raw materials are removed from the environment, varies mainly within 30 species. And often while planning the amount of raw materials of medicinal and food plants to be used, taxonomic differentiation of the species are not taken into consideration. This primarily concerns the representatives of the genera *Crataegus, Rosa, Thymus, Bidens etc.* Therefore, the list of plant species with limited raw material resources comprises only a genera name or one-two species (e.g. *Alnus incana* and *A. glutinosa*). However, it is important to define the plant species identity of significant raw materials.

The further step involves a critical initial data analysis concerning characteristics of the investigated species and their natural resources in a determined region.

The main groups of initial data comprise statistical records on collection of medicinal plant materials, data on forest and land management; inventory materials, assessment and primary registration of plant resources and acts of natural inspection (in case of changes in land categories as a result of economic activity, natural disasters and other factors); references and herbarium materials (or collections) of plants and fungi from territory of a district, region or Ukraine as a whole.

Initial data materials:

1. Statistic report materials on collection of raw medicinal plant materials (pharmacy network, forestry, Central Union of Consumer Associations of Ukraine, local units of the Ministry of Environment Protection and Natural Resources of Ukraine) for recent 3–5 years.

2. Cartographic materials (geobotanical, botanical and geographical maps of the most convenient scale 1: 2,500,000, 1: 600,000, 1: 300,000, and rarely 1: 100,000); map schemes of forest and land management.

3. Working materials on forest and land management, which contain the information necessary for these resource studies (distribution of forest, marsh, meadow areas with characteristics of vegetation).

4. Literary sources (articles, books, etc.) of information about the objects being studied.

5. Herbarium samples.

Analysis of aforementioned materials gives an idea of the potential representation of the objects in a particular region. On the basis of ecological and coenotic affinity of medicinal plants species and analysis of the required data are established potential raw habitat, the draft route for expeditions is developed. It should be kept in mind that the volume for harvesting of raw materials from useful plant species does not indicate the actual state of stocks, since nowadays an organized collection of raw wild plants occurs

rarely (except of forestry harvesting). In this regard, received data on collection of raw materials from wild plant species in a particular region may be used only as a subsidiary source of information in the preparation of route survey of an area.

Data processing of forest and land management materials

In a study of resources of wild medicinal plants are valuable data on land exploitation, which are at the disposal of appropriate state agencies. Amongst the most important data are forest and land management projects. Forest management project can be found in any State Forestry. This comprehensive document provides explanatory note, information on planned measures, forest type maps and cartographic materials. The last two are the most crucial for research of resources. The most valuable of these is the plan of afforestation comprising the cartographic image of the territory with located plantations and quarter network, boundaries of sub compartment taxation areas and other categories of lands. It is the basis for selection of the optimal route of studies, clarifying the geo-botanical frames of plant communities, their area, representative number of sample plots, etc.

Forest taxation maps and cartographic materials are sources for selection of available information concerning the studied species of useful plants. Many tax maps do not contain habitat of valuable raw plant species, or these taxons are mentioned without records of their participation in the grass layer, however in general, these descriptions provide an opportunity to determine areas of potential habitats of particular plant species based on their ecological and coenotic affinity.

On the basis of analysis of forest management data for each of studied plant species is formed a register, where are noted forestry, quarter, array comprising the species, array square and other features (if they are available in tax descriptions); the cartographic representations for potential resource areas are being sketched (Fig. 8).

Similar technique is applied to land management materials. They can be found in the district offices of state administration on land management. It is a comprehensive document developed for each household, which includes an explanatory note, planning and cartographic data. The explanatory note includes a description of the current state of the land fund and agriculture, natural and economic conditions. Planning and cartographic materials provide insight of the location and area of farmlands: fields, grasslands (pastures and hayfields), etc., and boundaries of households and farmlands.

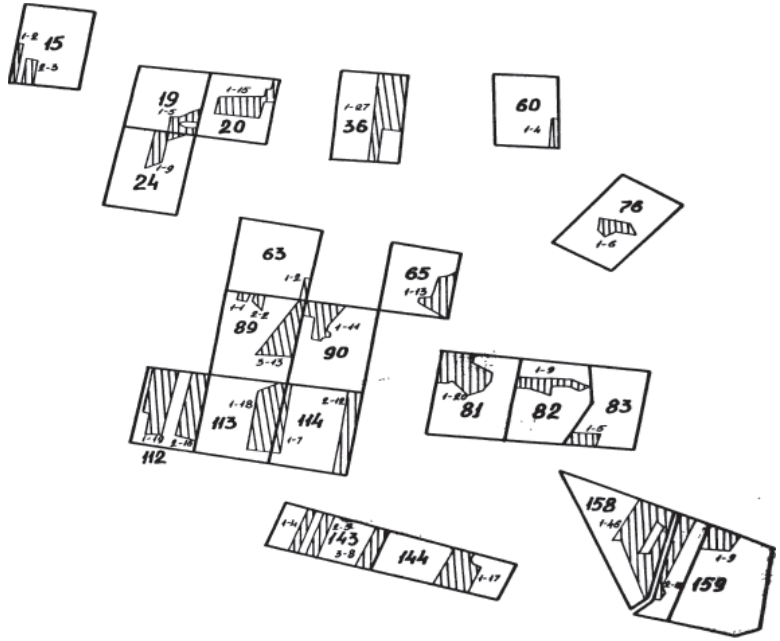


Figure 8. Layout of areas with lily-of-the-valley (shaded). Larger in font numbers specify the number of quarters, along with shaded areas (subcompartments) – their numbers and area (hectares)

The outline land management data contain information on economic use of non-forest areas (types of territories),

their physico-geographical and, sometimes, botanical characteristics. The cartographic materials of land management present significant value for resource studies if they indicate the distribution of different types of lands and their areas. It should be noted that for many species of medicinal plants is difficult to predetermine the potentially productive areas (*Arctium lappa, Tanacetum vulgare, Centaurium umbellatum, Valeriana officinalis, Tussilago farfara etc.*), thus during expeditions main habitats of these species are updated and checked by specialists of land and forestry authorities.

Within the first stage also are analyzed available information from literary or official materials relating to various aspects of natural resources of medicinal plant species of a particular region. These may be research papers, monographs, textbooks.

One of the most important components of the initial data are herbarium samples, because, first of all, it is essential to be acquainted with herbarium specimens of the studied species. This is especially important if valuable raw species are similar to closely related taxons, such as species of genera *Achillea, Bidens, Sambucus etc.*

In order to regulate the volumes of uses of useful plant resources at the local level, resource assessment is carried out within individual administrative regions (oblasts) and at the national level within the raw area of model species or taxons.

Taking into consideration that the maximum term for uses of results of resource assessment of herbaceous plants, shrubs, bushes and semi-bushes for regulation of the raw application lasts approximately for 5 years, the terms of expert assessment within a certain territory have to be as concise as possible. In general, the resource estimation of

raw plant species within the region is carried out once 2 years, so during planning is necessary to determine clearly the duration and sequence of resource survey of the area. In cases if there is a need to determine the resources of one or more plant species within the administrative region, resource studies can be performed during a year.

Simultaneously with determination of the list of model objects, the possible terms are being planned, as well as sequence and duration of expeditionary survey of the area. Field work pertaining to resource assessment of raw species is performed in the period of maximum resource significance for populations of certain species. Depending on the type of material and life forms of plants, these periods are not the same for all raw species. These features are taken into account when planning the sequence and frequency of inspection of particular regions. Our experience and practice of resource studies suggest that resource assessment of 20 % raw species of medicinal and food plants should be carried out in April-May, more than 60 % – in June and July, 10–15 % – in August and September, the rest – during any vegetation period. It means that resource field research in a particular area is planned in several stages.

During the preparation stage, the plans for implementation of field work are agreed with major land users, where the resource assessment of raw species is going to be carried out. It concerns the forestry and land management authorities in particular regions and their local units. This approval is required because «… evaluation of plant resources, volumes, character and mode of their uses… is carried out to provide information on the status of flora for executive governments and local authorities, as well as owners and users (including tenants) of land areas, where objects of the plant world are located « [11].

The obtained data are united into a unified registry for a particular species and region. On the basis of analysis of initial data the plans concerning expeditionary survey of the study area are developed. The route of expeditionary survey is put upon the administrative map. The key locations for field work investigation are determined, for which are working out the detailed routes, applying forest and land management maps and plans.

Expeditionary stage

Field works are carried out according to the drafted route and plan of resource assessment of medicinal plants. There are several approaches for evaluation of resources from wild raw materials.

Sampling approach is used the most frequently; the selection of potentially productive areas and drafting of working routes is based on initial data, considering coenotic and ecological affinity of the plant taxons. The area of potential raw habitats of particular species is not identical to the area of the species distribution. It concerns only the area in which the studied species has a raw value; for most herbaceous species such area can comprise from 1 to 10 % of coenotic ecotope area, potentially suitable for growth of the species in a particular region. If the value is less than 1 %, the species requires the restriction of its use or protection.

In order to provide a scientifically-based regulation on the use of resources within a particular administrative region, it is important to clarify the amplitude of resource significance of the coenopopulations of each model species on this territory and the area of lands, optimal for growth of the plant species. It is achieved in the course of field resource surveys in the region and determination of resource significance of coenopopulations of the studied species and further statistical processing of received results.

The general scheme of resource studies is described in classical techniques [14]; it involves the fulfillment of appropriate procedures on evaluation sections (areas) according to a particular route. The density of raw material resources is established by methods described below. Raw of model species from these sections are weighed or one can apply express-methods for resource estimation, determining indices of reserve density on the basis of the correlative connections or morphometric, weight and other resource value characteristics for populations of particular plant species.

Application of selective approach provides accurate evaluation results for individual area, the location of which is put on the map. These data are valuable for monitoring. The approach is used during preparation of the State Cadastre of Flora of Ukraine and its components, i.e. the Cadastre (inventory) of plant resources. Applying this selective approach, not all potential habitats and raw arrays are examined. If the resource studies cover large areas, the effectiveness of this approach is reduced, since even in the presence of transport provision and of the research team of 10–15 persons, the evaluation of raw materials of one plant species within the administrative region requires not less than 30 days.

It should be kept in mind that the main purpose of the resource assessment of a particular plant species is not the maximum application of natural resources, but the optimal conditions for the restoration of its populations. In addition, due to the current state of the legal framework on management regulation of natural resources of medicinal plants, it can be controlled only the special uses of these resources. It does not take into consideration the overall uses (for personal purposes), the volumes of which are often not determined even approximately, since it is difficult to

regulate such processes. The natural resources of medicinal plants can also be reduced because of their indirect uses, including the utilization of plots of valuable raw arrays of these plants for grazing, recreation, construction etc. Therefore, the implementation of selective approach is environmentally and economically justified.

To determine the natural resources in a large area within limited time is also possible to use an extrapolation approach, in the course of which the obtained quantitative characteristics of plant resources of particular plots are extrapolated upon the areas, similar in terms of ecological and phytocoenotic exponents. To determine the resources of medicinal plants using the extrapolation approach, it is required occurrence of density values for resources of particular plant species and the area of its potential raw habitats in the region, which can be determined in absolute numbers (ha) or as a percentage of the total area. In order of sustainable use of determined phytoresources, the applications of which have limitations, for extrapolation approach are taken the minimum density values for resources of these species. Evaluation of phytoresources by using extrapolation method gives less accurate results, mapping of arrays is often impossible, but it is economically more advantageous in resource surveys over large areas, as the results of appropriate resource research lose their value after 5–7 years.

Extrapolation is better to use for the species, area distribution of which can easily be determined by available forest or land survey maps, i.e. species of the genera *Pinus, Quercus, Alnus, Vaccinium, Ledum, Frangula, Urtica, Convallaria, Achillea*. Such species are put on the tax maps or are typical for certain agricultural lands. Based on the analysis of forest or land management data and surveyed habitats of the species are determined the percentage of

such communities within the determined area and then the estimated biological reserve of raw material.

Much more difficult task is to detect potential raw plots for species, distributed fragmentarily or singly, such *Acorus calamus, Nymphaea alba, Polygonatum spp., Rosa spp., Crataegus spp., Berberis spp., Potentilla erecta, Polygonum bistorta, Polygonum persicaria etc*. The selective approach combined with extrapolation is more frequently applied for these species.

Raw habitats of such species are often found during expeditions when examining the potential raw locations for the specified type of areas. The raw weight indices, which, in case of statistically reliable sample size, can be extrapolated to environmentally and coenotic similar areas with the further estimation of the approximate raw reserve in a particular area, are determined on the surveyed plots. This approach provides an approximate data on biological resources and can be used for species that are not subjected to the strict limitation for special application of their raw material. In addition, extrapolation is allowed only in case of the examining a large number of a particular plant habitats and its ecocoenotic affinity. For example, even if it is known that the appropriate forest plant conditions are suitable for the growth of *Helichrysum arenarium*, and it grows within a given forest area of about 40 hectares, it is necessary to lay at least 20 registration plots in different parts of the array to obtain statistically reliable data in relation to the raw material resources. This also concerns *Thymus marschallianus, Potentilla erecta, etc*.

In evaluation of phytoresources of any species within the administrative region or natural zone, it is optimal to use a combination of extrapolation and sampling (selective) approaches. For instance, evaluation the resources of *Acorus*

calamus, it is not always convenient to perform evaluation works throughout its growth area, especially when the species grows on both banks of a river (Fig. 9). In such cases, the registration plots are laid along one bank, where weight indicators are established, which are then extrapolated to an array on the opposite bank. The area of the latter is determined visually or applying cartographic materials.

The main and the most important indices of resource evaluation is determination of the raw array (brushwood) square and density of raw material reserve (sometimes the terms «yield» or «productivity» are used).

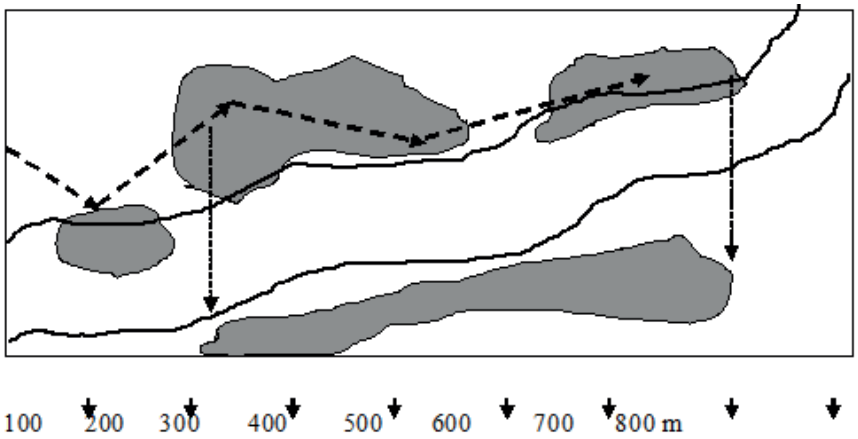


Fig. 9. Approximate route (_ _) and location of experimental plots (→) for evaluation the resources of Acorus calamus along the river. Extrapolation of resource indices to the array on the opposite bank (↓)

Methods of plant resources evaluation in the field

Among the methods for evaluation of plant resources the leading positions have the traditional specific evaluation methods performed directly in the field (registration areas and plots, transects, model specimens, etc.). The application

of these methods provides the most objective data on biological resources for raw of valuable plant species in the localities. However, the use of this method is appropriate only in rare cases where it is necessary to determine available phytoresources in a particular area. Resource assessment by these methods is time-consuming and quite laborious.

Method of registration areas and plots

According to the draft route, a survey of potential habitats of studied plant species is conducted. Registration (trial) areas and plots are laid on discovered arrays to account the raw material of the surveyed species according to determined criteria (account card). In Ukraine there is an elaborated an account card of plant resources (for medicinal, edible and other groups of useful plants). The primary account card comprises Ukrainian and Latin names of the species, type of raw material – the parts of a plant, that are harvested (roots, seeds, etc.).

Find below the characteristics of categories that describe the location, quantitative and qualitative state of the resources.

1. «Location» – indicates the name of the locality, for forests of forestry authorities – the forestry name and number of the quarter within which the community was observed.

2. «Landowner» – indicates the ownership of areas, where the plant communities occur: private, communal or state property (agricultural collective unit, the state forestry, wildlife reserve, national natural park, etc.).

3. «Vegetation type» – indicates the type of vegetation, which the plant communities belong to (forest, shrub, steppe, meadow, marsh, water, halophytic, arena, synanthropic). The descriptions of the main vegetation types are given below.

Forest	– vegetation, where trees are dominant in communities, except for suppressed trees on sphagnum bogs
Shrubby	– plant communities, where shrubs dominate

Steppe	– open herbaceous vegetation, dominated by sod grasses from dry habitats (xerophytes) with winter periods of rest (mainly species of genera Festuca and Stipa), sometimes shrubs
Meadow	– open herbaceous groups, where perennial grasses and sedges (Cyperaceae) of moderately wet habitats (mesophytes) are dominated
Marsh	– herbaceous, shrubby, woody and sphagnum communities of wetland (marsh) soils and peat bogs formed mainly in wetland habitats (helophyte)
The water	– open herbaceous communities formed by attached and free-floating hydrophytes
Halophytic	– open herbaceous, rarely semi shrub communities of saline soils (salt licks and salt marshes)
Arena	– open separate herbaceous communities of sands
Synanthropic	– a set of plants that grow on agricultural lands (segetal) and landfills (ruderal)

4. «Communities» – the name of the plant association is submitted (if it is possible).

5. «Environmental conditions» – provides a description of the habitat conditions of communities (topography, soil, humidity). Topography: plain, hilly, mountainous. Soils: bottom sediments (sandy, muddy, peaty), marsh (peaty, loamy, muddy, sandy), meadow (turf, peaty), forest (peaty, turf-podzolic, podzolic, chernozem podzol, light gray, gray, dark gray forest, brown forest, mountainous forest), black, salt, salt marshes and sandy. The degree of humidity: very dry, dry, moist, damp, wet. For aquatic vegetation data on a type of water basins (rivers, lakes, estuaries, artificial reservoirs etc.), the water thickness, in cm, and if it is possibly, eutrophication degree.

6. «Area» – the array area is presented. The universal unit of measurement is ha. An area less than a hectare is rounded to tenths and is given through a dot.

7. «Projecting cover» – states the projecting cover for herbaceous plants and semi-bushes. Unit of measurement – %. For shrubs and trees the number of individuals is given per area unit. Typically, it is a measure of the number of individuals per 0.1 hectare or per hectare; the specified area is pointed out.

8. «Density of the reserve» – the results of weighing raw material (fresh) per area unit. Unit of measurement – g\m^2 or kg\ha. The first expression is used for species if density of the stock is less than one kilogram to 0.01 ha. For data processing and the determination of biological reserve (stock) of raw material in a specified array, there is an important presentation of density for the reserve of the raw material in units kg\ha.

9. «Anthropogenic load» – human pressure within a specified array, namely pasture, hayfield, recreation, industrial area etc is described. If necessary, the degree of burden is provided: weak, moderate, strong. If the research is carried out in terms of wildlife reserve mode, the name of the protected area is also provided.

10. «Notes» – information on the need for regime change of the resource uses within a specified area and the results of assessment of the population is recorded. For instance, if the state of the population is unsatisfactory, the plants are blasted, then the use of resources should be terminated.

The main factor that affects the state of resources is lowering of the water level, which leads to reduced productivity. When a resource evaluation is carried out with the purpose of research, the reverse side of the card is filled in with geobotanic description.

The inventory provides data on: general projecting cover, list of species, layering, projecting cover of each surveyed medicinal plant species, also are noted rare species. If the species identity is difficult to determine, its generic name can be written.

An example:

LOCATION: right-hand slopes of the river Southern Bug, near farmstead Lviv, the slope of the north-eastern exposure

COMMUNITY: *Stipeto (capillatae) – Festucetum (vales.)*

General projecting cover: 80 %

I layer – up to 60 cm	***II layer – up to 40 cm***
Stipa capillata 10 %	*Eryngium campestre 1*
Stipa sp.1	*Senecio jacobae 1*
Festuca valesiaca 1	*Trifolium sp. 10 %*
Festuca stepposa1	*Medicago romanica 2*
Euphorbia agraria 1	*Plantago stepposa 1*
Agropyron pectinatum1	*Scabiosa ochroleuca 1*
Artemisia marschalliana 2	*Pulsatilla nigricans 1*
Salvia nutans 5 %	*Aster amelloides 5 %*
Campanula glomerata 1	*Veronica steppacea 1*
Betonica officinalis 1	*Thalictrum 1*
Caragana frutex 3	*Taraxacum 1*
Filipendula vulgaris 1	*Polygala-1*
	Asperula1
III layer – up to 20 cm	*Sedum ruprechtii 1*
Potentilla argentea 2	*Sempervivum ruthenicum 2*
Fragaria viridis 1	*Galium verum 2*
Thymus dimorphus 5 %	*Teucrium polium 2*
Convolvulus 1	*Helichrysum arenarium 1*
Artemisia austriaca 1	*Adonis vernalis 5 %*

To account the plant materials depending on the growth characters of species, the registration plot with evaluation sections (Fig. 10) or trial sites on the transects (Fig. 11) are laid.

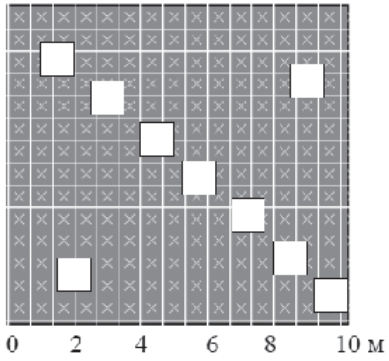


Figure 10. Placement of evaluation plots for unified type of growth

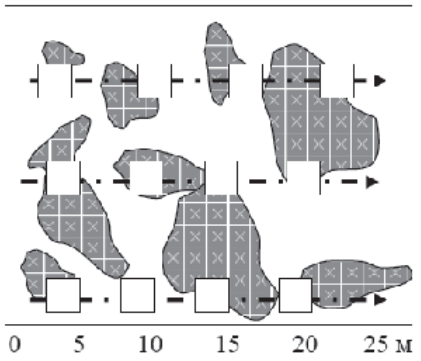


Figure 11. Placement of evaluation plots sites on the transects for fragmentary growth

The method of geobotanic description depends from the type of vegetation. Description of the forest vegetation is carried out as follows: stand, underbrush, herbaceous-subshrub or herbaceous, moss, lichen layers. In descriptions of the wood layer, as a combination of trees that form more or less homogeneous forest areas, should be indicated composition, layering, crown density, and average height. According to their composition, forest wood layers (stands) are divided into pure (formed by one species, the admixture of each of the other species is less than 10 %) and mixed (formed by two or more species, the admixture of at least one species comprises more than 10 %). Composition of the stand is recorded by taxation formula that reflects the proportion of its species. The contribution of each wood species in mixed stands is estimated in a ten point scale. For example, 6P4O+B rA; means that stands contains about 60 % of pine, 40 % of oak, birch as an admixture (more than 5 % but less than 10 %) and rarely aspen (*Populus tremulus*) trees (1-2 %). According to layering the stands are classified as single-layer stands (all the trees in a forest stand are approximately of the same height) and multi-layer stands

(crown are placed in two or more levels. As a separate layer is considered a part of the synfolium, the average height of which is differed from the height of the upper layer within 20–50 %.

The undergrowth, formed by shade-tolerant shrubs, grows lower the stand. The descriptions of the undergrowth include the dominant species, crown density, average height. Dominant of the undergrowth is a quantitatively predominant woody species of all the plant taxons that grow in this layer. Crown density is determined visually by the size of the projections of shrub crowns as the unit fraction. The average height is determined visually from the set of trees in the plantation, referred as the main species, the main age generation and basic layer.

Herbaceous-subshrub layer descriptions include the list of species within evaluation area, the dominant species, projecting cover and average height.

The sizes of surveyed and evaluation areas (registration plots) are determined according to morphological and biological features of the investigated species, its placement within the plot. For medium and tall herbaceous plants and shrubs that rarely form homogeneous thickets the trial area comprises 100–500 m^2 with registration plots of 1–10 m^2. The plot sizes may vary depending on the character of the thicket placement. Number of plots is established at the rate of one per 1–2 ha of thicket. The minimum area of thickets, which is appropriate for conducting the quantitative estimation of raw materials, usually exceeds 0.5 ha; however, in case of fragmentary growth of species on the area exceeding 1 ha is allowed its resource estimation.

Placement of evaluation plots within trial areas can be arbitrary, although more reliable information is obtained by

placing them on the transects across the same intervals. The number of registration plots on trial sites varies in terms of 25. The estimated data on the number of sites needed to achieve sufficient accuracy of the results can be obtained on the basis of the difference between the minimum and maximum mass of material collected from registration plots within surveyed area. If on 15 laid plots minimum and maximum values differ no more than in 5–7 times, the number of sites might be terminated. When the difference reaches 15–20 times, it is necessary to lay additionally 15–20 plots.

Projecting cover method

Evaluation for raw material is usually made by methods of projecting cover and model specimens. The projecting cover method is useful while evaluation herbaceous materials and subshrub plants which form dense thickets. The wire square with 1 meter side, divided into 100 equal squares (Fig. 12), is placed systematically or randomly to plots repeating for 15–25 times. The projecting cover is defined according to the number of squares, closed by plants of the investigated species (projection of plant parts on the Earth's surface). Each time after determination of the projecting cover value the raw materials are weighed.

To determine the density of raw material resources (stocks), the «value» of a point, i.e. the weight of material for 1 % of estimated cover, corresponding to a single cell of a square, is set. Projecting cover of the studied plant on a plot is determined by calculating the arithmetic mean (for a more precise estimation it is necessary to count standard deviation or error of the arithmetic mean, as described below). By multiplying the average «value» of a point on the mean projecting cover, the density of the raw material reserve for the surveyed area and the array is determined.

Experienced plant resource scientists determine projecting cover visually.

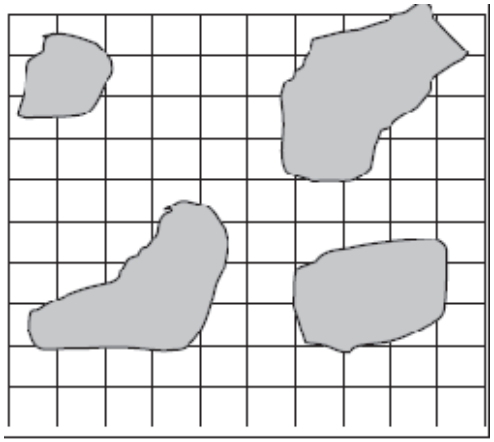


Figure 12. Determination of projecting cover surface by the grid

The area of the array is measured with a tape or by steps. During examination of large arrays, their area is determined using afforestation and land management plans.

To determine the density of the stock it is convenient to use calculation tables (for projection cover).

Method of model specimens

For resource estimation of shrub and woody plants (sometimes herbaceous, especially tall) a method of model specimens is applied. The term «model specimen» means the average by weight raw sample (or corm) of medicinal plant species, determined for a particular thicket or array.

In assessment of the yield (productivity) by to the method two parameters are set: the mass of raw material, derived from the model specimen, and the number of trade samples (corms) per area unit.

Individual raw samples are applied in cases if plants are relatively small and it is easy to detect specimen boundaries. If collection of raw materials requires the expenditure of much labor (trees, large shrubs) or its boundaries are difficult to determine, it is better to use as an evaluation unit a corm (or branch).

Estimation of the number of specimens (corms) is conducted on evaluation areas ranging in size from 10 to 50 m^2, the principles of laid for which are described in the previous section. However, in this case it is easier to count the number of trade samples (corms) in narrow (1–3 m wide) and elongated areas, called transects, laid along the route. In some cases, it is more convenient to lay the evaluation area of elongated form (2 x 50 or other). Raw specimens (or corms) for determination of the model specimen mass are selected from registration plots.

The most objective technique is systematic selection, when for estimation are taken each second, third, fifth or tenth specimen (corm) that occurs on the route. For each sample its raw part is weighed (xi) and then the average value of this indicator is calculated ($M = \sum x_1/N$). The number of specimens that accurately demonstrate the weight of the model plant is determined by the same principle (see above), applied for the number of evaluation areas (registration plots). Obviously, the value of the sample depends on the variation degree of the mass of raw materials of individual specimens.

On average, for determining the weight of underground parts or inflorescence it is sufficient to account 40–60 specimens. Since above-ground portions by weight vary more, the number of selected samples (shoots) is usually close to 100 or more.

In case of higher indices, it is advisable to reduce the size of plot, but the number of model specimens for raw

plant species cannot be less than 10. The raw of each model specimen is weighed; the average weight of raw material specimen and their number on the surveyed area are determined. While assessing the resources of woody plants, the raw materials are collected from single branches and recalculated per whole specimen. The density of the raw material reserve is received by multiplying the average weight of one material specimen (M) and their number per area unit.

The error of the arithmetic mean can be determined by the following formula:

$m_M = \sqrt{(\sum (x_1 - M)^2 / (N * (N - 1))}$,

where m_M – an error of the arithmetic mean;

$(\sum (x_1 - M)^2$ – the sum of squared deviations from the arithmetic mean;

N – size of surveyed sample [10].

Let's consider an example. 10 model corms of *Rhamnus cathartica* were selected from the registration plot. The bark from each corm was removed and the shoots were weighed (weight data are presented in the table):

i	1	2	3	4	5	6	7	8	9	10
x(g)	74,5	63,2	17,8	55,9	79,3	89,8	68,4	95,2	77,9	85

M = (74,5 + 63,2 + 17,8 + 55,9 + 79,3 + 89,8 + 68,4 + 95,2 + 77,9 + 85) / 10 = 70,7

An average weight of 1 buckthorn shoot is 70,7 g.

$\sqrt{((74,5 - 70,7)^2 + (63,2 - 70,7)^2 + (17,8 - 70,7)^2 + (55,9 - 70,7)^2 + (79,3 - 70,7)^2 + (89,8 - 70,7)^2 + (68,4 - 70,7)^2 + (95,2 - 70,7)^2 + (77,9 - 70,7)^2 + (85 - 70,7)^2) / 90}$

After calculations, according to the above formula, an error of arithmetic mean, its value 6.98, or approximately 7.0, is received. Thus, the average weight of buckthorn bark from one shoot comprises 70,7 ± 7 g.

Calculation of the error of arithmetic mean can be done in laboratory conditions using Microsoft Excel. In the common practice of the resource studies works, such calculations are often performed to determine the density of the reserve for species which have fragmented or scattered distribution.

In addition, the resource studies also might involve combined mathematical techniques aimed at increasing the reliability of results. In the fields are also used the tables to determine the weight indexes (Appendix, Tables 6–30).

In cases of fragmented or scattered distribution of investigated species (e.g., for a few km along the river) is determined the number of valuable raw material specimens with intervals of each 100 m repeating 5–10 times. According to cartographic materials the growth area of the investigated species is determined. Other calculations are similar to described above.

The appropriate parts of inventory sheets concerning the harvested material, prepared before the survey, and the date of investigation are filled. The raw material is collected and weighed, the received results are fixed in the account cards.

Features of determination of medicinal plant resources in wetland and coastal aquatic habitats

Carrying out of the resource survey works, the quite difficult task concerns resource evaluation for plants of wetland and coastal aquatic habitats, such as Nymphaea alba, *Nuphar luteum, Acorus calamus etc.* Their raw materials comprise underground organs, harvesting of which is labour consuming. The group also includes species that grow in shallow coastal waters of lakes, ponds; in wetland areas of floodplains, marshes, etc. (*Cicuta virosa, Comarum palustre, Filipendula denudata, Menyanthes trifoliata etc.*).

Several methodological approaches for evaluation of resources for these medicinal plants are described in literature. Most of them offer to lay the account sections 50 x 50 cm, which would cover an area of up to 10 % of raw arrays (with projecting cover more than 25 %) [13], although some studies have traditionally followed the 1 m^2 evaluation plots. In any case, evaluation resource surveys for aquatic macrophytes are rather labour-consuming, especially when raw materials comprise underground organs, so in practice the registration plots are placed in a statistically reliable number with accuracy within 15 % at a water depth up to 1.5 m with subsequent extrapolation upon the array area.

In most cases, thickets of the aforementioned medicinal herbs are characterized with small profiles or elongated along the coastline in more or less wide bands.

The presence of optimal environmental conditions plays an important role: the depth of the reservoir, siltation, the current velocities etc. Depending on the formation of the species thickets for the resource assessment are used various methodological approaches.

In cases of continuous or fragmentary overgrown ponds, that is typical for slow or standing water flow (bays, billabongs), the area is determined with a tape (on the boat or wading); for vast areas large-scale maps are used. If thickets located along the coast, it is necessary to lay the profiles along the entire watercourse (Fig. 9). The survey can be continuous when inspection is performed from a boat or coast within the entire shore for the presence of the studied plant species. Thus the evaluation is carried out on plots of at least 20 m^2. If there are species thickets occur more than 5 km, fragments are evenly investigated (at least 10 %), followed by extrapolation of the length of the watercourse, considering the growth characters of a

given species on individual segments. Processing field data, results of calculations on the mapped parts of the river (or other water bodies) are extrapolated into the missed area fragments taking into account these observations.

Express methods for evaluation of plant resources

In addition to the aforementioned items, in resource survey studies more attention is paid for search of ways and means to reduce the time expenditures during evaluation of the resources of economically important plants. Quantitative estimation of resources of valuable plant species is traditionally performed by methods of registration plots or model specimens, involved weighting of raw materials and subsequent extrapolation of the averaged data on the array area.

Procedures of cutting and weighing of raw materials usually takes a long time, which reduces the effectiveness of accounting works. Development and implementation of methods for rapid evaluation of resources of valuable raw materials are based on a statistical analysis of morphometric and weight characteristics of the appropriate populations that reduces the amount of survey time. Many resource scientists worked on rapid methods for evaluation of medicinal plant resources [1, 18, 30]. They have developed calculation tables for many species of medicinal plants (Appendix, Tables 6-8), but for numerous raw important species of medicinal and food plants, these rapid methods are still missing. The main reasons of it are slight dependency and significant dispersion of the variance values of morphometric and weight characteristics of the raw species, the small sample size of statistical data, and occurrence of sporadic growth.

The use of such materials provides a significant reduction of time, required to account the resources of valuable plant species in the field.

The laboratory stage

Basic calculations to determine the reserve of raw material is carried out after the termination of expedition works in laboratory conditions. Processing field data, biological and operational resources of a plant material are established, also an amount of allowable (possible) annual usage of particular arrays within appropriate administrative districts and regions. «Summary inventory for evaluation of resources» is filled in, the yield of the dry material (shrinking) is determined, card schemes of location of raw arrays are drawn.

The summary inventory for evaluation of plant resources is needed for data processing, obtained in field research: determination of the area of plant species arrays for a particular administrative district, biological and operational resources (stocks) of raw materials and the amount of allowable annual usage for a single array and an individual administrative district (region) as a whole.

Summary inventory for evaluation of resources

Plant species, raw material	Year of the survey
Region	District

Location village (forestry, sq.,) coordinates	Land owner	Area, ha	Biological reserve, t	Exploita-tive reserve, t	Amount of allowable annual usage, t
1	2	3	4	5	6

Number values of area, reserve and allowable annual usage are summarized for the administrative area and the

region as a whole. The maximum term for applying results of resource assessment of herbaceous plants, shrubs, bushes and semi-bushes to regulate the utilization of their raw materials comprises 5 years, for trees – 10 years. To update data on the resources of various plant species should be carried out recrudescent field surveys with the implementation of the aforementioned activities. This basic data for the recrudescent survey are inventory sheets of previous evaluation of the plant resources.

APPENDIX

Table 1

Production yield of dry medicinal material out of freshly harvested one; terms of storage and harvesting

№	Plant species	Medicinal plant material	Dry product yield, %	The maximum term of storage, years	Months for raw material collection
1	2	3	4	5	6
1	*Acorus calamus L.*	rhizomes	30	3	Sep-Oct
2	*Althaea officinalis L.*	roots	22	3	Apr-May, Sep-Oct
3	*Ledum palustre L.*	corms	32-36	2	Jun-Sep
4	*Vinca minor L.*	herb	50	2	May- Jun
5	*Atropa bella-donna L.*	leaves, herb, roots	14-16	2	Jun-Aug
6	*Betula spp.*	buds	40	2	Jan-Mar
7	*Menyanthes trifoliata L.*	leaves	17	2	Jun-Jul
8	*Vaccinium vitis-idaea L.*	leaves, corms	45	3	Mar-Jul
9	*Sambucus nigra L.*	flowers	18-20	3	May-Jun
10		fruits	15	2	Jul-Aug
11	*Melilotus officinalis L.*	herb	25	2	Jun-Aug

12	*Valeriana officinalis L.*	rhizomes with roots	25	3	Apr-May, Sep-Oct
13	*Alnus spp.*	fruits	38-40	3	Aug-Apr
14	*Ononis arvensis L.*	roots	30-32	3	Sep-Oct
15	*Centaurea cyanus L.*	flowers	20	1	Jun-Aug
16	*Crataegus spp.*	flowers	18-20	1	May- Jun
17	*Persicaria hydropiper (L.) Delab.*	fruits	25	2	Aug-Oct
18		herb	20-22	2	Jun-Aug
19	*Bistorta officinalis L. (Polygonum bistorta L. Delabre)*	rhizomes	25	6	Aug-Sep
20	*Persicaria maculosa L. (Polygonum persicaria L. S.F.Gray)*	herb	20-22	2	Jun-Aug
21	*Polygonum aviculare L.*	herb	20	3	Jun-Sep
22	*Nuphar lutea (L.) Smith*	rhizomes	8-10	2	Jul-Aug
23	*Sorbus aucuparia L.*	fruits	-	2	Sep
24	*Capsella bursa-pastoris (L.) Medik*	herb	26-28	3	May-Aug
25	*Achillea spp.*	herb, flowers	22	2	Jun-Aug
26	*Verbascum spp.*	flowers	16-18	1	Jul-Aug
27	*Quercus robur L.*	bark	40	5	Apr-May
28	*Angelica sylvestris L.*	rhizomes with roots	20	2	Aug-Sep

1	2	3	4	5	6
29	*Datura stramonium L.*	leaves	16-18	2	Jun-Aug
30	*Rhamnus cathartica L.*	fruits	17	4	Aug-Oct
31	*Hypericum perforatum L.*	herb	30	3	Jun-Jul
32	*Centaurium erythraea Rafn.*	herb	25	2	Jun-Aug
33	*Viburnum opulus L.*	bark	40	4	Mar-May
34	*Convallaria majalis L.*	herb, leaves	20	1	May- Jun
35	*Urtica dioica L.*	flowers	14	1	May
36		leaves	22	2	Jun-Aug
37	*Frangula alnus Mill.*	bark	40	5	Apr-May
38	*Taraxacum officinale Webb ex Wigg.*	roots	33-35	5	Aug-Sep
39	*Zea majus L.*	styles	25	3	Jun-Sep
40	*Tilia cordata Mill.*	flowers	25	2	Jun-Jul
41	*Arctium lappa L.*	roots	26-28	-	Mar-Apr, Sep-Oct
42	*Origanum vulgare L.*	herb	25	1	Jun-Aug
43	*Rubus idaeus L.*	fruits	16-18	2	Jun-Jul
44	*Tussilago farfara L.*	leaves	15	2	May-Jul
45	*Saponaria officinalis L.*	inflorescence	15	1	Mar-Apr
46		rhizomes	30-32	-	Jun-Aug

47	*Arctostaphylos uva-ursi (L.) Spreng.*	leaves	50	5	May, Jun, Sep, Oct
48	*Digitalis grandiflora Mill.*	leaves	19-20	1	Jun-Aug
49	*Inula helenium L.*	rhizomes with roots	30	2	Aug-Sep
50	*Viscum album L.*	corms	fresh raw	1	Jul
51	*Herniaria glabra L.*	herb	22-25	2	May-Aug
52	*Primula veris L.*	rhizomes with roots	28-30	2	Aug-Sep
53	*Potentilla erecta (L.) Rausch*	leaves	22-23	2	Apr-May
54		rhizomes	28-32	6	Apr-May, Sep-Oct
55	*Tanacetum vulgare L.*	inflorescences	25	3	Jul-Aug
56	*Lycopodium clavatum L.*	spores	6-7	10	May-Sep
57	*Plantago major L.*	leaves	25-30	2	May-Sep
58	*Artemisia absinthium L.*	herb, leaves	22	2	Jun-Aug
59	*Sanguisorba officinalis L.*	rhizomes with roots	25	5	Aug-Sep
60	*Polemonium coeruleum L.*	rhizomes with roots	30-32	-	Aug-Sep
61	*Leonurus villosus Desf. ex D'Urv (L.quinquelobatus), L.cardiaca L.*	herb	25	3	Jun-Sep
62	*Glycyrrhiza glabra L.*	roots	-	10	Aug-Sep
63	*Pinus sylvestris L.*	buds	40	2	Jan-Feb

1	2	3	4	5	6
64	*Fragaria vesca L.*	leaves	20	1	May- Jun
65	*Gnaphalium uliginosum L.*	herb	23-25	3	Jul-Aug
66	*Viola tricolor L.*	herb	20	2	May-Aug
67	*Matricaria recutita L.*	flowers (inflorescences)	20	1	May-Sep
68	*Equisetum arvense L.*	herb	25	4	Jun-Jul
69	*Helichrysum arenarium (L.) Moench*	flowers (inflorescences)	25-30	3	Jun-Aug
70	*Hierochloe odorata (L.) Beauv.*	herb	50	2	Jun-Aug
71	*Thymus spp.*	herb	25-28	1	Jun-Aug
72	*Veratrum lobelianum Bernh.*	rhizomes with roots	25	3	Sep-Oct
73	*Bidens tripartita L.*	herb	15	2	Jun-Aug
74	*Chelidonium majus L.*	herb	23-25	3	May-Jul
75	*Vaccinium myrtillus L.*	fruits	13	2	Jun-Aug
76	*Salvia officinalis L.*	leaves	25-30	1	Jun-Aug
77	*Rosa majalis Herrm.*	fruits	32-35	2	Aug-Sep
78	*Rumex confertus Willd.*	roots	-	3	Sep-Oct
79	*Juniperus communis L.*	pseudofruits	30	3	Sep-Oct

Note. Name of months are abbreviated by the first three letters

Table 2

The periodicity of harvesting of medicinal plant materials

№	Medicinal plant species	The periodicity of		Total
		exploitation (years)	populations (years)	
1	2	3	4	5
1	*Acorus calamus L.*	1	5-8	6-9
2	*Althaea officinalis L.*	1	5-6	6-7
3	*Ledum palustre L.*	1	2	3
4	*Vinca minor L.*	1	5-7	6-8
5	*Menyanthes trifoliata L.*	1	3-5	4-6
6	*Vaccinium vitis-idaea L.*	1	3-4	4-5
7	*Sambucus nigra L.*	annually		
8	*Melilotus officinalis L.*	1	1	2
9	*Valeriana spp.*	1	5	6
10	*Ononis arvensis L.*	1	6-7	7-8
11	*Centaurea cyanus L.*	annually		
12	*Crataegus spp.*	annually		
13	*Polygonum persicaria L. S.F.Gray*	1	1	2
14	*Polygonum bistorta L. Delabre*	1	5	6
15	*Polygonum aviculare L.*	annually		
16	*Nuphar lutea (L.) Smith*	1	7-10	8-11
17	*Capsella bursa-pastoris (L.) Medik*	annually		
18	*Achillea spp.*	annually		
19	*Rhamnus cathartica L.*	annually		
20	*Hypericum perforatum L.*	1	2-3	3-4
21	*Centaurium erythraea Rafn.*	1	2	3

1	2	3	4	5
22	*Viburnum opulus L.*	1	10	11
23	*Convallaria majalis L.*	1	3-4	4-5
24	*Verbascum spp.*	annually		
25	*Urtica dioica L.*	annually		
26	*Frangula alnus Mill*	1	3-5	4-6
27	*Taraxacum officinale Webb ex Wigg*	annually		
28	*Tilia cordata Mill.*	annually		
29	*Origanum vulgare L.*	1	3-4	4-5
30	*Tussilago farfara L.*	1	1	2
31	*Saponaria officinalis L.*	1	1	2
32	*Arctostaphylos uva-ursi (L.) Spreng.*	1	3-4	4-5
33	*Digitalis grandiflora Mill.*	1	1	2
34	*Viscum album L.*	annually		
35	*Herniaria glabra L.*	1	2	3
36	*Primula veris L.*	1	3	4
37	*Potentilla erecta (L.) Rausch*	1	4	5
38	*Tanacetum vulgare L.*	1	1	2
39	*Lycopodium clavatum L*	1	1	2
40	*Plantago major L*	1	1	2
41	*Artemisia absinthium L.*	1	1	2
42	*Sanguisorba officinalis L.*	1	5	6
43	*Polemonium coeruleum L.*	1	5	6
44	*Leonurus villosus Desf. ex D'Urv. (L. quinquelobatus)*	1	1	2
45	*Glycyrrhiza glabra L.*	1	3-4	4-5
46	*Fragaria vesca L.*	1	1	2

47	*Gnaphalium uliginosum L.*	1	2	3
48	*Viola tricolor L.*	annually		
49	*Matricaria recutita L.*	annually		
50	*Equisetum arvense L.*	annually		
51	*Helichrysum arenarium (L.) Moench*	1	1-2	2-3
52	*Thymus spp.*	1	2-3	3-4
53	*Veratrum lobelianum Bernh.*	1	3-4	4-5
54	*Bidens tripartita L.*	annually		
55	*Chelidonium majus L.*	1	1	2
56	*Salvia officinalis L.*	1	2-3	3-4
57	*Rosa spp.*	annually		
58	*Juniperus communis L.*	annually		

Table 3

Medicinal plants of Ukraine, their application and protection

№	Plant species	Medicinal plant material	State of resources	Protection
1	2	3	4	5
1.	*Acorus calamus L.*	rhizomes	-	RPnb
2.	*Arnica montana L.*	inflorescens	0	RPnb
3.	*Astragalus dasyanthus Pall.*	herb	0	RDBU
4.	**Althaea officinalis L.*	roots	-	RPnb
5.	*Ledum palustre L.*	corms	=	RPnb
6.	*Huperzia selago (L.) Bernh. ex Schrank & Mart*	herb	0	RDBU
7.	*Vinca minor L.*	herb	=	RP, RPnb

1	2	3	4	5
8.	*Atropa bella-donna L.*	leaves, herb, roots	0	RP
9.	*Betula spp.*	buds	+	
10.	*Menyanthes trifoliata L.*	leaves	=	RP, RPnb
11.	*Vaccinium vitis-idaea L.*	leaves, corms	-	RPnb
12.	*Sambucus nigra L.*	flowers, fruits	+	
13.	**Valeriana officinalis L.*	rhizomes with roots	-	
14.	*Alnus spp.*	fruits	+	
15.	**Ononis arvensis L.*	roots	-	
16.	*Centaurea cyanus L.*	flowers	+	
17.	*Crataegus spp.*	flowers, fruits	+	
18.	*Polygonum hydropiper L.*	herb	+	
19.	*Polygonum bistorta L. Delabre*	rhizomes	=	RP
20.	*Adonis vernalis L.*	herb	=	RDBU
21.	*Sorbus aucuparia L.*	fruits	+	
22.	**Aronia melanocarpa L.*	fruits	+	
23.	*Capsella bursa-pastoris (L.) Medik*	herb	+	
24.	*Achillea spp.*	herb, flowers	+	
25.	*Verbascum spp.*	flowers	-	
26.	*Quercus robur L.*	bark	+	
27.	**Echinacea purpurea (L.) Moench*	roots, herb		
28.	*Rhamnus cathartica L.*	fruits	-	
29.	**Hypericum perforatum L.*	herb	+	

30.	*Centaurium erythraea Rafn.*	herb	=	RP
31.	**Solidago canadensis L.*	herb	+	
32.	**Viburnum opulus L.*	bark	-	
33.	**Galega officinalis L.*	herb	=	RP
34.	*Convallaria majalis L.*	herb, leaves, flowers	–	RP
35.	*Urtica dioica L.*	leaves	+	
36.	*Frangula alnus Mill.*	bark	+	RPnb
37.	*Taraxacum officinale Webb ex Wigg.*	roots	+	
38.	*Tilia cordata Mill.*	flowers	+	
39.	*Arctium lappa L.*	roots	+	
40.	*Origanum vulgare L.*	herb	-	RP
41.	*Tussilago farfara L.*	leaves, inflorescence	+	
42.	*Arctostaphylos uva-ursi (L.) Spreng.*	leaves	0	RP
43.	**Calendula officinalis L.*	inflorescences		
44.	**Hippophaë rhamnoides L.*	fruits	+	
45.	**Inula helenium L.*	rhizomes with roots	=	RP
46.	*Primula veris L.*	rhizomes with roots, leaves	=	RP
47.	*Potentilla erecta (L.) Rausch*	rhizomes	-	RP
48.	*Tanacetum vulgare L.*	inflorescences	+	

1	2	3	4	5
49.	*Lycopodium clavatum L.*	spores	=	RP
50.	*Plantago major L.*	leaves	+	
51.	**Plantago psyllium L.*	herb, seeds	+	
52.	*Artemisia absinthium L.*	herb, leaves	+	
53.	*Rhodiola rosea L.*	rhizomes	0	RDBU
54.	*Sanguisorba officinalis L.*	rhizomes with roots	=	RPnb
55.	**Silybum marianum (L.) Gaertn.*	fruits		
56.	*Polemonium coeruleum L.*	rhizomes with roots	=	RP
57.	**Leonurus villosus Desf. ex D'Urv (L.quinquelobatus)*	herb	+	
58.	*Glycyrrhiza glabra L.*	roots	0	RDBU
59.	*Pinus sylvestris L.*	buds	+	
60.	*Polygonum aviculare L.*	herb	+	
61.	*Gnaphalium uliginosum L.*	herb	-	RPnb
62.	*Viola tricolor L.*	herb	+	
63.	*Chamaerion angustifolium (L.) Schur*	herb	+	
64	*Matricaria recutita L.	flowers (inflorescences)	+	
65.	Equisetum arvense L.	herb	+	
66.	*Helichrysum arenarium (L.) Moench	flowers (inflorescences)	-	

67.	Thymus spp.	herb	=	RPnb
68.	*Bidens tripartita L.	herb	+	
69.	Chelidonium majus L.	herb	+	
70.	Vaccinium myrtillus L.	fruits	+	
71.	*Salvia officinalis L.	leaves		
72.	*Rosa spp.	fruits	+	
73.	Juniperus communis L.	pseudofruits	+	

Notes. Resources:

+ significant resources requires limiting of collection;

- limited resources, the species requires limiting of collection;

= very limited resources, species require strict limitation of collection;

0 there are no resources, sufficient for harvesting;

* species is introduced, cultivated (cultivated medicinal plants in 1999).

Protection:

RDBU – the species is listed in the Red Data Book of Ukraine (2009);

RP - the protected species at the regional level;

RPnb – the species needs to be protected at regional level.

Table 4

Medicinal plant species, cultivated in Ukraine as sources of raw material

1. Achillea millefolium L. 2. Achillea nobilis L. 3. Aerva lanata (L.) Juss * 4. Agrimonia eupatoria L. 5. Althaea officinalis L.	61. Leonurus quinquelobatus Gilib. 62. Levisticum officinale Koch * 63. Linum usitatissimum L. *

6. Ammi majus L.*	64. Lophanthus anisatus Adans. *
7. Ammi visnaga (L.) Lam*	65. Majorana hortensis Moench
8. Anethum graveolens L. *	66. Marrubium vulgare L.
9. Anisum vulgare Gaertn. (Pimpinella anisum L.)*	67. Melilotus officinalis (L.) Lam.
10. Anthemis tinctoria L	68. Melissa officinalis L *
11. Arctium lappa L	69. Mentha longifolia (L.) Huds.
12. Armoracia rusticana P.G. Gaertn. *	70. Mentha piperita L*
13. Aronia melanocarpa L.*	71. Monarda media L*
14. Artemisia absinthium L.	72. Monarda fistulosa L. *
15. Artemisia annua L.	73. Nepeta cataria. L.
16. Astragalus dasyanthus Pall.	74. Nepeta grandiflora MB
17. Astragalus falcatus Lam*	75. Nepeta transcaucasica L.*
18. Atropa belladonna L.	76. Nicotiana restica L*
19. Bidens tripartita L.	77. Nicotiana tabacum L. *
20. Brassica juncea (L.) Czern (Sinapis juncea L.)	78. Nigella damascena. L. *
21. Brassica nigra (L.) Koch	79. Nigella sativa L*
22. Calendula officinalis L*	80. Ocimum basilicum L*
23. Carthamus lanatus L. *	81. Oenothera biennis L.
24. Carthamus tinctorius L.*	82. Ononis arvensis L.
25. Carum carvi L	83. Origanum vulgare L.
26. Centaurea cyanus L.	84. Panax ginseng C.A. Meyer*
27. Chamomilla recutita (L.) Rauschert	85. Papaver somniferum L. *
28. Chelidonium majus L	86. Pastinaca sativa L. *
29. Cichorium intybus L.	87. Petroselinum crispum (Mill.) A.W.Hill. (P. sativum Hoffm.) *
30. Cnicus benedictus L. *	88. Phytolacca americana L*
31. Conium maculatum L	89. Plantago lanceolata L.
32. Coriandrum sativum. L.	90. Plantago major L
33. Datura stramonium L	91. Plantago psyllium L.
34. Daucus carota L.	92. Polemonium coeruleum L
35. Desmodium canadense L. *	93. Rhaponticum carthamoides Willd. *
36. Digitalis lanata Ehrh*	94. Rheum officinale Baill. *
37. Digitalis purpurea L. *	
38. Dioscorea caucasica Lipsky*	
39. Dioscorea nipponica Makino	
40. Dracocephalum moldavica L.*	

41. Echinacea angustifolia DC*	95. Ricinus communis L. *
42. Echinacea atrorubens Nutt) * *	96. Rosa spp.
43. Echinacea pallida Nutt. *	97. Rubia tinctorum L*
44. Echinacea purpurea (L.) Moench. *	98. Rumex acetosa L
45. Echinops ritro L.	99. Rumex confertus Willd.
46. Echinops sphaerocephalus L.	100. Ruta graveolens L*
47. Erysimum canescens Roth. *	101. Salvia officinalis. L. *
48. Erysimum cheiranthoides L. *	102. Satureia hortensis L. *
49. Faba vulgaris L*	103. Scutellaria baicalensis Georgi*
50. Fagopyrum esculentum Moench *	104. Securinega suffruticosa (Pall.) Rehder*
51. Foeniculum vulgare Mill. *	105. Sinapis alba L*
52. Galega officinalis L.	106. Solidago canadensis L
53. Glaucium flavum Crantz. *	107. Stevia rebaudiana Bertoni*
54. Glycyrrhiza glabra L.	108. Sylibum marianum (L.) Gaerth*
55. Grindelia squarrosa. (Pursh) Dun.	109. Taraxacum officinale Wigg
56. Helichrysum arenarium (L.) Moench	110. Thymus serpyllum L*
57. Hypericum perforatum L	111. Trigonella foenum-graecum L. *
58. Hyssopus officinalis L*	112. Valeriana officinalis L. s.l.
59. Inula helenium L.	113. Viburnum opulus L.
60. Lavandula angustifolia Mill. (L. officinalis Chaix) *	

Note. * - the species grows in Ukraine predominantly on plantations, sometimes occur as wild. In italics are listed species whose raw materials in 2011 were grown in significant volumes (more than 20 tons).

Table 5

The medicinal plants listed in the State Pharmacopoeia of Ukraine

Plant species	Raw material	*Availability of the resources	Reference to the SPU
1	2	3	4
Althaea officinalis L.	roots, leaves, herb	-, c	1.2

1	2	3	4
Pimpinella anisum L.	fruits	c	1.2
Arachis hypogaea L.	shelled seeds	c	1.2
Gossypium hirsutum L. or other Gossypium spp,	seeds	i	
Menyanthes trifoliata L.	leaves	-	1.2
Sambucus nigra L.	flowers	+	1.2
Valeriana officinalis L. s.l.	rhizomes with roots	-, c	1.2
Ononis spinosa L.	roots	-, c	1.2
Syzygium aromaticum (L.) Merill et L.M.Perry (Eugenia caryophyllus (C.Spreng.) Bull. et Harr).	flowering buds	i	1.2
Hibiscus sabdariffa L.	calyces	i	1.2
Ginkgo biloba L.	leaves	c, i	1.2
Crataegus monogyna Jacq. C. laevigata (Poir.) DC. The use of C. sanguinea, C.korolkowii C.chlorocarpa C.dahurica C.alemanniensis C.pentagyna C.orientobaltica C.curvisepala C x curonica C x dunensis or their hybrids is also allowed	fruits	+ + i i i i i + i + i i	1.2

Achillea millefolium L.	herb	+, c	1.2
Eucalyptus globulus Labill.	leaves	i	1.2
Eucalyptus globulus Labill. E. polybractea R.T.Baker E. smithii R.T.Baker	fresh leaves and fresh top corms	i i i	1.2
Hypericum perforatum L. H.maculatum Crantz (H. quadrangulum auct. non L.	herb	+, c +	1.2
Cocos nucifera L.	the solid part of the endosperm	i	
Cinnamomum cassia Blume (C. aromaticum Nees)	leaves and young branches	i	1.2
Cinnamomum zeylanicum Nees (C. verum J.S.Presl.)	bark	i	1.2
Cinnamomum verum J.S.Presl.	leaves	i	1.2
Sesanum indicum L.	seeds	i	1.2
Lavandula angustifolia Mill. (L. officinalis Chaix)	flowers	c, i	1.2
Citrus limon (L.) Burman fil.	fresh mesocarp	i	1.2

1	2	3	4
Tilia cordata Mill. T. platyphyllos Scop. T x vulgaris Heyne	flowers (inflorescens)	+, c +, c c	1.2
Olea europaea L.	fruits	i	1.2
Prunus dulcis (Mill.) D.A.Webb var. dulcis Prunus dulcis (Mill.) D.A.Webb var. amara (DC.) Buchheim	seeds	i i	1.2
Calendula officinalis L.	flowers (inflorescens)	c	1.4
Passiflora incarnata L.	above-ground parts, flowers, fruits	i	1.2
Triticum aestivum L.	endosperm	c	
Rosmarinus officinalis L.	flowering aerial parts	c, i	1.2
Leonurus cardiaca L. L. quinquelobatus Gilib.	herb	+ +	1.2
Glycine soya Seeb. et Zucc.			
G. max (L.) Merr. (G. hispida (Moench) Maxim.	seeds	c c	
Glycyrrhiza glabra L. G. inflata Bat. G.uralensis Fisch.	roots	p, c, i i i	1.2

Melaleuca alternifolia (Maiden et Betch) Cheel M. linariifolia Smith M.dissitiflora F.Mueller	leaves and top corms	i i i	1.2
Chelidonium majus L.	herb	+, c	1.2
Atropa belladonna L.	leaves and flowering tops	p, c, i	1.3
Ascophyllum nodosum L Jolis. Fucus vesiculosus L. F. serratus L.	thalli	i i i	1.3
Crataegus monogyna Jacq. (Lindm.), C. laevigata (Poir.)DC. C. nigra Waldst. et Kit. C. pentagyna Waldst. et Kit. ex Willd. C. azarolus L.	leaves and flowers	+ + i + i	1.3
Echinacea pallida Nutt	roots	c	1.3
Echinacea angustifolia DS	roots	c	1.3
Echinacea purpurea (L.) Moench.	roots, herb	c	1.3
Cassia angustifolia Vahl.	fruits	i	1.3
Cassia senna L. (C. acutifolia Delile)	fruits, leaves	i	1.3

1	2	3	4
Urtica dioica L. Urtica urens L.	leaves	+ +	1.3
Origanum onites L. Origanum vulgare L. subsp. hirtum (Link) Ietsw. Origanum vulgare L.	herb	i +, c +, c	1.3
Mentha x piperita	leaves	c	1.3
Plantago lanceolata L. s.l.	leaves	+, c	1.3
Matricaria recutita L. (Chamomilla recutita (L.) Rauschert)	flowers (inflorescens)	+, c, i	1.3
Polygonum aviculare L. s.l.	herb	+	1.3
Equisetum arvense L.	herb	+	1.3
Humulus lupulus L.	female inflorescences (cones)	c, +	1.3
Thymus vulgaris L. Thymus zygis L.	herb	c i	1.3
Thymus serpyllum L.s.l.	herb	+	1.3
Arnica montana L.	flowers (inflorescens)	-, i	1.4
Cynara scolymus L.	leaves	i	1.4
Betula pendula Roth Betula pubescens Ehrh.	leaves	+ +	1.4
Melilotus officinalis (L.) Lam. Melilotus altissimus Thuill.	herb	+, c -, +	1.4

Verbena officinalis L.	herb	+	1.4
Vitex agnus castus L.	fruits	i	1.4
Hamamelis virginiana L.	leaves	i	1.4
Hydrastis canadensis L.	rhizomes	i	1.4
Quercus robur L. Q. petraea (Matt.) Liebl Q. pubescens Willd.	bark	+ + +	1.4
Datura stramonium L.	leaves	c, +	1.4
Illicium verum Hooker fil.	fruits	i	1.4
Zingiber officinale Roscoe	rhizomes	i	1.4
Rhamnus purshiana DS (Frangula purshiana (DS) A. Gray).	bark	i	1.4
Cola nitida (Vent) Schott et Endl. (C. vera) C. acuminate (P.Beauv.) Schott et Endl	seeds	i i	1.4
Cinnamomum verum J. Presl.	bark	i	1.4
Coriandrum sativum L.	fruits	c	1.4
Frangula alnus Miller. (Rhamnus frangula L.)	bark	+	1.4
Curcuma xanthorrhiza Roxb.	rhizomes	i	1.4
Laminaria japonica Aresch			

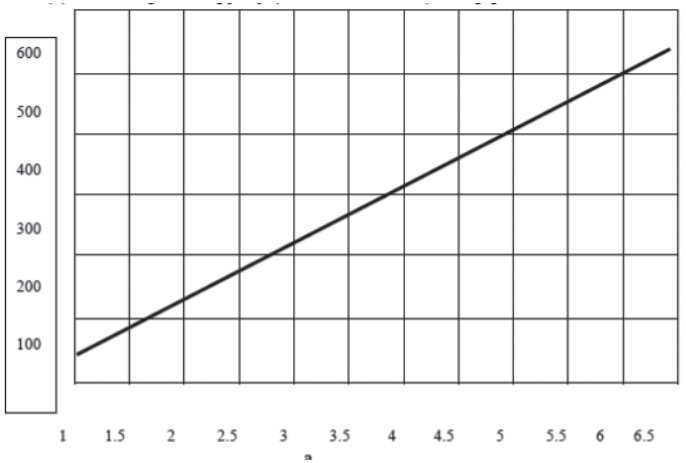
1	2	3	4
L. saccharina (L.) Lam.	thalli	i i	1.4
Commiphora molmol Engler	resin	i	1.4
Arctostaphyllos uva-ursi (L.) Spreng.	leaves	-,i	1.4
Digitalis purpurea L.	leaves	c	1.4
Potentilla erecta (L.) Raeusch. (P. tormentilla Stokes.).	rhizomes	+	1.4
Plantago major L.	leaves	+	1.4
Artemisia absinthium L.	herb	+	1.4
Citrus aurantium L. ssp. aurantium (C. aurantium L. ssp. amara Engl.)	endocarp and mesocarp of the ripe fruits	i	1.4
Alchemilla vulgaris L. s. l.	herb	+	1.4
Krameria triandra Ruiz et Pavon	roots	i	1.4
Chamaemelum nobile L.) All. (Anthemis nobilis L.)	flowers (inflorescens)	c, i	1.4
Silybum marianum (L.) Gaertner.	fruits	c	1.4
Ruscus aculeorus L.	rhizomes	i	1.4
Capsicum annuum L. var. minimum (Miller.) Heiser C. frutescens L.	fruits	+ +	1.4
Gentiana lutea L.	roots	p	1.4

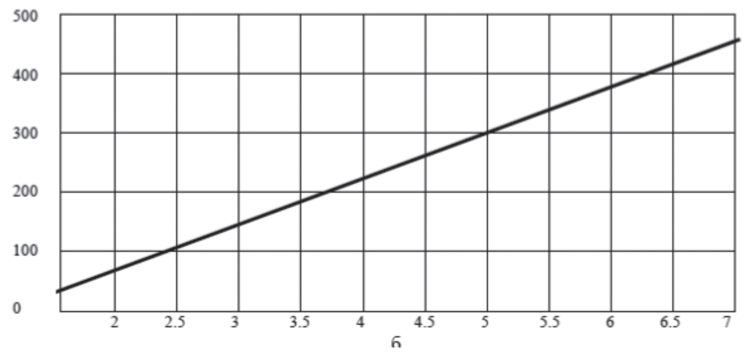
Cinchona pubescens Vahl. (Cinchona succirubra Pav.), C. calisaya Wedd., C. ledgeriana Moens ex Trimen	bark	i	1.4
Centella asiatica (L.) Urban.	herb	i	1.4
Cymbopogon winterianus Jowirr.	herb	i	1.4
Salvia officinalis L.	leaves	c, i	1.4

*Note: «c» – the plant is cultivated for the raw material; «+» – the natural resources are sufficient to use; «-« – the natural resources are limited; «p» – the species is under protection, «i» – the raw material is being imported

Table 6

Dependence of the mass of freshly harvested bark of the raw corms of Frangula alnus Mill. (along the axis of the ordinates, g) from its diameter at the level of : (a) 100 cm and (b) 5 cm above the surface of the soil (on the abscissa axis, cm) * [1]





*Note: The average mass of raw bark corms is 61.0 +- 35 g / pc

Table 7

Determination of the density of raw material reserve (yield, or productivity) of annual corms of Ledum palustre according to their projecting cover [13]

Density of raw material reserve (yield, productivity)	Projecting cover, %							
	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
fresh weight, g/m^2	55-85	93-123	130-160	169-200	207-237	245-275	283-313	321-351
air-dried weight, kg/ ha	250	380	500	640	770	910	1040	1180

Table 8

Determination of productivity of the leafy corms of Thymus marschallianus Willd. and T. serpyllum L. in accordance with their projecting cover [13]

Productivity	Projective cover, %								
	6–10	11–15	21–25	26–30	31–35	36–40	41–45	46–50
fresh weight, g / m^2	24–40	44–60	64–80	84–100	104–120	124–136	140–156	160–176
air-dried weight, kg / ha	80	130	180	230	280	325	370	420

Table 9

Determination of productivity of the leafy corms of Vaccinium vitis-idaea L. and Vaccinium myrtillus L. according to their projecting cover [13]

Productivity	Projecting cover, %					
	5-9	10-14	1519	2024	25-29	30-34
Vaccinium vitis- idaea L.						
fresh weight, g / m^2 air-dried weight, kg / ha	40-64 230	70-94 370	100-124 500	130-154 640	160-184 770	190-214 910
Vaccinium myrtillus L.						
fresh weight, g / m^2 air-dried weight, kg / ha	34-50 140	54-70 200	74-90 270	94-100 340	114-130 400	134-150 470

Productivity	Projecting cover, %					
	35-39	40-44	45-49	50-54	55-59	30-34
Vaccinium vitis-idaea L.						
fresh weight, g / m^2 air-dried weight, kg / ha	220-224 1040	250-274 1180	280-304 1310	310-334 1450	340-365 1580	190-214 910
Vaccinium myrtillus L.						
fresh weight, g / m^2 air-dried weight, kg / ha	154-170 540	174-190 600	194-210 670	214-230 740	234-250 800	134-150 470

Table 10

Species of medicinal plants from the State Register of Medicines in Ukraine for the period from 2014 to 2018, which are components of allopathic and homeopathic remedies

(Species are presented from the largest number of remedies to the smallest)

№	Name of medicinal plant	Number of remedies from plants raw material of		Sourse of medicinal plants material in Ukraine		
		domestic origin	foreign origin	wild plants	cultivated plants	import raw material or substantion
1	2	3	4	5	6	7
1	Leonurus quinquelobatus Gilib.	76	4	+	+	
2	Mentha piperita L.	72	26		+	
3	Valeriana officinalis L.	67	23/1*	+	+	
4	Crataegus monogyna Jacq. (Lindm.)	58	14/7	+		+
5	Humulus lupulus L.	55	6	+	+	
6	Calendula officinalis L.	53	2/7		+	+
7	Matricaria chamomilla L.= Chamomilla recutita (L.) Rauschert	41	11/13		+	+
8	Glycyrrhiza glabra L.	34	26		+	+
9	Hypericum perforatum L.	34	9/8	+		
10	Polygonum aviculare L.	28	3	+		
11	Eucalyptus viminalis Labill.	27	28			+
12	Althaea officinalis L.	26	10		+	
13	Achillea millefolium L.	25	6/4	+		
14	Atropa belladonna L.	17/3*	3/18		+	
15	Equisetum spp.	25	8/3	+		
16	Acorus calamus L.	23	4	+		
17	Rosa canina L.+ Rosa spp.	21	1	+		
18	Echinacea purpurea (L.) Moench.	20	6/18		+	
19	Thymus serpyllum L.	20	1	+		

1	2	3	4	5	6	7
20	Betula pendula Roth	20	3/1	+		
21	Urtica dioica L.	19	1	+		
22	Chelidonium majus L.	18/1	1/7	+		
23	Salvia officinalis L.	17	5/1		+	
24	Styphnolobium japonicum (L.) Schott =Sophora japonica L.	16			+	
25	Melissa officinalis L.	15	16		+	
26	Helichrysum arenarium (L.) Moench	15		+		
27	Eleutherococcus senticosus (Rupr. & Maxim.) Maxim.	15	3		+	
28	Origanum vulgare L.	14		+		
29	Melilotus officinalis (L.) Pall.	14	-/2	+		
30	Artemisia absinthium L.	13	3/1	+		
31	Aesculus hippocastanum L.	13	9/5		+	
32	Bidens tripartita L.	12		+	+	
33	Sambucus nigra L.	12	8/3	+		
34	Tilia cordata Mill.	12	2	+		
35	Senna acutifolia (Delile) Batka	11	6		+	+
36	Avena sativa L.	11	1/5		+	

37	Levisticum officinale W.D.J.Koch	11	5		+	
38	Tussilago farfara L.	10	1	+		
39	Quercus robur L.	10	10	+		
40	Convallaria majalis L.	9	-/3	+		
41	Plantago major L.	9	-/1	+	+	
42	Inula helenium L.	9	4	+	+	
43	Coriandrum sativum L.	9	2		+	
44	Ginkgo biloba L.	9/1	18/3		+	+
45	Ammi visnaga L.	9	-/1		+	
46	Anethum graveolens L.	9	1		+	
47	Zea mays L.	9	1		+	
48	Silybum marianum (L.) Gaertn.	9	12/6		+	
49	Paeonia anomala L.	9			+	
50	Frangula alnus Mill.	8	-/1	+		
51	Daucus carota L.	8		+	+	
52	Deschampsia caespitosa L.	8		+		
53	Abies sibirica Ledeb.	8		+		
54	Calamagrostis epigeios (L.) Roth	8		+		

1	2	3	4	5	6	7
55	Arctostaphylos uva-ursi (L.) Spreng.	8	3	+		+
56	Capsella bursa-pastoris (L.) Medic.	7	-/1	+		
57	Centaurium erythraea Rafn	7	2	+		
58	Menyanthes trifoliata L.	7	1	+		
59	Petroselinum sativum Hoffm.	7	4/1		+	
60	Vinca minor L.	7		+	+	
61	Solidago virgaurea L.	7	5/3	+		
62	Capsicum annuum L.	6			+	
63	Potentilla erecta L.	6	1	+		
64	Phaseolus vulgare L.	6			+	
65	Viscum album L.	6	-/5	+		
66	Linum usitatissimum L.	6	3		+	
67	Cynara scolymus L.	6	7/2		+	
68	Trigonella foenum-graecum L.	6	4		+	
69	Allium cepa L.	6	3/1		+	
70	Agropyron repens (L.) Gould	6	3/1	+		
71	Ricinus communis L.	6	3		+	
72	Taraxacum officinale (L.) Weber ex F.H.Wigg	6	2/7	+		

73	Rosmarinus officinalis L.	5	2/1		+	
74	Tanacetum vulgare L.	5		+		
75	Viola tricolor L.	5		+	+	
76	Arnica montana L.	5	2/18	+		
77	Persicaria hydropiper =Polygonum hydropiper L.	5		+		
78	Myristica fragrans Houtt.	5	5/2			+
79	Pelargonium sidoides R.Knuth	5	4			+
80	Sorbus aucuparia L.	4		+	+	
81	Pinus sylvestris L.	4	21/2	+		
82	Syzygium aromaticum (L.) Merr. et Perry	4	4			+
83	Hedera helix L.	4	18/3	+	+	
84	Thermopsis lanceolata R.Br.	4	2		+	
85	Alnus glutinosa (L.) Gaertn.	4		+		
86	Leuzea carthamoides Willd.	4			+	
87	Cucurbita pepo L.	4	7		+	
88	Vaccinium myrtillus L.	4	3/1	+		
89	Hippophae rhamnoides L.	4	3		+	
90	Passiflora incarnata L.	4	6/3			+
91	Digitalis spp.	3	-/2		+	

1	2	3	4	5	6	7
92	Symphytum officinale L.	3	2/7	+		
93	Aloe arborescens Mill.	3	3/1		+	
94	Arctium lappa L.	3		+		
95	Curcuma longa L.	3	9			+
96	Foeniculum vulgare Mill.	3	5		+	
97	Orthosiphon stamineus Benth.	3	1/1		+	+
98	Ledum palustre L.	3	1/3	+		
99	Adonis vernalis L.	2			+	+
100	Carum carvi L.	2	1		+	
101	Lavandula angustifolia Mill.	2	2		+	+
102	Amorpha fruticosa L.	2		+		+
103	Anisum vulgare Gaertn.	2	2		+	
104	Vaccinium vitis-idaea L.	2		+		
105	Aronia melanocarpa (Michx.) Elliot	2			+	
106	Panax ginseng C. A. Meyer	2	4/3			+
107	Laminaria spp.	2				+
108	Corylus avellana (L.) H.Karst.	2		+		
109	Plantago lanceolata L.	2	7/1	+		
110	Stevia spp.	2			+	+

111	Solanum tuberosum L.	2			+	
112	Veratrum spp.	2/1	-/10	+		
113	Plantago psyllium L.	2	2		+	
114	Trifolium spp.	2		+	+	
115	Cinnamomum cassia Presl.	2	3			+
116	Thea sinensis (L.) Kuntze	2	5			+
117	Aralia elata (Miq.) Seem.	1			+	+
118	Aerva lanata (L.) JUSS. ex SCHULT.	1	1		+	
119	Filipendula vulgaris Moench	1		+		
120	Linaria vulgaris Mill.	1		+		
121	Galium spp.	1	-/6	+		
122	Rhodiola rosea L.	1	1		+	+
123	Apium graveolens L.	1	2		+	
124	Juniperus communis L.	1	-/1	+		
125	Adhatoda vasika Nees.	1	9			+
126	Ocimum basilicum L.	1	4		+	+
127	Berberis vulgaris L.	1/3	-/7		+	
128	Ononis arvensis L.	1	-/1	+	+	
129	Galega officinalis L.	1			+	
130	Garcinia cambogia (L.) Roxb.	1	2			+

1	2	3	4	5	6	7
131	Hibiscus syriacus L.	1	2			+
132	Desmodium canadensis (L.) DC.	1			+	+
133	Zingiber officinale Roscoe	1	17		+	+
134	Calotropis gigantea (L.) Dryand.	1				+
135	Lespedeza bicolor Turcz.	1				+
136	Terminalia belerica (Gaertn.) Roxb.	1	1			+
137	Piper longum L.	1	9			+
138	Piper nigrum L.	1	1			+
139	Lycopodium clavatum L.	½	-/8	+		
140	Pueraria spp.	1	1			+
141	Rauwolfia serpentina Benth.	1	1/1			+
142	Agrimonia eupatoria L.	1		+	+	
143	Sarcostemma brevestigma R.Br.	1				+
144	Glycyne spp.	1	14		+	
145	Pistacia Integerrima J.Stewart	1				+
146	Thuja occidentalis L.	1/3	1/6		+	
147	Allium sativum L.	1			+	

148	Scutellaria baicalensis Georgi	1			+	
149	Thymus vulgaris L.		22		+	+
150	Emblica officinalis Geartn		11			+
151	Primula veris L.		10	+	+	
152	Viola odorata L.		8	+		
153	Serenoa repens (Bartram) J.K.Small		7/4			+
154	Alpinia galanga (L.) Willd.		5			+
155	Salix alba L.		7/1	+		
156	Cetraria islandica (L.) Acharius s.l.		5	+		
157	Berberis aristata DC.		4		+	
158	Raphanus sativus L.		4		+	
159	Gentiana lutea L.		5/5		+	
160	Solanum nigrum L.		3/2	+		
161	Rumex confertus Willd.		5	+		
162	Cimicifuga racemosa L.	-/2	5/8	+		+
163	Verbena spp.		5	+		
164	Saxifraga ligulata L.		5		+	
165	Centella asiatica (L.) Urb.		4			+
166	Vitis vinifera L.		3		+	
167	Boerhaavia diffusa L.		3			+

1	2	3	4	5	6	7
168	Angelica archangelica L.		2	+		
169	Tamarix gallica L.		3		+	+
170	Cichorium intybus L.		3	+	+	
171	Juglans regia L.		2/2		+	
172	Amomum subulatum Roxb.		3			+
173	Anisum stellatum L.		3		+	
174	Solanum xanthocarpum L.		3			+
175	Picrorrhiza kurroa Benth		2			+
176	Potentilla anserina L.		3	+		
177	Aegle marmelos (L.) Corrêa		2			+
178	Butea frondosa (Lam.) Taub.		2			+
179	Tribulus terrestris L.		3	+	+	
180	Abies picea L.		1	+		
181	Cordia latifolia Roxb.		3			+
182	Saponaria officinalis L.		2/2	+		
183	Myrtus communis L.		2		+	
184	Mimosa pudica L.		1			+
185	Triticum vulgare L.		3		+	
186	Sphaeranthus indicu L.		2			+
187	Olea europea L.		3			+

188	Capsicum annuum L.		1/4		+	
189	Onosma bracteatum Wall.		3			+
190	Prunus africana (Hook.f.) Kalkman		2			+
191	Herpestis monniera Linn. (Brahmi)		2			+
192	Holarrhena antidysenterica Wall. Kurchi		2			+
193	Cytisum scoparium (L.) Link		1			+
194	Fumaria officinalis L.		2/2			+
195	Citrus aurantium L.		2			+
196	Plantago ovata Forssk.		1			+
197	Populus tremula L.		1/4	+		
198	Terminalia chebula Retz.		2			+
199	Harpagophytum procumbens (Burch.) DC. ex Meisn.		1			+
200	Cnicum benedicticus L.		1		+	
201	Zyzyphus vulgaris Lam.		2			+
202	Iberis amara L.		1/1			+
203	Ruscus aculeatus L.		1			+
204	Echinacea pallida Nutt.		1		+	
205	Gymnema sylvestre R. Br.		1			+

1	2	3	4	5	6	7
206	Hamamelis virginiana L.		1/5		+	+
207	Withania somnifera (L.) Dunal		2			+
208	Bapticia tinctoria L.		1			+
209	Persea americana Mill.		2			+
210	Alisma orientalis Sam.		1			+
211	Anemarrhena asphodeloides Bge.		1			+
212	Argyreia speciosa (L.f.) Sweet		1			+
213	Phellodendron chinensis Schneid.		1			+
214	Vernonia cinerea Schreb.		1			+
215	Bacopa monnieri (L.) Wettst.		1			
216	Centaurea cyanus L.		1	+		
217	Lamium album L.		1/1	+		
218	Didymocarpus pedicellata R. Br.		1			+
219	Dolichos biflorus L.		1			+
220	Capparis spinosa L.		1			+
221	Cassia occidentalis L.		1			+
222	Crinum latifolium L.		1			+
223	Urtica urens L.		1/2	+		
224	Rhaponticum carthamoides L.		1		+	

225	Schizandra chinensis (Turcz.) Baill.		1		+	
226	Malva sylvestris L.		1	+	+	
227	Rubia cordifolia L.		1			+
228	Mukuna pruriens (L.) DC.		1			+
229	Tectona grandis L.f.		1			+
230	Hyriopsis cumingii Lea		1			+
231	Prunus persica L.		1		+	+
232	Paeonia lactiflora Pall.		2		+	+
233	Colchicum autumnale L.		1/7	+		
234	Artemisia pontica L.		1	+		
235	Leonurus japonicus Houtt.		1		+	
236	Rheum palmatum L.		1/2		+	
237	Plumbago zeylanica L.		1			+
238	Cyperus scariosus R.Br.		1			+
239	Achyranthes aspera L.		1			+
240	Rhus toxicodendron =Rhus toxicodendron Mill.		1/6			+
241	Rhus aromatica Ait.		1			+
242	Terminalia arjuna (Roxb.) Wight & Arn.		1			+

1	2	3	4	5	6	7
243	Tinospora cordifolia (Thunb.) Miers		1			+
244	Xysmalobium undulatum (L.) R.Br.		1			+
245	Phyllanthus amarus Schumach. & Thonn		1			+
246	Phoenix sylvestris (L.) Roxb.		1			+
247	Fucus vesiculosus L.		1/2			+
248	Satureja hortensis L.		1		+	+
249	Ilex paraguensis A.St.-Hil.		1			+
250	Marrubium vulgare L.		1/2	+	+	
251	Justicia adhatoda L.		1			+
252	Embelia ribes Burm.f.		1			+
253	Strychnos ignatia Lindl.	-/2	-/10			+
254	Conium maculatum L.	-/1	-/11	+		
255	Eupatorium spp.	-/1	-/13	+		
256	Phytolacca americana L.	-/1	-/5		+	
257	Clematis recta L.	-/1	-/3	+	+	
258	Coffea spp.	-/1	-/2			+
259	Gelsemium sempervirens L.	-/1	-/10			+
260	Podophyllum peltatum L.	-/1	-/3		+	

261	Sanguinaria canadensis L.	-/1	-/8			+
262	Aconitum napellus L.		-/20	+	+	
263	Pulsatilla pratensis (L.) Mill.		-/17	+		
264	Bryonia alba L.		-/14	+	+	
265	Solanum dulcamara L.		-/8	+		
266	Cinchona pubescens L.	-/1	-/9			+
267	Bellis perennis L.		-/6	+		
268	Luffa operculata Cogn.		-/8			+
269	Hydrastis canadensis L.		-/6			+
270	Baptisia tinctoria (L.) R.Br.		-/5			+
271	Citrullus colocynthis (L.) Schrad.		-/9		+	+
272	Vincetoxicum hirundinaria Medik.		-/5	+		
273	Vitex agnus-castus L.		2/4		+	
274	Hyoscyamus niger L.		-/4	+		
275	Ruta graveolens L.		-/4		+	
276	Smilax L.		-/5			+
277	Ipecacuanha spp.		-/6			+
278	Strychnos nux-vomica L.		-/6			+
279	Pilocarpus Jaborandi Vahl.		-/4			+

1	2	3	4	5	6	7
280	Viburnum opulus L.		-/3	+		
281	Chamaelirium luteum (L.) Gray		-/3			+
282	Lilium lancifolium Thunb.		-/4		+	+
283	Nasturtium officinale W.T. Aiton		-/3		+	
284	Scrophularia nodosa L.		-/3	+		
285	Teucrium scorodonia L.		-/1			+
286	Anamirta cocculus (L.) Wight & Arn.		-/1			+
287	Asclepias tuberosa L.		-/1			+
288	Bryonia cretica L.		-/3			+
289	Caulophyllum thalictroides (L.) Michaux.		-/1			+
290	Cyclamen purpurascens Mill.		-/2		+	
291	Drosera L.		-/1	+		
292	Euphrasia officinalis L.		-/2	+		
293	Geranium robertianum L.		-/2	+		
294	Glechoma hederacea L.		-/3	+		
295	Guajacum officinale L.		-/3			+
296	Iris versicolor L.		-/1			+

297	Veronica officinalis L.		-/2	+		
298	Mandragora officinarum L.		-/2			+
299	Spigelia anthelmia L.		-/2			+
300	Secale cornutum L. (Claviceps purpurea)		-/3		+	
301	Myosotis arvensis (L.) Hill		-/3	+		
302	Selenicereus grandiflorus (L.) Britton & Rose		-/2			+
303	Semecarpus anacardium L.f.		-/2			+
304	Nicotiana tabacum L.		-/3		+	
305	Actaea spicata L.		-/1	+		
306	Echinacea angustifolia DC.		-/2		+	
307	Cardiospermum L.		-/1			+
308	Ceanothus americanus L.		-/1			+
309	Cicuta virosa L.		-/1	+		
310	Galphimia glauca Cav.		-/1			+
311	Cochlearia officinalis L.		-/1			+
312	Collinsonia canadensis L.		-/1			+
313	Momordica balsamina L.		-/1		+	+
314	Sedum acre L.		-/2	+		
315	Sempervivum tectorum L.		-/2	+		

1	2	3	4	5	6	7
316	Sinapis nigra (L.) W.D.J.Koch		-/1		+	
317	Filipendula ulmaria= Spiraea ulmaria L.		-/1	+		
318	Beta vulgaris L.		-/1		+	
319	Chionanthus virginicus L.		-/1			+
320	Chondrodendron tomentosum Ruiz & Pavón	-/1	-/2			+
321	Bothrops lanceolatus Bonnaterre		-/1			+
322	Caladium seguinum Vent.		-/1			+
323	Caltha palustris L.		-/1	+		
324	Croton tiglium L.		-/1		+	
325	Ailanthus altissima (Mill.) Swingle		-/1			+
326	Aletris farinosa L.		-/1			+
327	Cypripedium parviflorum Salisb.		-/1			+
328	Gratiola officinalis L.		-/1	+		
329	Helianthemum canadense (L.) Michx.		-/1			+
330	Aquilegia vulgaris L.		-/1	+		

331	Armoracia rusticana G.Gaertn., B.Mey. & Scherb.		-/1		+	
332	Arisaema triphyllum =Arum triphyllum (L.) Schott		-/1			+
333	Barosma Willd.		-/1			+
334	Lobaria pulmonaria (L.) Hoffm.		-/2			+
335	Lobelia inflata L.		-/1			+
336	Mahonia aquifolium (Pursh) Nutt.		-/1			+
337	Okoubaka Pellegr. & Normand		-/1			+
338	Peumus boldus Molina		-/1			+
339	Pilosella Vaill.		-/1			+
340	Piper methysticum G.Forst.		-/1			+
341	Ranunculus bulbosus L.		-/1	+		
342	Pseudognaphalium obtusifolium (L.) Hilliard & B.L.Burtt		-/1			+
343	Rumex crispus L.		-/1	+		
344	Sabadilla Brandt & Ratzeb. (Schoenocaulon officinale Asa Gray)		-/2			+
345	Simarouba cedron Baill.		-/1			+

1	2	3	4	5	6	7
346	Delphinium staphisagria L.		-/1			+
347	Toxicodendron quercifolium (Michx.) Greene		-/1			+
348	Turnera diffusa Willd. ex Schult.		-/2			+
349	Strophanthus gratus (Wall. & Hook.) Baill.		-/1			+
350	Abrus precatorius L.		-/1			+
351	Xanthoxylum fraxineum L.		1			+

*Note: Number before slash – amount of allopatic medicinals, which consist plant raw material of plant species/ numeral after slash – amount of homeopatic medicinals

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Навчальний посібник містить інформацію про сучасні тенденції обліку, застосування та збереження ресурсів лікарських рослин, лишайників та грибів на міжнародному та національному рівнях. Окреслено основні поняття як національного, так і міжнародного законодавства щодо використання та охорони лікарських рослин; охоплюються стан і умови природних ресурсів цих видів в Україні, а також накопичення біологічно активних речовин у цих видах; проаналізовано застосування лікарських рослин у різних регіонах світу в науковій і традиційній медицині, а також лікарських рослинах України та їх біологічно активних речовин, які є джерелами активних засад іноземних і вітчизняних рослинних препаратів і лікарських препаратів рослинного походження. Навчальний посібник містить методичні матеріали для оцінки (оцінки) ресурсів лікарських рослин. Наведено приклади оцінювання ресурсів лікарських рослин. Деякі інформаційні дані, включаючи розрахункові форми для визначення щільності рослинного запасу, наведені у додатках.

Навчальний посібник може бути використаний для викладання ресурсознавства (в аспекті лікарських рослин) у вищих навчальних закладах відповідно до навчальних планів, для викладання біологічних та екологічних наук у вищій школі, а також для оцінки рослинних ресурсів.

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